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Preface

2020 2nd International Conference on Management Science and Industrial Engineering (MSIE 2020) and 2020 International Conference on Industrial Engineering and Artificial Intelligence (IEAI 2020) have been successfully held during April 7-9, 2020. This is a great opportunity for every participant to exchange new ideas and application experiences in the area of Management Science, Industrial Engineering and Artificial Intelligence.

Unfortunately, all around the world are fighting against coronavirus. On March 11, WHO declared COVID-19 a pandemic. The safety of the participants remains our top priority, while some countries also prohibit travelling. After careful consideration, in light of the global health emergency and the travel restrictions, the conference committee has made the difficult decision to change the MSIE 2020 into online meeting, so that delegates can participate in the conference under a safe, productive and well-attended atmosphere. Fortunately, conference was held smoothly and successfully, this is inseparable from everyones understanding and support .

The conference received strong support from experts and researchers from different countries. It is my great honor to serve as the Conference Chair. It is also our great honor to invite Professor Xu Yang from Beijing University, China and Professor Maged M. Dessouky from University of Southern California, USA as keynote speakers sharing their insightful research findings and foresights.

MSIE 2020 and IEAI 2020 have received more than 160 submissions by researchers in many countries such as Philippines, Thailand, Indonesia, Poland, China, Turkey, Singapore, Taiwan, the United States, and so on. After two rounds of rigorous peer reviews, 56 were selected in this proceeding. Sincere appreciations to all authors, session chairs, and reviewers for their participation and supports for this conference! The conference consists of the sessions of six important topics, all presenters contributed with their inspiring speeches and shared their latest research on the Management Science, Industrial Engineering and Artificial Intelligence. Among them, Mr. Jerry Li, Mr. Jing-Wen Wang, Ms. Zou Yan, Mr. Bilal Khalid, and Ms. Sunisa Junsawang have been evaluated and thus chosen as the best presenters by the session chair of each of the sessions.

MSIE 2020 and IEAI 2020 have provided a platform for scientists and engineers from around the world to showcase and exchange breakthrough ideas related to Management Science, Industrial Engineering and Artificial Intelligence technologies. It also enabled fruitful discussions of related studies to be conducted and further research directions to be focused in the related fields. Indeed, the participants have enjoyed the opportunity for future research and potential collaborations within this community, while we look forward to seeing you in future MSIE conferences.

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April 7-9, 2020

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Session I

Supply Chain Management

Study on Closed-Loop Supply Chain Strategy Based on Carbon Tax Policy and Reward-Penalty Mechanism

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ABSTRACT
Considering the environmental awareness of consumers, a Stackelberg game model is established for the closed-loop supply chain composed of manufacturer, retailer and third-party recycler. This paper analyzes three strategies of carbon tax policy (CTP), reward-penalty mechanism (RPM), carbon tax policy and reward-penalty mechanism (CTP and RPM) under decentralized decision. The results show that increasing consumers' awareness of environmental protection can improve price, demand and recovery rate of product under all three strategies. When there is a carbon tax policy, carbon emissions can be reduced. When there is a reward-penalty mechanism, it can improve the recovery rate of waste products and increase the profits of closed-loop supply chain members.

CCS Concepts
•**Applied computing→Operations research→Decision analysis**

Keywords
Closed-loop supply chain; carbon tax policy; reward-penalty mechanism; game theory

1. INTRODUCTION
In recent years, environmental pollution and shortage of resources have become increasingly serious. How to effectively realize the recycling and remanufacturing of waste products, reduce carbon emissions, and achieve sustainable development has become the world's leading trend.

Many scholars have conducted relevant research on the supply chain. From the perspective of supply chain emission reduction, Ghosh [1], Su. J [2] and J. Jian [3] studied the impact of greening level on supply chain pricing and profits. Xiong Z.K. [4] studied the impact of carbon tax and consumer environmental awareness under two different channel structures, especially the impact on carbon emissions and profits of supply chain members. Lu Z.N. [5] and Wang N. [6] discussed the impact of carbon tax policy and consumer demand preference on pricing decisions. Based on the carbon tax policy and government subsidies, Gao J.H. [7] and Guo C.H. [8] considered how the members of the closed-loop supply chain implement the pricing decision.

From the perspective of reward-penalty mechanism, on the basis of considering the government's reward and penalty to recyclers, Si F.S. [9] proposed the optimal strategy. And on this basis, they analyzed the impact of the reward-penalty intensity and reward-penalty standard on the optimal strategy. Gong Y.D. [10] constructed two closed-loop supply chain models and considered the impact of subsidy ratio on strategy choices. Based on the consideration of consumer preference and subsidy mechanism, Xiao M. [11] studied the influence of different decisions on retail price and recovery price.

Therefore, considering the impact of the consumers' environmental awareness on demand, this paper compares three strategies CTP, RPM, CTP and RPM by establishing models and analyzing relevant statistics. It provides the basis for the government to choose a reasonable strategy.

2. PROBLEM DESCRIPTIONS
2.1 Problem Description and Symbol Description
This paper constructs a closed-loop supply chain composed of a single manufacturer, a single retailer and a single recycler, as shown in Figure 1.

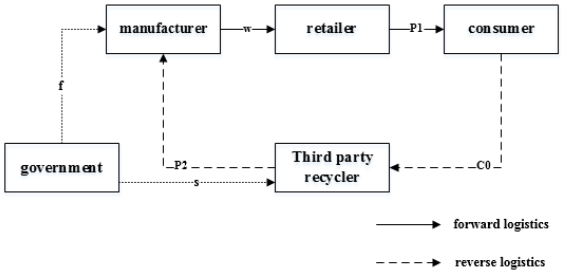

Figure 1. Structure of remanufacturing modes.

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Manufacturers produce products, including new and remanufactured products. The unit production costs of these two products are c_m and c_r respectively, and $\Delta c = c_m - c_r > 0$. The manufacturer sells the products to the retailer at the wholesale price w, and the retailer sells the products to the consumer at the retail price P_1. The third party recycler recycles the waste products at the unit recycling price c_0, and then resells the products to the manufacturer at the unit price P_2. In this paper, e_m and e_r are used to represent the carbon emission of the unit new products and the unit remanufactured products respectively, and $\Delta e = e_m - e_r > 0$. In order to control carbon emission, the government can impose a carbon tax on manufacturers and use f as the unit carbon tax. In order to encourage recycling and remanufacturing, a reward-penalty mechanism can be implemented for recyclers. Reward will be given when the recovery rate $\tau(0 < \tau < 1)$ reaches the recovery standard τ_0, otherwise penalty will be given. The reward-penalty intensity is s. π_j^i represents profit, i represents supply chain enterprise and j represents strategy. M, R, 3p represents manufacturer, retailer and recycler respectively. F, S, FS respectively represents strategies: CTP, RPM, CTP and RPM.

2.2 Model Assumptions

Assumption 1. There is no difference in the quality and use of new products and remanufactured products, and they enter the market at the same price.

Assumption 2. Supply chain members are independent decision makers. Manufacturer is the leader of Stackelberg game, retailer and recycler are the followers.

Assumption 3. Average production cost per unit product is $c = \tau c_r + (1-\tau)c_m = c_m - \tau\Delta c$. Average carbon emission per unit product is $\bar{e} = \tau e_r + (1-\tau)e_m = e_m - \Delta e\tau$. The recovery fixed cost of the recycler is $k\tau^2$, where k ($k > 0$) is the fixed recovery cost sensitivity coefficient.

Assumption 4. Demand is related to consumer price sensitivity and environmental awareness. Demand is $Q = \alpha - \beta P_1 + \gamma(e_m - e_r)$, Where α is the maximum market capacity, β is the consumer price sensitivity coefficient, γ represents the intensity of consumers' environmental awareness (For every unit of carbon emission reduction, consumers' purchase demand will increase γ.) and α、β、$\gamma > 0$.

Assumption 5. The market is completely open, and the information between the upstream and downstream enterprises is symmetrical.

3. MODEL FORMULATIONS

3.1 Closed-loop Supply Chain Decision Based on CTP (Model F)

Under the CTP, the government collects carbon tax for manufacturer, and the profit function of closed-loop supply chain members is as follows:

$$\pi_F^M = (w - c_m + \tau\Delta c)Q - P_2\tau Q - f(e_m - \Delta e\tau)Q, \quad (1)$$

$$\pi_F^R = (P_1 - w)Q, \quad (2)$$

$$\pi_F^{3p} = (P_2 - C_0)\tau Q - k\tau^2. \quad (3)$$

3.2 Closed-loop Supply Chain Decision Based on RPM (Model S)

Under the RPM, the government takes reward and penalty measures according to the recovery rate of recycler, and the profit function of closed-loop supply chain members is as follows:

$$\pi_S^M = (w - c_m + \tau\Delta c)Q - P_2\tau Q, \quad (4)$$

$$\pi_S^R = (P_1 - w)Q, \quad (5)$$

$$\pi_S^{3p} = (P_2 - c_0)\tau Q - k\tau^2 + s(\tau - \tau_0). \quad (6)$$

3.3 Closed-loop Supply Chain Decision Based on CTP and RPM (Model FS)

Under the CTP and RPM, the government imposes a carbon tax on manufacturer while taking reward and penalty on recycler, and the profit function of closed-loop supply chain members is as follows:

$$\pi_{FS}^M = (w - c_m + \tau\Delta c)Q - P_2\tau Q - f(e_m - \Delta e\tau)Q, \quad (7)$$

$$\pi_{FS}^R = (P_1 - w)Q, \quad (8)$$

$$\pi_{FS}^{3p} = (P_2 - c_0)\tau Q - k\tau^2 + s(\tau - \tau_0). \quad (9)$$

According to the above assumptions, the manufacturer makes the decision first, and then the retailer and the recycler make the decision separately according to the manufacturer's decision. Therefore, the backward induction method is used to solve the above model, and the optimal decision is shown in Table 1.

Table 1. Optimal decision of closed-loop supply chain

	CTP	RPM	CTP and RPM
w^*	$\frac{\beta AB - 2k\beta(c_m + fe_m) - 2kB}{\beta^2 A - 4k\beta}$	$\frac{\beta ABC - 2k\beta c_m + s\beta C - 2kB}{\beta^2 AC - 4k\beta}$	$\frac{\beta AB(C + f\Delta e) + s\beta(C + f\Delta e) - 2k\beta(c_m + fe_m) - 2kB}{\beta^2 A(C + f\Delta e) - 4k\beta}$
${P_1}^*$	$\frac{\beta AB - k\beta(c_m + fe_m) - 3kB}{\beta^2 A - 4k\beta}$	$\frac{\beta ABC - k\beta c_m + \frac{1}{2}s\beta C - 3kB}{\beta^2 AC - 4k\beta}$	$\frac{\beta AB(C + f\Delta e) + \frac{1}{2}s\beta(C + f\Delta e) - k\beta(c_m + fe_m) - 3kB}{\beta^2 A(C + f\Delta e) - 4k\beta}$
τ^*	$\frac{k\beta A(c_m + fe_m) - kAB}{2k\beta A - 8k^2}$	$\frac{k\beta c_m A - kAB + \frac{1}{2}s\beta AC - 4ks}{2k\beta AC - 8k^2}$	$\frac{k\beta(c_m + fe_m)A - kAB + \frac{1}{2}s\beta A(C + f\Delta e) - 4ks}{2k\beta A(C + f\Delta e) - 8k^2}$
Q^*	$\frac{k\beta(c_m + fe_m) - kB}{\beta A - 4k}$	$\frac{k\beta c_m - kB - \frac{1}{2}s\beta C}{\beta AC - 4k}$	$\frac{k\beta(c_m + fe_m) - kB - \frac{1}{2}s\beta(C + f\Delta e)}{\beta A(C + f\Delta e) - 4k}$
${\pi_M}^*$	$(w^* - c_m + \tau^*\Delta c)Q^* - P_2\tau^* Q^* - f(e_m - \Delta e\tau^*)Q^*$	$(w^* - c_m + \tau^*\Delta c)Q^* - P_2\tau^* Q^*$	$(w^* - c_m + \tau^*\Delta c)Q^* - P_2\tau^* Q^* - f(e_m - \Delta e\tau^*)Q^*$
${\pi_R}^*$	$({P_1}^* - w^*)Q^*$	$({P_1}^* - w^*)Q^*$	$({P_1}^* - w^*)Q^*$
${\pi_{3p}}^*$	$A\tau^* Q^* - k{\tau^*}^2$	$A\tau^* Q^* - k{\tau^*}^2 + s(\tau^* - \tau_0)$	$A\tau^* Q^* - k{\tau^*}^2 + s(\tau^* - \tau_0)$

Where $A = P_2 - c_0 > 0$, $B = \alpha + \gamma\Delta e > 0$, $C = \Delta c - P_2 > 0$

4. NUMERICAL ANALYSIS

According to Table 1, it is difficult to directly compare the optimal wholesale price, retail price, recovery rate and profit under the above three strategies. Therefore, the above results are analyzed by numerical examples in order to obtain some useful ideas. After summarizing a large number of references, the parameters in the models are defined as $c_m = 9, c_r = 4, e_m = 30, e_r = 20, \alpha = 30, \beta = 1.5, \gamma = 4, P_2 = 2, k = 20, c_0 = 1, s = 3, \tau_0 = 0.05$. The optimal solution is shown in table 2.

Table 2. The optimal solution

	CTP	RPM	CTP and RPM
w	42.76	26.59	40.95
P_1	44.71	36.63	43.81
τ	0.07	0.45	0.18
Q	2.93	15.06	4.29
M's profit	13.81	285.25	18.52
R's profit	5.72	151.13	12.24
3p's profit	0.11	3.93	0.51

As can be seen from the above table, from the perspective of only considering carbon emissions, the strategy of CTP is better. And from the perspective of only considering supply chain profit, the strategy of RPM is better.

Under the strategy of CTP and RPM, the wholesale price of the manufacturer and the retail price of the retailer are reduced compared to the strategy of CTP. With the participation of the government, some subsidies are provided to the qualified third-party recyclers. Such measures can promote the recyclers to recycle products, resulting in an increase in recovery quantity and recovery rate. At the same time, compared with the CTP, the strategy of CTP and RPM can increase the profits of closed-loop supply chain members.

Compared with RPM, the strategy of CTP and RPM can effectively reduce carbon emissions. But it increases wholesale price and retail price, and reduces the profits of closed-loop supply chain members.

In order to compare the three strategies more intuitively, the following analysis mainly studies the effect of the changes of β, γ, f and s on the recovery rate, profit and other parameters, as shown in Figure 2 to Figure 15.

Figure 2 and Figure 3 show that no matter which strategy is adopted, the higher consumer's sensitivity to price, the lower wholesale price and retail price will be. According to Figures 4 and 5, under the three strategies, the increase of β will lead to the loss of supply chain members' profits. In order to ensure sales of the products, manufacturers and retailers will reduce the selling price, resulting in lower profits.

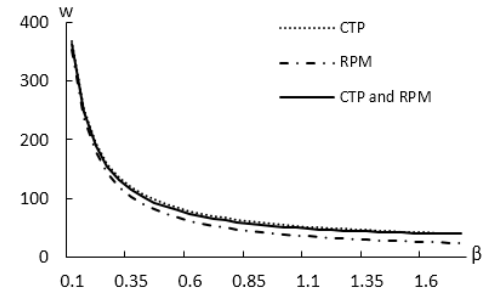

Figure 2. Effect of β on w

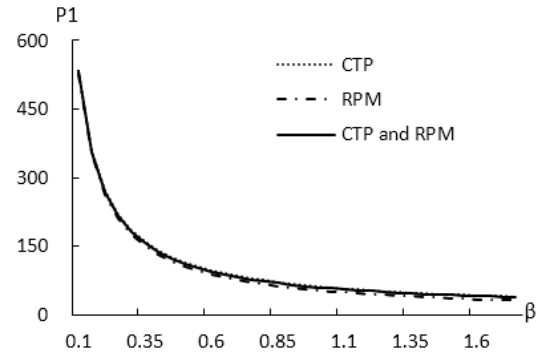

Figure 3. Effect of β on P1

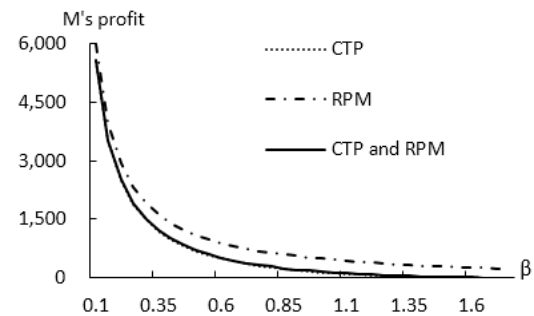

Figure 4. Effect of β on M's profit

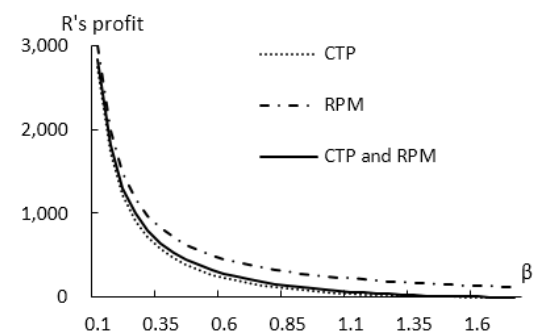

Figure 5. Effect of β on R's profit

When consumers are less sensitive to price, there is almost no difference between the three strategies. When consumers are more sensitive to price, it is more effective to adopt the RPM to reduce product price and improve profit of supply chain.The more you recycle, the less carbon dioxide you will produce in the production process. And with the increasing awareness of environmental protection, consumers will be encouraged to buy remanufactured products. Therefore, under the CTP, the amount of consumers' purchase can be promoted, as shown in Figure 6. And when there is a carbon tax policy, the wholesale price of the manufacturer and the retail price of the retailer are the highest, as shown in Figure 7 and 8. At the same time, due to the enhancement of consumers' awareness of environmental protection, their enthusiasm to participate in product recycling increases, which makes the recovery rate of products increase, as shown in Figure 9.

Therefore, when consumers have a high awareness of environmental protection, all three strategies can improve product price, demand and recovery rate.

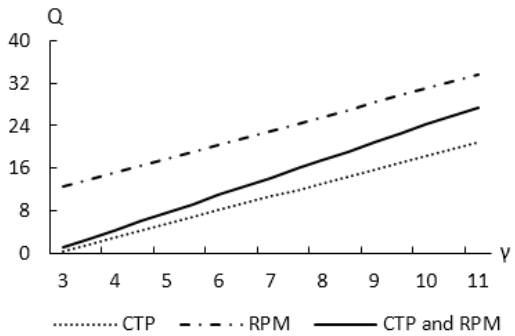

Figure 6. Effect of γ on Q

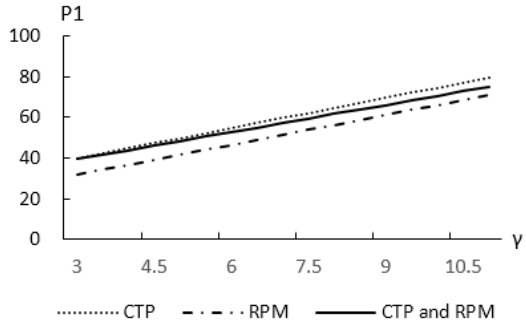

Figure 7. Effect of γ on P1

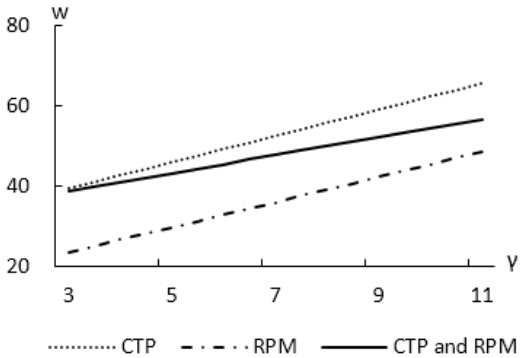

Figure 8. Effect of γ on w

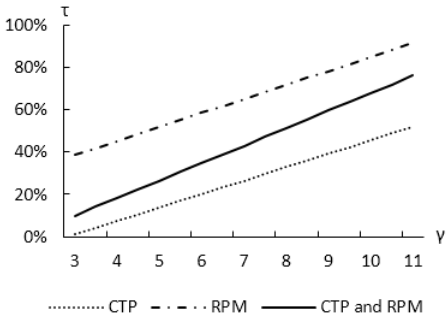

Figure 9. Effect of γ on τ

When the unit carbon tax increases, it will lead to an increase in the manufacturer's production costs. And manufacturer will increase the wholesale price to maintain their own profits, which will then lead to an increase in retail prices, as shown in Figure 10 and 11. From the above assumptions, carbon emissions are positively correlated with consumer demand. So when there is a carbon tax policy, carbon emissions will be effectively controlled. However, with the increase of unit carbon tax, the demand of consumers decreases, as shown in Figure 12. Therefore, the government needs to set a reasonable unit carbon tax.

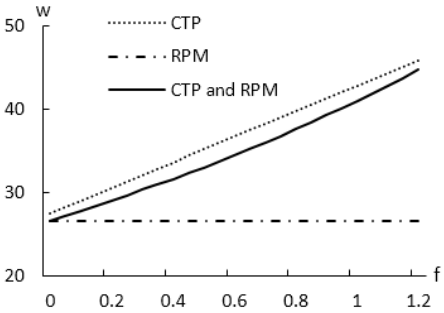

Figure 10. Effect of f on w

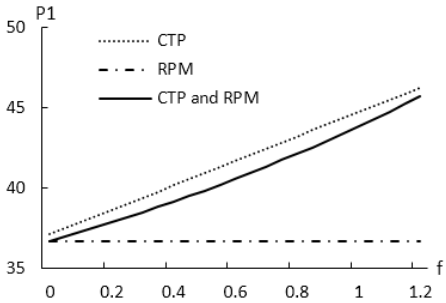

Figure 11. Effect of f on P1

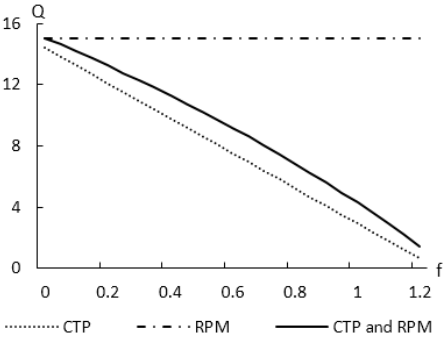

Figure 12. Effect of f on Q

The reward-penalty intensity has a positive effect on the recycler reward or penalty. When the reward-penalty intensity increases, the recycler will actively participate in the recycling work in order to get more rewards. So it will lead to the increase of recovery rate. As manufacturer needs to pay carbon tax, it will lead to a series of chain reactions, which will make consumers reluctant to sell products to recyclers at a lower price. This will hinder product recycling to some extent. Therefore, under the CTP and RPM, the recovery rate is lower than that in only RPM, as shown in Figure 13. As the reward-penalty mechanism is only for the third-party recycler, when s increases, the profit increase of the manufacturer is not obvious in these three strategies, as shown in Figure 14. But the profit of the recycler can be greatly improved by increasing s, as shown in Figure 15.

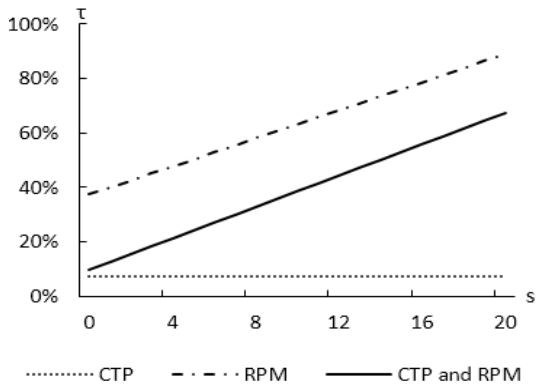

Figure 13. Effect of s on τ

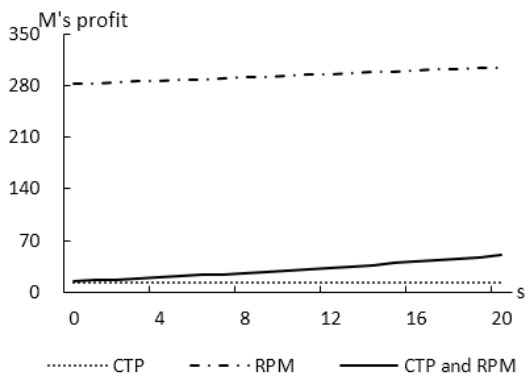

Figure 14. Effect of s on M's profit

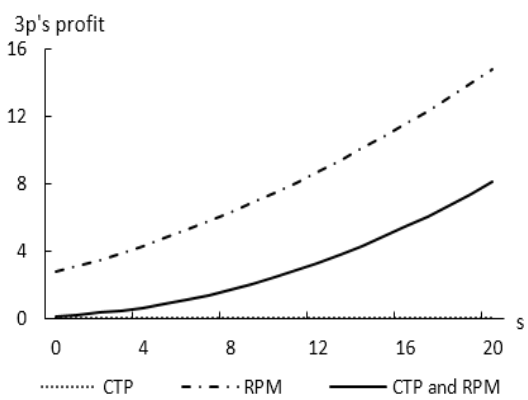

Figure 15. Effect of s on 3p's profit

Therefore, when there is a reward-penalty mechanism, it can improve the recovery rate and increase the profits of closed-loop supply chain members, especially the profit of recycler.

5. CONCLUSIONS

This paper mainly analyzes and compares three strategies of carbon tax policy (CTP), reward-penalty mechanism (RPM), carbon tax policy and reward-penalty mechanism (CTP and RPM). Firstly, this paper constructs a closed-loop supply chain model, and uses the backward induction method to obtain the optimal decision under the three strategies. Then, the optimal decision is analyzed by numerical examples. Finally, based on the numerical results obtained from the examples, we analyze and compare these three strategies. The main conclusions are as follows: (1) When consumers are less sensitive to price, there is almost no difference between the three strategies. When consumers are more sensitive to price, it is more effective to adopt the RPM to reduce product price and improve profit of supply chain. (2) When consumer's awareness of environmental protection is enhanced, the demand, wholesale price, retail price and recovery rate of products will increase under the three strategies. Therefore, the government should actively promote and improve consumers' awareness of environmental protection, which will help improve the profit of the supply chain. (3) When there is a carton tax policy, carbon emissions can be reduced. When the unit carbon tax increases, the wholesale price and the retail price increase. But it leads to lower consumer demand. So government should set up carbon tax reasonably. (4) When there is a reward-penalty mechanism, increasing the reward-penalty intensity can improve the recovery rate and increase the profits of closed-loop supply chain members, especially the profit of recycler.

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Differential Pricing of Closed-loop Supply Chain Based on Recycling Competition between Retailer and Third-party Recycler

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ABSTRACT
In a closed-loop supply chain(CLSC) consisting of a manufacturer, a retailer and a third-party recycler, this work takes into account both products competition and recycling channels competition to explore the optimal pricing strategy of the CLSC. It builds the decentralized and centralized differential pricing models respectively, and the numerical examples are conducted to verify the effectiveness and practicality of the proposed models. The results show that under the decentralized decision, the sale price of new products and remanufactured products rises with the increase of product substitution coefficient; when the recycling competitive elasticity coefficient increases, the recycling prices of retailer and third-party recycler rise while the manufacturer's recycling price remains unchanged. Under centralized decision, the recycling prices of retailers and third-party recyclers are not affected by recycling competition. The results also show that the product competition coefficient has a positive impact on the supply chain profit, and the recycling competitive elasticity coefficient has a negative impact on the profit of supply chain participants but benefits customers.

CCS Concepts
• **Applied computing→ Operations research→ Decision analysis**

Keywords
Closed-loop supply chain; Product substitution; Recycling competition; Differential pricing

1. INTRODUCTION
At present, the pricing decision of closed-loop supply chain has been deeply studied. It can be divided into two categories according to the choice of recycling channels: manufacturers, retailers or third-party recyclers recycle products respectively; manufacturers, retailers, and third-party recyclers form a mixed recycling model.

FLEISCHMANN M et al. [1] divided the closed-loop supply chain into three modes: manufacturer recycling, retailer recycling, and third-party recycling based on the recycling channels of used products. Savaskan et al. [2] studied the selection of recycling channels of closed-loop supply chain under three recycling modes: direct recycling by manufacturers, indirect recycling by retailers and third parties. Gu et al. [3] analyzed the reverse supply chain pricing problem when retailers were responsible for recycling from the perspective of game theory. Huo et al. [4] established the decentralized and centralized pricing strategies for the process of recycling and re-manufacturing when retailers were responsible for recycling, and numerical examples were conducted to verify the validity of the model. Guo et al. [5] studied the closed-loop supply chain pricing model when third-party recyclers were responsible for recycling. Wang et al. [6] constructed a three-stage closed-loop supply chain model under the third-party recycling, and designed a two-stage coordination contract based on revenue sharing and data discount to achieve supply chain coordination.

For the mixed recycling model, Huang et al. [7] analyzed how to make choices to optimize supply chain decisions in dual-channel recycling. Feng et al. [8] designed a reverse supply chain with dual recycling channel that considers customer behavior, and the results show that the dual recycling channel is always better than the single recycling channel in terms of recyclers and supply chain systems. Yi et al. [9] studied the selection of optimal mixed recycling mode by constructing a remanufacturing closed-loop supply chain model of manufacturers, retailers and third parties. Zhang et al. [10] studied the bullwhip effect of closed-loop supply chains where manufacturers and third-party recycle together. Wang et al.[11] built a pricing model considering both manufacturer's direct recycling and retailer's indirect recycling, and introduced three coordination contracts to carry out "Pareto improvement." Gong et al. [12] constructed two types of closed-loop supply chain models, one is mixed recycling model of manufacturers and retailers, another one is mixed recycling model of manufacturers, retailers and third-party recyclers. Then the two types of models were compared and analyzed.

In real life, there is another hybrid recycling mode. Some manufacturers don't have enough energy to deal with all businesses. They usually entrust the recycling business to third-party recyclers and retailers. Faced with the same recycling market, retailers and third-party recyclers will compete in recycling price. Also, the above literature mainly assumed that there was no price difference between new products and remanufactured products. But the fact is that consumers have

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different levels of acceptance of new and remanufactured products. Manufacturers and retailers should therefore give different prices for different products. In addition, the recycled products can hardly be remanufactured completely, only a certain proportion of them can be remanufactured actually, while other products may be completely damaged which need to be processed. Closed-loop supply chain should consider this cost. Based on the above consideration, in this paper, we will establish centralized and decentralized pricing strategies, considering two types of competition simultaneously. One is the competition between new products and remanufactured products, another is the competition of recycling channels between retailer and third-party recycler. Numerical examples were conducted to analyze the effects of product substitution coefficient and recovery competitive elasticity coefficient on both model equilibrium solution and closed-loop supply chain system profit. Thus, this paper aims at designing an optimized closed-loop supply chain decision model taking both products competition and recycling channels competition into account, in order to be more realistic, so as to provide some helpful suggestions for enterprises and the government to better manage the closed-loop supply chain.

2. PROBLEM DESCRIPTION

2.1 Signs and Symbols

The notations are consistent throughout the paper and are illustrated in the list below ($i = 1$ for new products, $i = 2$ for remanufactured products; $j = r$ means retailer, $j=t$ means third-party recycler, $j=m$ means manufacturer).

ω_i: Wholesale price of product.

p_i: Retail price of product.

Q_i: Demand volume of product.

c_n: Unit cost of manufacturing from raw material.

c_r: Unit cost of remanufacturing from used product.

a_j: Recycling price.

D_j: Recycling quantity.

c_s : Residual value of products that have not been remanufactured.

c_d : Processing costs for products that have not been remanufactured.

y: Subsidies from government for each unit of recycled products.

Manufacturer, retailer, and third-party recycler form a Stackelberg game relationship shown in Figure1. In this closed-loop supply chain system, the manufacturer is responsible for the production of new products and the remanufacturing of used products, and then sold them to retailer at wholesale price ω_1, ω_2, respectively. The retailer then sells the new and remanufactured products to the customers at retail price p_1, p_2, respectively. In the reverse supply chain, retailers and third-party recyclers recycle used products at price a_r,a_t simultaneously. The manufacturer recycles the used products from both the retailer and the third-party recyclers at recycling price a_m. The residual value of the unit waste product that has not been remanufactured is c_s, and the manufacturer will process it at the processing cost of c_d . To encourage manufacturers to recycle and remanufacture, the government gives manufacturers a subsidy of y per unit of recycled product.

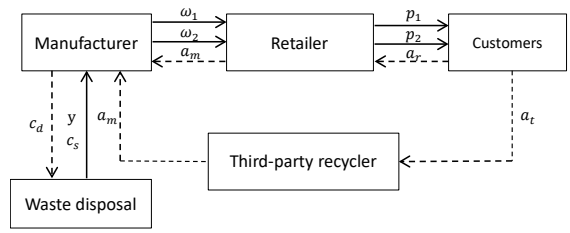

Figure.1 Structure of the Closed-loop Supply Chain

2.2 Assumptions

This paper has based its proposed model on the following assumptions:

Assumption1 The closed-loop supply chain consists of a manufacturer (M), a retailer (R) and a third-party recycler (T). The information between the closed-loop members is symmetrical and risk-neutral. In the non-cooperative case, manufacturers, retailers and third-party recyclers pursue their maximum profits, and all members are completely rational [13].

Assumption2 The function and quality of new products and remanufactured products are different, and they are sold at different prices [14].

Assumption3 A consumer can only buys one new product or one remanufactured product at a time [15].

Assumption4 We assume that the demand functions of the new product and the remanufactured product are $Q_1 = \alpha - \beta p_1 + \sigma p_2$, $Q_2 = \alpha - \beta p_2 + \sigma p_1$, respectively. α is the market capacity; β is the demand price elasticity coefficient; σ is the product substitution coefficient between the new product and the remanufactured product, and $\beta > \sigma$ (ie, the sensitivity of the demand relative to the price of the product itself is stronger than the sensitivity of the demand relative to other alternative products) [16].

Assumption5 The cost of the new product is c_n, the cost of remanufactured product production is c_r ,and $0 < c_r < c_n$. The manufacturer is subsidized by the government. The subsidy for per unit of waste product is y, and $0 < y < c_n - c_r$ [17].

Assumption6 Over-storage costs and out-of-stock costs for new and remanufactured products are exogenous variables and we will not consider it.

Assumption7 We consider two channels of recycling. One is that the manufacturer entrusts the retailer to recycle, the other is that the manufacturer entrusts a third party to recycle. Different recycling channels compete with each other. We assume that the recycling quantity functions of the retailer and the third-party recycler are $D_r = ka_r - sa_t$, $D_t = ka_t - sa_r$, and the total quantity is $D_m = D_r + D_t$, k is the elastic coefficient of product recycling price, s is the elastic coefficient of recycling competition between recycling channels, and $k > s > 0$ (ie, the sensitivity of the company's own recycling quantity relative to its own recycling price is higher than that of other companies) [12].

Assumption8 Remanufactured products can always meet the market demand, ie, $D_m > Q_2$ [6].

3. DECISION MODEL OF A CLOSED-LOOP SUPPLY CHAIN

3.1 Decentralized Decision Model

There is a Stackelberg game among participants. Manufacturer is the leader, retailers and third-party recyclers are followers. In decentralized decision-making, every node enterprise in the supply chain is "economic man" not "social man", and they tend to firstly consider maximizing their own profits, rather than maximizing the overall profits of the supply chain. Therefore, the decision-making process can be regarded as a two-stage dynamic game. In the first stage, the manufacturer decides ω_1, ω_2, a_m. In the second stage, the retailer decides p_1, p_2, a_r, and the third-party recycler decides a_t at the same time. In summary, each member's profit is expressed as follows:

$$\pi_m^D = (\omega_1 - c_n)Q_1 + (\omega_2 - c_r)Q_2 + (y - a_m)(D_r + D_t) + (c_s - c_d)(D_r + D_t - Q_2) \tag{1}$$

$$\pi_r^D = (p_1 - \omega_1)Q_1 + (p_2 - \omega_2)Q_2 + D_r(a_m - a_r) \tag{2}$$

$$\pi_t^D = D_t(a_m - a_t) \tag{3}$$

According to the reverse solution method, firstly, take the first-order partial derivatives of retailer's profit function π_r^D on its own decision variables p_1, p_2, a_r respectively, we obtain the first-order conditions that make retailer profitable:

$$\begin{aligned} &\alpha - 2\beta p_1^D + 2\delta p_2^D + \beta\omega_1 - \delta\omega_2 = 0 \\ &\alpha + 2\delta p_1^D - 2\beta p_2^D - \delta\omega_1 + \beta\omega_2 = 0 \\ &ka_m - 2ka_r^D + sa_t = 0 \end{aligned} \tag{4}$$

Similarly, the first-order condition for third-party recyclers to maximize profits is as follows:

$$ka_m - 2ka_t^D + sa_r = 0 \tag{5}$$

so,

$$p_1^D = \frac{\alpha + \omega_1\beta - \omega_1\delta}{2\beta - 2\delta} \tag{6}$$

$$p_2^D = \frac{\alpha + \omega_2\beta - \omega_2\delta}{2\beta - 2\delta} \tag{7}$$

$$a_r^D = a_t^D = \frac{ka_m}{2k - s} \tag{8}$$

Secondly, bring the equations (6)-(8) into the manufacturer's profit function formula (1), taking the first-order partial derivatives of manufacturer's profit function π_m^D on its own decision variables ω_1, ω_2, a_m respectively, we obtain the first-order conditions that make manufacturer profitable:

$$\begin{aligned} &A + B_1\omega_1^D + B_2\omega_2^D + C = 0 \\ &A + B_2\omega_1^D + B_1\omega_2^D + E = 0 \\ &\frac{2k(k - s)(y + c_s - c_d - 2a_m^D)}{2k - s} = 0 \end{aligned} \tag{9}$$

Let

$A = \alpha\beta - \alpha\delta;$

$B_1 = 2\beta\sigma - 2\beta^2;$

$B_2 = 2\beta\sigma - 2\delta^2;$

$C = c_n\beta^2 + c_r\sigma^2 - c_n\beta\delta - c_r\beta\delta - (c_s - c_d)(\beta\delta - \sigma^2);$

$E = c_n\sigma^2 + c_r\beta^2 - c_n\beta\delta - c_r\beta\delta + (c_s - c_d)(\beta^2 - \beta\delta).$

Therefore, we can get the optimal decisions under the decentralized decision-making as follows:

$$\omega_1^D = \frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2} \tag{10}$$

$$\omega_2^D = \frac{A + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2} \tag{11}$$

$$p_1^D = \frac{\alpha}{2\beta - 2\sigma} + \frac{-AB_1 - CB_1 + AB_2 + B_2E}{2(B_1^2 - B_2^2)} \tag{12}$$

$$p_2^D = \frac{\alpha}{2\beta - 2\sigma} + \frac{A + CB_2 - AB_1 - B_1E}{2(B_1^2 - B_2^2)} \tag{13}$$

$$a_r^D = \frac{k(y + c_s - c_d)}{2(2k - s)} \tag{14}$$

$$a_t^D = \frac{k(y + c_s - c_d)}{2(2k - s)} \tag{15}$$

$$a_m^D = \frac{y + c_s - c_d}{2} \tag{16}$$

The profits of manufacturer, retailer and third-party under decentralized decision-making are obtained as follows:

$$\begin{aligned} \pi_m^D = &-\frac{\beta}{2}\left[\left(\frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2}\right)^2 + \left(\frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2}\right)^2\right] \\ &+\sigma \times \frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2} \times \frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2} \\ &+\left[-\frac{\alpha}{2} + \frac{\beta}{2}c_n - \frac{\sigma}{2}\left(c_r + c_s - c_d\right)\right] \times \frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2} \\ &+\left[-\frac{\alpha}{2} - \frac{\sigma}{2}c_n + \frac{\beta}{2}\left(c_r + c_s - c_d\right)\right] \times \frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2} \\ &+\alpha\left(\frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2} + \frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2} - c_n - c_r - c_s + c_d\right) \\ &+\frac{\alpha}{2}\left(c_n + c_r + c_s - c_d\right) + \frac{k\left(k - s\right)\left(y + c_s - c_d\right)^2}{2\left(2k - s\right)} \end{aligned}$$

$$\begin{aligned} \pi_r^D = &\frac{\beta}{4}\left[\left(\frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2}\right)^2 + \left(\frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2}\right)^2\right] \\ &-\frac{\alpha}{2}\left(\frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2} + \frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2}\right) \\ &-\frac{\sigma}{2} \times \frac{-AB_1 - CB_1 + AB_2 + B_2E}{B_1^2 - B_2^2} \times \frac{AB_2 + CB_2 - AB_1 - B_1E}{B_1^2 - B_2^2} \\ &-\frac{2\alpha^2\beta}{\left(2\beta - 2\sigma\right)^2} + \frac{2\alpha^2\sigma}{\left(2\beta - 2\sigma\right)^2} + \frac{2\alpha^2}{2\beta - 2\sigma} + \frac{k\left(k - s\right)^2\left(y + c_s - c_d\right)^2}{4\left(2k - s\right)^2} \end{aligned}$$

$$\pi_t^D = \frac{k\left(k - s\right)^2\left(y + c_s - c_d\right)^2}{4\left(2k - s\right)^2}$$

3.2 Centralized Decision Model

Under the centralized decision-making, the supply chain system is regarded as an "idealized" organization. There is no competition between manufacturers, retailers and third-party recyclers. But manufacturers are regarded as the core enterprises of the supply chain, and connect each node enterprise in order to maximize the profit of the whole supply chain. Decision variables to be determined in the system are the price of new and remanufactured products, and the recycling price of the retailer and the third-party recycler. The wholesale price and the recycling price of the manufacturer only determine the distribution of revenue among members in this CLSC and will not affect the total revenue of the

system.

The profit function of the whole closed-loop supply chain can be obtained as follows:

$$\pi^C = (p_1 - c_n)Q_1 + (p_2 - c_r)Q_2 + (y - a_r)D_r + (y - a_t)D_t + (c_s - c_d)(D_r + D_t - Q_2) \quad (17)$$

We obtain the first-order conditions that make manufacturer profitable:

$$\alpha - 2\beta p_1^C + 2\sigma P_2^C + c_n\beta - c_r\sigma - \sigma(c_s - c_d) = 0$$

$$\alpha + 2\sigma p_1^C - 2\beta P_2^C - c_n\sigma + c_r\beta + \beta(c_s - c_d) = 0$$

$$yk - ys - 2ka_r^C + 2sa_t^C + (k - s)(c_s - c_d) = 0$$

$$yk - ys + 2sa_r^C - 2ka_t^C + (k - s)(c_s - c_d) = 0$$

Because $\frac{\partial^2\pi^C}{\partial p_1^2} = \frac{\partial^2\pi^C}{\partial p_2^2} = -2\beta < 0$, $\frac{\partial^2\pi^C}{\partial a_r^2} = \frac{\partial^2\pi^C}{\partial a_r^2} = -2k < 0$, so we can obtain the following:

$$p_1^C = \frac{c_n}{2} + \frac{\alpha}{2\beta - 2\sigma} \quad (18)$$

$$P_2^C = \frac{c_r + c_s - c_d}{2} + \frac{\alpha}{2\beta - 2\sigma} \quad (19)$$

$$a_r^C = \frac{y + c_s - c_d}{2} \quad (20)$$

$$a_t^C = \frac{y + c_s - c_d}{2} \quad (21)$$

The overall profits of the closed-loop supply chain can be obtained as follows:

$$\pi^C = -\beta\left[\left(\frac{c_n}{2} + \frac{\alpha}{2\beta - 2\sigma}\right)^2 + \left(\frac{c_r + c_s - c_d}{2} + \frac{\alpha}{2\beta - 2\sigma}\right)^2\right]$$
$$+\left(\alpha + \beta c_n - \sigma c_r - \sigma c_s + \sigma c_d\right) \times \left(\frac{c_n}{2} + \frac{\alpha}{2\beta - 2\sigma}\right)$$
$$+\left(\alpha - \sigma c_n + \beta c_r + \beta c_s - \beta c_d\right) \times \left(\frac{c_r + c_s - c_d}{2} + \frac{\alpha}{2\beta - 2\sigma}\right)$$
$$+2\sigma\left(\frac{c_n}{2} + \frac{\alpha}{2\beta - 2\sigma}\right) \times \left(\frac{c_r + c_s - c_d}{2} + \frac{\alpha}{2\beta - 2\sigma}\right)$$
$$-\alpha\left(c_n + c_r + c_s - c_d\right) + \frac{(k - s)\left(y + c_s - c_d\right)^2}{2}$$

3.3 Comparison between Decentralized Decision Model and Centralized Decision Model

According to the models established and related results obtained above, we make comparison on the corresponding properties between decentralized decision-making and centralized decision-making:

Proposition 1: In centralized decision-making, the retail prices of new products and remanufactured products are less than the corresponding prices under the decentralized decision, ie $p_1^C < p_1^D$, $p_2^C < p_2^D$. That is: $p_1^D - p_1^C = \frac{\alpha}{2\beta - 2\sigma} + \frac{-AB_1 - CB_1 + AB_2 + B_2E}{2(B_1^2 - B_2^2)} - \frac{c_n}{2} - \frac{\alpha}{2\beta - 2\sigma} = \frac{(\beta + \sigma)[\alpha - c_n(\beta - \sigma)]}{4(\beta^2 - \sigma^2)}$, because $\beta > \sigma$, $p_1 > c_n$, so $\alpha - c_n(\beta - \sigma) > \alpha - p_1(\beta - \sigma) = Q_1 > 0$, $p_1^D - p_1^C > 0$, so $p_1^C < p_1^D$. $p_2^D - P_2^C > 0$ can be proved similarly.

Conclusion 1: The retail prices of new products and remanufactured products under centralized decision-making are lower than that under decentralized decision-making. Information can be exchanged directly and accurately in centralized decision-making, thus, the bullwhip effect can be reduced.

Proposition 2: The recycling prices of the two recycling channels under centralized decision-making are greater than that under decentralized decision-making, ie $a_r^C > a_r^D$, $a_t^C > a_t^D$. That is $a_r^C - a_r^D = \frac{y + c_s - c_d}{2} - \frac{k(y + c_s - c_d)}{2(2k - s)} = \frac{(y + c_s - c_d)(k - s)}{2(2k - s)} > 0$, because $k - s > 0$, so $a_r^C > a_r^D$. $a_t^C > a_t^D$ can be proved similarly.

Conclusion 2: The retailer and third-party recyclers have higher recycling prices for waste products under centralized decision-making. For the reason that the recycling price is only related to the recycling subsidy, residual value and processing cost under centralized decision-making, without considering the price sensitivity and the competition between recycling channels.

Proposition 3: The total profit of the CLSC under centralized decision-making is greater than the total profit under decentralized decision-making, ie, $\pi^C > \pi^D$.

Conclusion 3: In the centralized decision-making, the total profit of the CLSC is higher than the total profit of CLSC in the decentralized decision-making. The decision-making of each participant is transparent, which is beneficial to the overall profit.

4. NUMERICAL STUDY

4.1 Numerical Examples

In order to verify the rationality of the model further, this section gives numerical examples for analysis. All parameters are based on the logical relationship and effective range. We assume that the values of the relevant parameters in the model are shown in Table 1.

Table 1. Value of parameters

Parameter	α	β	c_n	c_r	c_s	c_d	y	k
Value	500	20	20	12	6	3	5	50

When σ=5, s=30, the optimal values of each variable under the centralized decision and the decentralized decision can be obtained in Table 2. It can be seen from the table that under centralized decision-making, the profit of the supply chain system is higher.

4.2 Sensitivity Analysis

4.2.1 Influence of product substitution coefficient σ on equilibrium solutions under two modes

We can see from Figure2, as the product substitution coefficient increases, the wholesale price and the retail price increases accordingly. The increase of the product substitution coefficient means that remanufactured products can substitute new products better. With the awareness of environmental protection of consumers increase, the recognition of remanufactured products will increase. Consumers are willing to buy remanufactured products. The demand of both remanufactured products and whole market will increase. At this time, greater profits can be obtained by increasing the wholesale price of new products. Increasing the retail price of new products will enhance the competitiveness of remanufactured products and promote demand for remanufactured products further. Figure3 shows that under the centralized decision, the sales price of new products and remanufactured products increase with the increase of the product substitution coefficient.

Table 2. The optimal value of each decision variable

Decision Variable	Decentralized Decision Optimal Value	Centralized Decision Optimal Value
ω_1	26	——
ω_2	24	——
p_1	30	27
p_2	28	24
a_r	2.86	4
a_t	2.86	4
a_m	4	——
π_m	1507.6	——
π_r	585.2	——
π_t	65.2	——
π	2158	2595

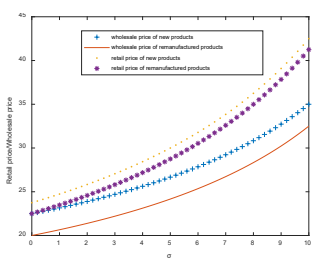

Figure 2. Relevance between σ and p_i/ω_i under decentralized decision-making

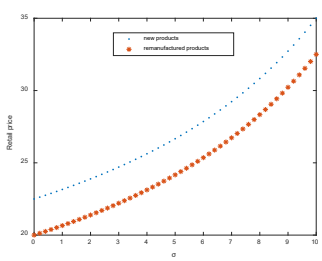

Figure 3. Relevance between σ and p_i under centralized decision-making

4.2.2 Influence of recycling competitive elasticity coefficient s on equilibrium solutions under two modes

Figure4 depicts the relationship between the recycling competition coefficient and the recycling price under decentralized decision-making. As the recycling competition coefficient increases, the recycling prices of both retailers and third-party recyclers increase, while the manufacturer's recycling price remains unchanged. It shows that retailers and third-party recyclers increase their competitiveness to gain market share by increasing recycling prices as the competition in recycling channels intensifies. As the manufacturer's recycling price has not changed, the profit of retailer will decrease accordingly. Figure5 shows the relationship between the recycling competition coefficient and the recycling price under centralized decision-making. Manufacturers, retailers and third-party recyclers determine the recycling price of the two recycling channels together in centralized decision-making so that the recycling price of the CLSC is not affected by the recycling competition.

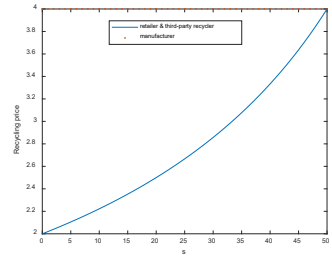

Figure 4. Relevance between s and a_j under decentralized decision-making

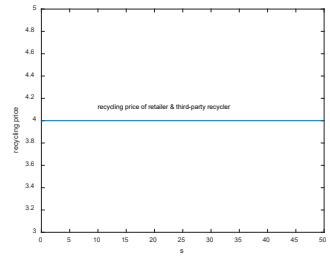

Figure 5. Relevance between s and a_j under centralized decision-making

4.2.3 The influence of product substitution coefficient σ and recycling competitive elastic coefficient s on the profit of CLSC

It can be seen from Figure6 and Figure7 that the product substitution coefficient σ has a positive impact on the overall profit of the CLSC under the two modes. In other words, the closer the consumer's acceptance of new and remanufactured products is, the greater the profit of the entire supply chain system will be. So manufacturers can increase their investment in remanufactured products to improve the quality and to win consumer's recognition. At the same time, each participant and social organization should increase efforts of publicity to enhance the environmental awareness of consumers. As a result, consumers will be more likely to accept remanufactured products.

In addition, Figure6 and Figure7 show that the recycling competitive elasticity coefficient s has a negative impact on the overall revenue of the CLSC. The increase of the recycling competition coefficient means that the competition between retailers and third-party recyclers has intensified and both sides seize the market by raising the recycling price. In this case, consumers who participate in recycling activities get more profit, but the overall profit of the supply chain and the profits of each member are correspondingly lost. In this circumstance, the government can encourage the recycling of companies in CLSC by increasing subsidies.

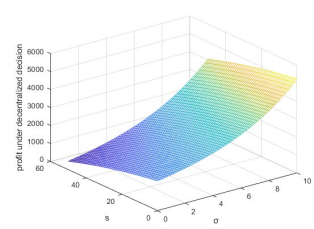

Figure 6. Effect of both σ and s on system profit under decentralized decision

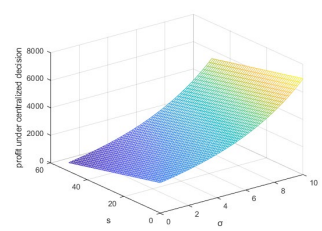

Figure 7. Effect of both σ and s on system profit under centralized decision

5. CONCLUSION

This paper constructs a pricing model that considers both products competition and recycling channels competition in a closed-loop supply chain system consisting of manufacturers, retailers, and third-party recyclers. The model also considers the cost of dealing with recycled products that are not remanufactured to be more realistic. The equilibrium solutions and maximum benefits of the models under both centralized and decentralized decision-making are solved. Under the two modes, the increase of the product

substitution coefficient makes the retail price and sales price of new products and remanufactured products rise, which has a positive impact on the overall profit of the system. The increase in the recycling competition coefficient makes consumers benefit more, but damage the profits of closed-loop supply chain members to a certain extent.

Some managerial insights are provided by this research. Firstly, enterprises should increase investment in remanufacturing to improve the quality of remanufactured products. This is because as the quality of remanufactured products improves, consumer's acceptance of remanufactured products increases, which means that the product's substitution factor increases. From the analysis in the article, it can be obtained that the increase of the product substitution coefficient will bring more benefits to the enterprise. Secondly, by intensifying publicity on remanufactured products, consumers' acceptance of remanufactured products can also be increased. Finally, from the above analysis, it can be known that when there is competition among recycling channels in the closed-loop supply chain, the revenue of the members of the supply chain will be damaged. Therefore, third-party recyclers and retailers should actively cooperate with manufacturers to improve the overall profit of the supply chain system and establish a reasonable profit distribution mechanism to make up for the losses.

However, this work is not free of limitations. The above analysis only explores the changing law of the profit of the closed-loop supply chain system when there is competition between retailer recycling and third-party recycling, and new and old products are priced differently. The following research can be carried out on the specific profit distribution mechanism of such closed-loop supply chains. In addition, more game scenarios that integrate multiple supply chain participants and complex competitive environment should be further studied in future research. For example, a multiple competitions under random demand closed-loop supply chain [18], a "multi-period environment" [19] and a "multi-retailer and third-party recycler" closed-loop supply chain.

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Effect of Weibull Distribution on Supplier Comparison using Lower Process Capability Index: The Examples Study

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ABSTRACT
This paper aims to study the effect of Weibull distribution on supplier comparison via 3 examples obtained from the simulated data and real data. The study compares two supplier using lower process capability index (C_{pl}). To understand the effect, each example is divided into 3 cases. According to Weibull distributed process, the examples show that the result of supplier comparison is sensitive to process's shape. The symmetric process produces that the p-values of supplier comparison are not different in all cases. As a result, the comparing results are the same. On the other hand, there is a possibly misleading result in case of the right-skewed process. Although the methods of handling non-normal C_{pl} are applied to compare suppliers, the p-values are different and depend on skewness and kurtosis. So, the comparing results are not the same.

CCS Concepts
•Mathematics of computing→ Probability and statistics→ Probabilistic inference problems→ Hypothesis testing and confidence interval computation

Keywords
Supplier comparison; Process capability analysis; Lower process capability index; Weibull distribution; Durability; Lifetime

1. INTRODUCTION
In supplier comparison, lifetime or durability of products is an important criterion that manufacturers should focus on because it represents the effectively operated life of product [1]. The data are common modeled with Weibull distribution—flexible shape providing a good model for small data set [2].

Process capability indices (PCIs) are widely used to compare suppliers [3]."Several researchers have applied PCIs to compare supplier with single quality characteristics such as Chou [4], Hubele et al. [5], Pearn et al. [6], Manomat and Sudasna-na-Ayudthya [7], Pearn et al. [8], Wu et al. [9] etc. For multiple quality characteristics, the methods of supplier comparison are developed by Pearn and Wu [10], Pearn and Wu [11], Lan and Lin [12]. According to the literature review, the Manomat and Sudasna-na-Ayudthya method [7] is appropriate in practice for supplier comparison regarding to lifetime characteristic because it is able to compare multiple suppliers using one-sided PCIs and more efficient to the small sample size. Moreover, the method is more comfortable to apply in the industries as it is easily calculated. However, this method is under the normal distribution assumption, so applying Weibull distribution brings some misleading results.

Therefore, this paper aims to study the effect of Weibull distribution on Manomat and Sudasna-na-Ayudthya method [7] via 3 examples obtained from simulated and real data. The study emphasizes on Weibull distribution with different process's shape, especially right-skewed process. The right-skewed process is approximated to various distributions relating to lifetime such as exponential, lognormal etc. The C_{pl} is used to evaluate capability of two supplier's process because lifetime is widely assessed the process capability with lower-sided specification. To understand the effect, supplier comparison in each example is divided into 3 cases. Case I is supplier comparison by the studied method. For case II and III, this study combines non-normal PCIs methods (e.g. Clement percentile method, Johnson transformation) and the studied method to compare the suppliers.

2. THEORIES BACKGROUND

2.1 The Lower Process Capability Index
In manufacturing or service process, the C_{pl} developed by Kane [13] is the index used to assess process capability by lower specification limits (LSL) as shown in the equation (1). In general, process mean (μ) and standard deviation (σ) are unknown, so they are replaced by an estimated sample mean ($\bar{x}$) and standard deviation (S) [1] as $\hat{C}_{pl}$ in the equation (2).

$$C_{pl} = \frac{\mu - LSL}{3\sigma}, \quad (1)$$

$$\hat{C}_{pl} = \frac{\bar{X} - LSL}{3S}. \quad (2)$$

For important assumptions of C_{pl}, the process should be under control and normal distributed.

In the non-normal C_{pl} methods, there are two approaches to handle the non-normal C_{pl}:

1) modifying the new C_{pl} for non-normal data;

2) transforming non-normal to normal data and estimating the C_{pl} based on normal distribution (equation (2)).

Clement percentile is the method that modifies the C_{pl} for non-normal data. This method is proposed by Clement [14] and recommended by ISO [15]. The method employs Pearson curve to

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provide the estimated quantiles $X_{0.135\%}$, $X_{50\%}$ (median) and $X_{99.865\%}$. The $\hat{C}_{pl}$ can be calculated as:

$$\hat{C}_{pl} = \frac{\hat{X}_{50\%} - LSL}{\hat{X}_{50\%} - \hat{X}_{0.135\%}}. \quad (3)$$

Where $\hat{X}_{50\%}$ and $\hat{X}_{0.135\%}$ are the estimated 50% and 0.135% quantiles from standardized Pearson curve respectively.

Johnson transformation is widely used to transform non-normal to normal distributed data and easily calculated the PCIs by statistical software (e.g. Minitab). This method proposed by Johnson [16] optimally selects only one from three families of Johnson distribution to transform the non-normal to normal distributed data. After transforming, the C_{pl} is estimated by equation (2). The three families of Johnson distribution are:

1) The Johnson family distribution with the variable bounded (S_B):

$$X = \gamma + \eta \ln\left[(x-\varepsilon)/(\lambda+\varepsilon-x)\right] \quad \text{for} \quad \eta, \lambda > 0; \varepsilon < x < \varepsilon + \lambda; \quad (4)$$

2) The Johnson family distribution with the variable lognormal (S_L):

$$X = \gamma + \eta \ln(x-\varepsilon) \text{ for } \eta > 0; \varepsilon < x; \quad (5)$$

3) The Johnson family distribution with the variable unbounded (S_U):

$$X = \gamma + \eta \sinh^{-1}\left[(x-\varepsilon)/\lambda\right] \text{ for } \eta, \lambda > 0. \quad (6)$$

Where γ, η, ε and λ are parameter of Johnson distribution.

2.2 The Supplier Comparison Using the C_{pl}

This paper employs the supplier comparison method obtained from Manomat and Sudasna-na-Ayudthya [7] to compare two suppliers using the C_{pl}. The method can be summarized as:

Step1 : Random sample data from two suppliers;

Step2 : Calculate $\hat{C}_{pl}$ of each supplier from equation (2);

Step 3: Rearrange $\hat{C}_{pl}$ in order from the smallest to greatest. Let $\hat{C}_{PL_1}$ is the supplier with the smallest $\hat{C}_{pl}$, and $\hat{C}_{PL_2}$ is the greatest $\hat{C}_{pl}$;

Step 4: Test the equality of the capability indices as;

- Define d' vector as the vector of the difference of C_{PL} between the first supplier (C_{PL_1}) and other suppliers as shown in equation (7):

$$d' = \left[C_{PL_1} - C_{PL_2}\right] \quad (7)$$

- Define the test hypothesis and significance level (α) as:

$$H_0 : d' = 0 \text{ vs. } H_1 : d' \neq 0; \quad (8)$$

- Construct $\hat{d}'$ vector using equations (9)—(11):

$$\hat{d}' = [\hat{C}'_{PL_1} - \hat{C}'_{PL_2}]; \quad (9)$$

$$\hat{C}'_{PL_i} = \sqrt{\frac{n_i}{n_i - 1}} b_{n_i - 1} \hat{C}_{PL_i}; \quad (10)$$

$$b_{n_i - 1} = \sqrt{\frac{2}{(n_i - 1)}} \times \frac{\Gamma\left[(n_i - 1)/2\right]}{\Gamma\left[(n_i - 2)/2\right]}. \quad (11)$$

Where $\hat{C}'_{PL_i}$ are the maximum likelihood and unbiased estimator of C_{PL_i}, and n_i is the sample size of supplier i[th] where i=1, 2;

- Construct H matrix as:

$$H = \left[\frac{\partial d'}{\partial C_{PL}}\right] = [1 \quad -1]; \quad (12)$$

- Calculate V' from equation (13):

$$V' = diag\left[\frac{1}{n_1}\left(\frac{1}{9} + \frac{1}{2}\hat{C}'^2_{PL_1}\right), \frac{1}{n_2}\left(\frac{1}{9} + \frac{1}{2}\hat{C}'^2_{PL_2}\right)\right]; \quad (13)$$

- Calculate the Wald's statistics from equation (14):

$$W = \hat{d}'^T \left[HV'H^T\right]^{-1} \hat{d}'; \quad (14)$$

- Decide whether the first supplier is different from at least one other supplier (reject the null hypothesis) when $W > \chi_c^2$ (Let $\chi_c^2 = \chi_{\alpha,1}^2$ from chi-square statistic with degree of freedom =1).

2.4 Weibull Distribution

The two-parameter Weibull distribution $W(\delta, \beta)$ with scale parameter δ and shape parameter β is employed in this study because it widely used for modelling the life of the products or components [17]. The cumulative distribution function is shown as:

$$F(x) = 1 - e^{-\left(\frac{x}{\delta}\right)^{\beta}}, x > 0, \ \delta > 0, \ \beta > 0. \quad (15)$$

The shape parameter β is sensitive to the process's shape as shown in Figure 1. Weibull distribution can be used in many situations depended on shape parameter β [2]: 1) β=1, Weibull distribution is equivalent to the exponential distribution; 2) 1≤ β ≤3.6: the Weibull distribution approximates to be the lognormal distribution; 3) 3≤ β ≤4: the Weibull distribution approximates to be the normal distribution (β=3.6 is the best estimation).

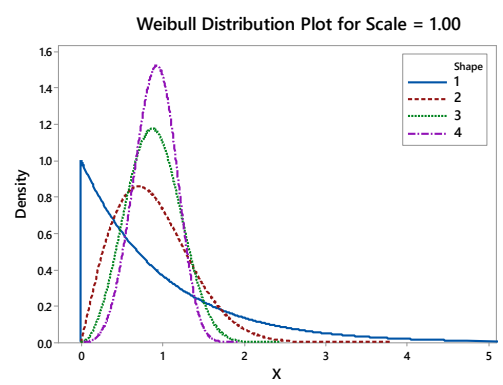

Figure 1. Weibull distribution with various shape parameter

3. RESEARCH METHODOLOGY

This study examines the effect of Weibull distribution on supplier comparison calculating by Minitab version 18 and MS office version 2016. The research focuses on the effect of the following examples: 1) example I: simulated data (symmetric processes); 2) example II: simulated data (right-skewed processes); 3) example III: real data.

The summarized data are shown in Table 1—3 respectively. About example I and II, the data of supplier A and B are obtained from simulated data and assumed LSL=0.1. From Table 1, the processes of both suppliers are symmetry and the skewness and kurtosis close to normal distribution (skewness=0 and kurtosis=3). The goodness of fit test indicates that both processes are normal and Weibull distributed because of the p-values>0.05. The scale and shape parameter of supplier A are 9.84 and 3.57 while B's are 9.82 and 5.36 respectively.

From Table 2, the supplier's processes in example II are right-skewed. The skewness and kurtosis of supplier A are 1.79 and 6.88 while B's are 1.36 and 5.23 respectively. The p-values indicate that the processes are Weibull distributed. The scale and shape parameter of supplier A are 9.45 and 0.99 while B's are 9.37 and 1.49 respectively.

Table 1. The summarized data of example I

Summarized Statistic	Supplier A	Supplier B
1. Descriptive Statistics		
- Sample mean ($\bar{x}$)	8.86	9.06
- Sample standard deviation (S)	2.84	1.90
- Sample size (n)	30	30
- Skewness, Kurtosis	0.30, 2.44	0.07, 2.53
2. Goodness of fit test:		
- Normal distribution	p-value =0.733	p-value =0.956
- Weibull distribution	p-value >0.250	p-value >0.250
3. Parameter estimation using maximum likelihood method	$\hat{\delta}_A = 9.84$, $\hat{\beta}_A = 3.57$	$\hat{\delta}_B = 9.82$, $\hat{\beta}_B = 5.36$

Table 2. The summarized data of example II

Summarized Statistic	Supplier A	Supplier B
1. Descriptive Statistics		
- Sample mean ($\bar{x}$)	9.48	8.44
- Sample standard deviation (S)	9.34	6.09
- Sample size (n)	30	30
- Skewness, Kurtosis	1.79, 6.88	1.36, 5.23
2. Goodness of fit test:		
- Normal distribution	p-value <0.005	p-value <0.035
- Weibull distribution	p-value >0.250	p-value >0.250
3. Parameter estimation using maximum likelihood method	$\hat{\delta}_A = 9.45$, $\hat{\beta}_A = 0.99$	$\hat{\delta}_B = 9.37$, $\hat{\beta}_B = 1.49$

Example III represents real data about failure time (in hour) of two air-conditioning systems [18]. It assumes that the systems are supplier process of A and B with LSL = 0.01. The data of two suppliers are summarized in Table 3 shown that both supplier's processes are right-skewed. The result of goodness of fit test indicates that the processes are Weibull distributed. The scale and shape parameter of supplier A are 64.79 and 1.02 while B's are 79.92 and 1.12 respectively.

Table 3. The summarized data of example III

Summarized Statistic	Supplier A	Supplier B
1. Descriptive Statistics		
- Sample mean ($\bar{x}$)	64.12	76.81
- Sample standard deviation (S)	62.65	63.71
- Sample size (n)	24	27
- Skewness, Kurtosis	1.18, 3.25	0.80, 2.57
2. Goodness of fit test:		
- Normal distribution	p-value <0.005	p-value =0.025
- Weibull distribution	p-value >0.250	p-value >0.250
3. Parameter estimation using maximum likelihood method	$\hat{\delta}_A = 64.79$, $\hat{\beta}_A = 1.02$	$\hat{\delta}_B = 79.92$, $\hat{\beta}_B = 1.12$

To understand the effect, each example is divided into 3 cases:

- case I: comparing supplier by the studied method (Manomat and Sudasna-na-Ayudthya method [7]);
- case II: comparing supplier by the studied method using the $\hat{C}_{pl}$ from Clement percentile method in equation (3);
- case III: comparing supplier by the studied method using transformed data via Johnson transformation method.

Consequently, the results of supplier comparison in each example are compared and discussed to point out the effect of Weibull distributed data on supplier comparison.

4. RESULTS AND DISCUSSION

In example I, supplier's processes are symmetric, and their skewness and kurtosis close to normal distribution. From goodness of fit test, the supplier's processes are both Weibull and normal distributed. According to Table 4, the p-values are not different in all cases resulting in the same result of supplier comparisons. Supplier A and B are not significantly different at 5% and 10% significance levels. There is not enough evidence to conclude that both suppliers are different. Thus, the manufacturer can select either suppliers A or B.

The supplier's processes in example II are right-skewed, and their skewness and kurtosis are larger than example I. From goodness of fit test, these processes are Weibull distributed. The results of supplier comparison from Table 5 show that the p-values are different in all cases. In case I, the p-value=0.2851 yields that supplier A and B are not significantly different. For case II and III, this study combines non-normal PCIs methods and the studied method to compare the suppliers. The p-values of case II (0.8840) and case III (0.0057) are obviously different, so the results of supplier comparison are not the same. Either supplier A or B is selected for case II while supplier B is only selected for case III.

Example III presents supplier comparison using real data that are failure time (in hour) of air-conditioning system. The supplier's processes are Weibull distributed and right-skewed. The p-value of case I=0.6090 yields that supplier A and B are not significantly

different as shown in Table 6. After applying non-normal PCIs to compare suppliers, the p-values of case II (0.5316) and case III (0.0714) are different. Since the skewness and kurtosis of example III are less than example II, p-value of case II is decreased but increased in case III. As a result, the comparison result of"case III is not sensitive at 5% significance level. Therefore, the supplier comparisons are not the same in all case as example II.

According to the Weibull distributed process, the comparison result of suppliers in case I is reliable in case of the symmetric supplier's processes (example I) because the comparison follows under the normality assumption. The p-values of case II and case I are slightly different since the C_{pl} estimation of equation 3 is close to equation 2. For case III, the p-value is same to case I because the data are not transformed. Therefore, the results in all cases are alike. On the other hand, right-skewed process (example II and III) influences on supplier comparison, skewness>1 in particular. In case I, there is a possibly misleading result in supplier comparison since the comparison does not follow under the normality assumption. Although the non-normal PCI methods are employed to compare two suppliers (case II and III), the p-values of case II and III are different depending on the skewness and kurtosis. The difference of p-value between case II and III tends to increase when skewness and kurtosis are higher. As a result, the comparing results of these cases are not the same.

This study indicates that the result of supplier comparison is sensitive to process's shape when the process is Weibull distributed. Right-skewed process leads to a possible misleading result. Even though manufacturers apply non-normal PCIs to compare suppliers using the popular methods, the comparing results are not the same depending on skewness and kurtosis."

Table 4. The results of supplier comparison for example I

Type of result	Case I	Case II	Case III
1. The $\hat{C}_{pl}$ of supplier A	1.25	1.14	1.25
2. The $\hat{C}_{pl}$ of supplier B	1.58	1.39	1.58
3. Supplier comparison results			
- p-value	0.2346	0.3149	0.2346
- Hypothesis testing result at $\alpha = 0.05$	Do not reject H_0	Do not reject H_0	Do not reject H_0
(Selected supplier)	(Either one)	(Either one)	(Either one)
- Hypothesis testing result at $\alpha = 0.10$	Do not reject H_0	Do not reject H_0	Do not reject H_0
(Selected supplier)	(Either one)	(Either one)	(Either one)

Table 5. The results of supplier comparison for example II

Type of result	Case I	Case II	Case III
1. The $\hat{C}_{pl}$ of supplier A	0.33	0.69	0.68
2. The $\hat{C}_{pl}$ of supplier B	0.46	0.67	1.24
3. Supplier comparison results			
- p-value	0.2851	0.8840	0.0057
- Hypothesis testing result at $\alpha = 0.05$	Do not reject H_0	Do not reject H_0	Reject H_0*
(Selected supplier)	(Either one)	(Either one)	(Supplier B)
- Hypothesis testing result at $\alpha = 0.10$	Do not reject H_0	Do not reject H_0	Reject H_0*
(Selected supplier)	(Either one)	(Either one)	(Supplier B)

Note that "*" is p-value< α .

Table 6. The results of supplier comparison for example III

Type of result	Case I	Case II	Case III
1. The $\hat{C}_{pl}$ of supplier A	0.34	0.55	1.24
2. The $\hat{C}_{pl}$ of supplier B	0.40	0.46	0.82
3. Supplier comparison results			
- p-value	0.6090	0.5316	0.0714
- Hypothesis testing result at $\alpha = 0.05$	Do not reject H_0	Do not reject H_0	Do not reject H_0
(Selected supplier)	(Either one)	(Either one)	(Either one)
- Hypothesis testing result at $\alpha = 0.10$	Do not reject H_0	Do not reject H_0	Reject H_0*
(Selected supplier)	(Either one)	(Either one)	(Supplier A)

Note that "*" is p-value< α .

5. CONCLUSION

One of important criteria for supplier comparison is lifetime or durability"widely modeled with Weibull distribution [2]. Manomat and Sudasna-na-Ayudthya method [7]"outperforms other methods for supplier comparison using PCIs. However, applying Weibull distribution in the method brings"a possibly misleading results because the method is developed under normality assumption. This paper study the effect of Weibull distributed process on Manomat and Sudasna-na-Ayudthya method"[7]"via 3 examples obtained from the simulated data and real data. This study focuses on two suppliers using C_{pl}. To understand the effect of supplier comparison, each example is divided into 3 cases. The studied method is used for case I while methods of handling non-normal PCIs and the studied method are applied for case II and III to compare suppliers.

According to Weibull distributed process, the examples show that process's shape influences on the result of supplier comparison. The symmetric process yields that the p-values of supplier comparison are not different in all cases. So, the comparing results are the same as shown in example I. On the other hand, there is a possibly misleading result in case of right-skewed process. Although manufacturers apply the methods of handling non-normal C_{pl} to compare suppliers (case II and III), the p-values are different and depend on skewness and kurtosis. The difference of p-value between case II and III tends to increase when skewness and kurtosis are higher. As a result, the results of supplier comparison are not the same as shown in example II and III.

For manufacturing industry, this study suggests that manufacturers should be aware in supplier comparison regarding to lifetime data and ensure that suppliers' processes are normal distributed obtained from the goodness of fit test. The further study will develop the new method of supplier comparison using C_{pl} for Weibull distribution to compare multiple suppliers with lifetime data efficiently and comfortably.

6. ACKNOWLEDGMENTS

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Determining Sources of Uncertainty, Performance, and Strategy in Biodiesel Supply Chain

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ABSTRACT
Recently, biodiesel as a biofuel has a significant role in replacing fossil fuels because of its benefits, including energy security, reducing environmental impacts (e.g., global warming and GHG emissions), and improving the economy in the rural area. However, the utilization of large-scale biodiesel industry faces many challenges, mainly uncertainties that inherent within decision making in the biodiesel supply chain. Therefore, this paper contributes by identifying several sources of uncertainty in upstream, midstream, and downstream along the biodiesel supply chain. The sources of uncertainty were investigated by using a fishbone diagram as the tool to identify the root causes in which its elements derived from the Supply Chain Operations Reference (SCOR) model. SCOR model provides several basic supply chain processes, i.e., plan, source, make, and deliver. Due to these uncertainty issues related to the biodiesel supply chain, it highlights the need to set performance measures to be achieved through the alignment of supply chain strategies. In the Indonesian context, critical uncertainty sources in the biodiesel supply chain are oil palm supply, oil palm price, land farming, CPO price, CPO supply, production, and operation, technology, policy and regulation, transportation and logistics, biodiesel price, and biodiesel demand. Key performance measures for each source of uncertainty are also determined, such as oil palm yields and oil palm quality for biomass supply uncertainty. The uncertainty management strategies discussed refer to lean strategies, but agile or hybrid strategies are also considered. Future research directions are also presented in this paper.

CCS Concepts
• General and reference→ Reference works

Keywords
Biodiesel; supply chain; uncertainty; fishbone-SCOR diagram; performance; strategy.

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1. INTRODUCTION
Energy security refers to the availability, accessibility, purchasing ability, and sustainability of the environment in the use of energy. The impendence of an energy crisis has forced countries in the world to develop alternative renewable energy sources to achieve better energy security. One of them is Indonesia; this country has been experiencing falling oil production; on the other hand, domestic oil consumption increased by 2.5% per year [1]. Indonesia will face a significant deficit in liquid fuels, the deficit of gasoline of ± 64 million kl (kiloliter) and diesel ± 35 million kl are projected in 2025 [2]. Therefore, the government wants to replace some domestic oil consumption with biofuels, such as biodiesel, bioethanol, kerosene substitutes, and substitutes for fuel oil.

Globally, demand for biofuels continues to increase. Biofuel consumption for the transportation sector grew from around 417 PJ (Petajoule) in 2000 to 2,410 PJ in 2010. The most common biofuels in commercial use are bioethanol and biodiesel. In more detail, bioethanol consumption grew at around 18% per year, while biodiesel grew faster at 42% per year. This upward trend will reach up to six times between 2010 and 2030 [3]. The growing popularity of biofuels could not be separated from policy interventions for the adoption and promotion of countries in the world over the past few decades [4].

Biodiesel is a biofuel that requires a simpler processing technology than ethanol. Biodiesel is usually produced from oil crops, animal fats, waste cooking oil by reacting them with catalyst and then purifying these products. Oil crop sources as feedstock include, but not limited to, oil palm, jatropha, coconut, soybeans, rapeseed and canola, and sunflower. However, biodiesel could not be used as a complete substitution fuel because the production costs are still higher [5]. Therefore, the use of biodiesel as liquid fuel is blended into petroleum diesel at a certain percentage. Even though, there is a lot of evidence from previous Life Cycle Assessment (LCA) studies that biodiesel could significantly reduce greenhouse gas (GHG) emissions and have higher net energy value than fossil fuels [6]. Biodiesel from oil palm has reported reducing CO_2 emissions by 60% and has a net energy value of 37.45 MJ/L (Megajoules per liter) compared to other feedstocks [7].

Even though these benefits have been reported in many studies, the development of the biofuel industry is indeed risky. [8] outlined the technical and economic challenges that hinder the intensive use of biofuel. Moreover, the related empirical studies are still very limited, especially for biofuel produced from palm oil in Southeast Asia [9]. Indonesia is known as the world's largest producer of palm oil at 120 million tons/year, with a total land area of 15.2 million hectares [10]. The plantation has been supported by established processing industries with increasing production capacity.

However, several phenomena in the biodiesel industry take place, for example, an increase in the price of crude palm oil against the price of fossil fuels will cause the price of biodiesel to be relatively higher. This situation resulted in the closure of six of the eleven palm-based biodiesel plants in Indonesia, with the rest operating under 5% of capacity. Additionally, in Malaysia, as a consequence of the discontinuity of raw materials, it has failed to reach the palm oil-based biodiesel target of 5%. From these phenomena, the uncertainties are essential aspects to take into account in the biodiesel industry.

According to [11], uncertainty is a complex and interrelated phenomenon that can occur at any stream along the supply chain. Hence, the reliability of the supply chain system can be enhanced by the inclusion of the uncertainty factors in the decision-making process [12]. Furthermore, the nature of uncertainty encompasses three levels of decision-making: i.e., the strategic, tactical, and operational levels [13]. Finally, to manage uncertainty, it is first necessary to understand the sources of uncertainty itself. Several sources of uncertainty, such as the amount of biomass supply, market demand, market prices, and processing technology, will influence investment decisions. Under those conditions of uncertainty, it will increase the risk of failure if the decision-maker does not manage it well [14].

There are numerous studies on uncertainty in the biodiesel supply chain, indicating that it has developed extensively [15] [16]. Many studies have elaborated on mathematical models that tend to focus on a narrow set of uncertainties. More specifically, [17] developed a two-stage stochastic programming model for capturing the impact of biomass supply and technology uncertainty in the biodiesel supply chain. Also, robust multi-objective programming able to integrate three aspects (multiple objectives, uncertainty, and risk attitude of the decision-maker) was introduced by [18] in the biodiesel market. However, studies to determine sources of uncertainty and alignment of strategies are needed to improve supply chain performance comprehensively [19]. The fact that in the field of supply chain management, studies associated with uncertainty, performance, and strategy are well established [20] [21]. In contrast, it was extremely sparse in the bioenergy sector based on our best knowledge.

The purpose of this study sought to investigate the sources of uncertainty in the biodiesel supply chain and formulate appropriate uncertainty management strategies based on performance-oriented. [22] explained the concept of a circle of uncertainty in which each source (process, supply, demand, and control) is described as a circle segment. The concept has implications for the importance of a comprehensive understanding of the causes and effects of existing dynamics, internal and external relations, as well as upstream and downstream flows in the supply chain. To this purpose, a cause and effects analysis is applied to delve the sources of uncertainty in the biodiesel supply chain, making use of the fishbone diagram. This method has been applied to the remanufacturing process problems to address variability, uncertainty, and complexity, including seven m's (i.e., material, machine, market, measurement, maintenance, and method) with recommended actions [23]. However, uncertainties in supply chain networks can lead to inefficient processes, and non-value added activities [21]. Therefore, knowing the fundamental processes that exist in the supply chain becomes the foundation in anticipating uncertainties. [24] argued that a typical supply chain had four basic processes (plan, source, make, and deliver). Those were explained in the Supply Chain Operations Reference (SCOR) model, where a process at the top level will be cascaded to a sub-process at the next level. To adapt to this, then this study will use four basic processes as factors in a cause-effect analysis.

Having identified a set of uncertainty is relevant to the biodiesel supply chain, strategies for managing uncertainty based on performance measures are formulated. Supply chain performance can be improved by implementing the appropriate supply chain strategy. The process of aligning supply chain characteristics with the strategy requires a systematic and comprehensive framework. Although in the prior supply chain management literature, several frameworks have been discussed [25] [26]. However, the alignment process must regard to the characteristics of the sources of uncertainty itself. Because every source of uncertainty will require different strategies from each other. Therefore, the utilization of frameworks to formulate uncertainty management strategies must be chosen appropriately.

The remainder of this paper is organized as follows: in the second section, the methodology of this research is described. Then some results and discussion of this research are presented in section three. Finally, we will offer the conclusion of this research and some suggestions for further study.

2. METHODOLOGY

The decision-making process in the biodiesel supply chain is influenced by the availability of information. More complete information will have an impact on better quality decisions. However, the information available is still very limited, so uncertainty should be incorporated in the decision-making process.

This study investigated sources of uncertainty along biodiesel supply chain in four steps. In the following Figure 1, the research method of this study was applied. As the first step, an expert and theories analysis were carried out in parallel or it's called by a bi-directional analysis [23]. Theory analysis was constructed and mapped by literature reviews on uncertainty in the supply chain management and specifically in the biofuel supply chain area. Meanwhile, an analysis of an expert was conducted by an interview with the director of Fund Disbursement in Badan Pengelola Dana Perkebunan Kelapa Sawit (BPDPKS) Indonesia. BPDPKS was established by the Government under the Ministry of Finance to realize sustainable palm oil in Indonesia. The main role of BPDPKS is to collect, develop and use the palm oil plantation fund for the benefit of the palm oil industry. The data collection was performed through semi-structured interview with expert. During the interview, layers, players, and sources of uncertainty in the biodiesel supply chain were obtained. Second step, the following analysis builds a cause and effect analysis to investigate parameters and root causes of uncertainty in the biodiesel supply chain. This analysis is documented and illustrated as a fishbone diagram modified with SCOR model. The third step is to compile a set of performance measures based on sources of uncertainty. After that, the fourth step is to align sources of uncertainty with the appropriate strategies in order to improve supply chain performance.

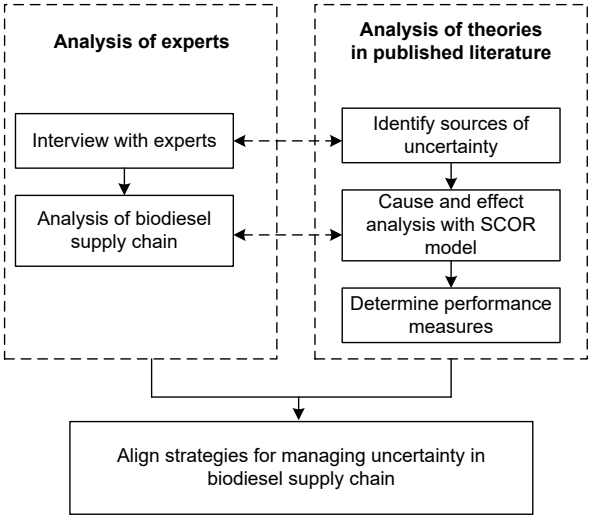

Figure 1. Research method of this study

As a basis for this study, a fishbone diagram is constructed based on SCOR model and it is called as fishbone-SCOR diagram. SCOR model is developed by the supply chain council. The SCOR model is a strategic planning tool and focuses on four principal components of the supply chain processes. The processes in the SCOR model are deployed in three levels. Level-1 describes process definition, level-2 identifies the process type level and then level-3 defines the subprocesses of level-2 as process category. As we have seen in Table 1, four basic supply chain processes in level-1 and level-2 are listed. Those are plan, source, make and deliver that each process element is identified into several sub-elements in level-2 [27]. The process characteristics in the SCOR model are described below:

a. The source process contains the procurement of goods and services to meet the demand for raw materials, components, and other services needed in production.
b. The make process contains activities that convert the product into a finished condition.
c. The deliver process contains the transportation and distribution of finished products to customers.
d. The planning process balances the demand and supply of products and resources in other processes.

Tabel 1. Four basic supply chain processes and sub-elements in SCOR model

Plan	Source	Make	Deliver
Demand/supply planning	Sourcing/material acquisition	Production execution	Demand management
Plan infrastructure	Source infrastructure	Make infrastructure	Order management
			Warehouse management
			Transportation management
			Installation management
			Deliver infrastructure

To further enhance the knowledge of uncertainty management strategies, we will elaborate on several frameworks in the strategic management literature, more specifically, in the uncertainty management strategy. The desired expectation is to build a framework that is in line with the problem of uncertainty, performance and strategy in the biodiesel supply chain.

3. RESULTS AND DISCUSSION

3.1 Biodiesel Supply Chain

This study focuses on the biodiesel supply chain. As previously discussed, biodiesel can be produced with several raw materials, but in this study biodiesel from palm oil will be discussed. The advantage of palm oil compared to other oil crops is that the level of production per hectare is relatively higher [28]. Palm oil is a promising raw material for cooking oil and biodiesel with a level of demand that tends to increase every year. Figure 2 demonstrates multiechelon network with five layers of the supply chain: i.e., oil palm plantations, Crude Palm Oil (CPO) production, biorefinery, blending stations, and dispensing stations.

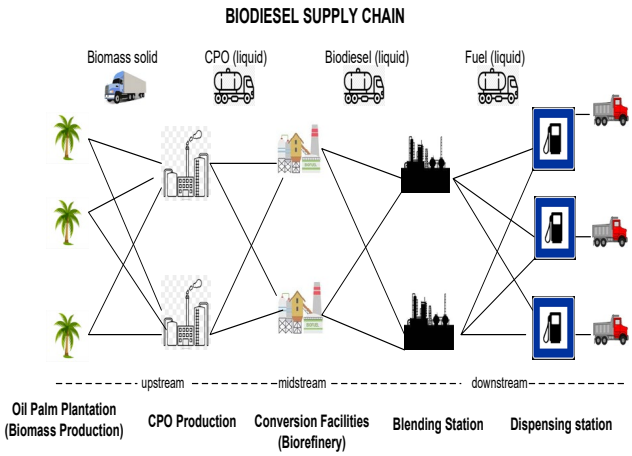

Figure 2. The proposed palm oil biodiesel supply chain network

In the following, [29] suggest that there are five activities of the biofuel supply chain network, i.e., raw material/biomass production, biomass logistic, biofuel production, biofuel distribution and biofuel end-users. Considering the network structure, the biodiesel supply chain network is divided into three streams: upstream, midstream, and downstream. The upstream network is started from the oil palm plantation until the CPO production or feedstocks preparation process, while the midstream network explains the flow of materials or products in the biorefinery or biodiesel production site. The downstream network is responsible for distributing biodiesel by mixing it with petroleum diesel according to the bioenergy mandate at the blending station, and finally, it is sent to consumers through the dispensing station.

3.2 Sources of Uncertainty in Biodiesel Supply Chain

To achieve optimal performance, the decisions in biofuel supply chain management should involve uncertainty. So that, the identification of sources of uncertainty is very important. Understanding related to uncertainty, operational activities such as the selection of feedstocks; harvesting and pre-treatment; the conversion process and transportation are the most common examined more closely [4]. However, the selection of appropriate feedstocks and related processes is very important because most of the cost of bioenergy is influenced by the cost of the feedstocks itself. Therefore, the use of feedstocks is highly dependent on conditions and availability in the local area. Thus, feedstocks can

be obtained from different suppliers which will ultimately increase the complexity of the system. Harvesting of biomass is possible in a limited period of time and cannot be directly processed into bioenergy. It requires pre-treatment process: i.e., physical, physicochemical, and chemical treatment. Biomass conversion processes can be broadly categorized into three types: i.e., thermal and thermochemical, chemical, and biochemical processing. The thermochemical process converts biomass into solid, liquid or gas fuels. Biochemical conversion is based on biological processes, whereas chemical conversion produces liquid fuels through chemical processes [30]. The final stage is the storage of biofuel and their distribution to consumers.

In the previous studies, [21] categorized the sources of supply chain uncertainty into three types, i.e., inherent characteristics (demand, product, process, supply); characteristic features of the chain; and exogenous phenomena that disturb the system. Additionally, [31] have discussed the risk model based on uncertainties and broadly classified into three types of risk sources: internal risk (process and control), network-related risk (supply and demand) and external risk. However, the utilization of the SCOR model as a framework for recognizing sources of uncertainty will be exceeded and more detailed because it is based on basic processes in the supply chain. Thus, this study will also indirectly embody their arguments about sources of uncertainty. Figure 3 shows an illustration of the cause-effect analysis in the fishbone-SCOR diagram incorporated sources of uncertainty in the biodiesel supply chain.

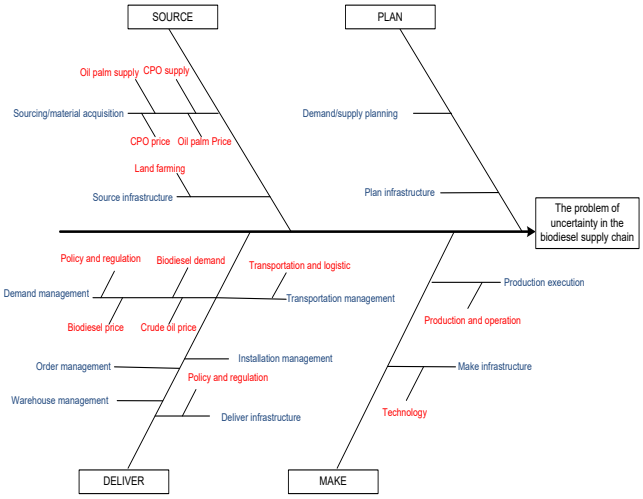

Figure 3. Illustration of the fishbone-SCOR diagram

The biodiesel sector is characterized by a large number of stakeholders. The stakeholders involved in the supply chain either directly or indirectly in fulfilling customer demand include producers, suppliers, transporters, warehouses, retailers, and even customers themselves [32]. A clear understanding of how the roles and positions of each stakeholder related to the biodiesel project are essential. An efficient biodiesel supply chain will require coordinated and collaborative actions from various stakeholders because these stakeholders have intersection interests in impacts of the development of this sector. Achieving the biodiesel target set by the government requires a key role from all stakeholders. Stakeholders and sources of uncertainty are shown in Figure 4 which can be observed as a large system consisting of five main subsystems from farmers' fields to consumers. This system explains all of the streams in the biodiesel supply chain network including sources of uncertainty and stakeholders.

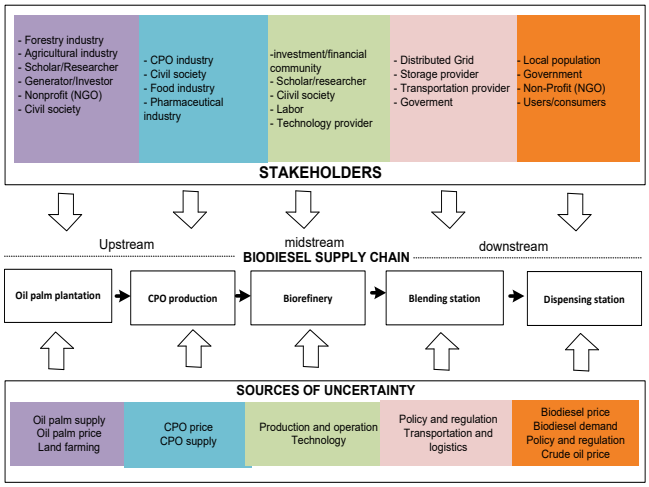

Figure 4. Stakeholders and sources of uncertainty along the biodiesel supply chain

3.3 Performance in Biodiesel Supply Chain

To monitor the viability of the strategies adopted, a performance measurement system is implemented. While setting the strategic direction of the supply chain required performance attributes as a combination of metrics [33]. Performance measurement is related to the utilization of a multi-dimensional set of performance measures that include financial and non-financial measures, internal and external measures. Table 2 outlines some of the performance measures in the biodiesel supply chain based on sources of uncertainty including references for each measure.

Table 2. Performance measures based on source of uncertainty in the biodiesel supply chain

Sources of uncertainty	Performance measures	References
U1. Biomass (oil palm) supply	P1.1. Oil palm yield	[34] [35]
	P.1.2 Oil palm quality	[36]
U2. Biomass price	P.2.1 Oil palm selling price	[37]
U3. CPO price	P.3.1 CPO selling price	
U4. CPO supply	P.4.1 CPO quantity	
U5. Land farming	P.5.1 Land availability	[38]
U6. Production and operation	P.6.1 Production capacity	[39]
	P.6.2 Investment/production cost	[40]
U7. Technology	P7.1 Transformation yield	[35] [18]
	P.7.2 Production emission	[18] [41]
	P.7.3 Conversion capacity	[41]
U8. Biodisel price	P.8.1 Biodiesel selling price	[35]

U9. Biodisel demand	P.9.1 Biodiesel quantity	[34][35]
U10. Policy and regulation	P.10.1 Blending restriction	[16]
	P.10.2 Blending yield	[18]
	P.10.3 Distribution and storage subsidy	[41]
	P.10.4 Fixed capital investment subsidy	[41]
U11. Crude oil price	P.11.1 Crude oil selling price	[43]
U12. Transportation and logistic	P.12.1 Transportation cost	[16][39]
	P.12.2 Transportation time	[42]

Performance measures based on sources of uncertainty in Table 2 are at least classified into price, availability, quantity, quality, cost, subsidy, and so on. In this regard, the subsidy performance measure gives a unique character to the biodiesel business model, which may be rare to find in other business models. Government subsidies or incentives are given to farmers, producers, or users of biodiesel to ensure the sustainability of the industry in the future. Some countries, such as Colombia, Brazil, Argentina, and Peru, have developed conditions suitable for the growth of the bioenergy industry sector through incentives [44].

3.4 Uncertainty Management Strategies

Supply chain management literature provides several frameworks to design supply chain strategies that have developed, gradually becoming more complex in element types and strategy matches. The first was introduced by [25] and his framework has been widely considered from both conceptual and practical points of view [45]. Based on Fisher's model, the supply chain strategy is established based on nature of the product (functional or innovative products). Functional products are characterized by low uncertainty while innovative products are by high uncertainty. He offered two types of strategy, i.e., functional products follow an efficiency strategy while innovative products follow a responsive strategy. In addition to the product, [26] extended Fisher's model with a strategy based on supply and demand uncertainties. These include efficient supply chain, risk-hedging supply chain, responsive supply chain, and agile supply chain.

As discussed above, we have identified several sources of uncertainty in the biodiesel supply chain. These sources of uncertainty derived from supply, demand, costs, prices, production and operations, technology and others. The complexity of the strategic management models above is limited to the uncertainty of supply and demand only. Therefore, these models are less relevant to biodiesel supply chain issues. In this regard, strategic management models with a wider source of uncertainty will be elaborated. [47] suggests a framework for achieving optimal supply chain performance by implementing a supply chain strategy that can be determined by the product characteristics, manufacturing characteristics, and decision drivers of the supply chain. However, the characteristics of the product have already been discussed by [25] and [26], while the manufacturing characteristics are based on identifying four representative supply chains. These include make-to-stock (MTS); assemble-to-order (ATO); make-to- order (MTO); and engineer-to-order (ETO). Other important characteristics are mentioned in the decision drivers of the supply chain, such as: production, inventory, location, transportation, information, sourcing, and pricing. Furthermore, that study categorized into three main strategies for the supply chain (lean, agile, and lean/agile supply chain).

Based on a review of the literature focusing on management approaches, notably supply chain collaboration, two distinct types of uncertainty management strategy can be employed: i.e., reducing uncertainty strategies and coping with uncertainty strategies [19]. In summary, reducing uncertainty strategies is a way for organizations to reduce uncertainty directly at its source, for example, lean operations, product design, process performance measurement and so on. Another type relates to coping with uncertainty strategies, it is another way for the organization to adapt by minimizing uncertainty impacts, but not addressing the source of the uncertainty, for example, delays, volume/delivery flexibility, process flexibility and so on. However, these strategies have the same concept with the strategies suggested by [47] (lean and agile) which lead to efficiency and responsive strategies.

Similarly, based on both product and manufacturing characteristics, we can align the supply chain strategy for biodiesel. Biodiesel is a functional product used for fuel in transportation, industry, electrical generating station and so on. This product is classified as a functional product because it has a standard configuration, long product life cycle, little variation and customer needs over time is relatively stable [25]. And also based on manufacturing characteristics, biodiesel is produced to fulfill inventory with keeping minimum inventory level in production (MTS). The business process in the palm oil supply chain starts from the plantation to the CPO processing industry following a push cycle, because in this case Fresh Fruit Bunches (FFB) are produced continuously. Then, CPO is distributed to the food processing industry, pharmaceuticals and biodiesel both in the domestic and export markets. In addition, biodiesel is produced based on quota targets set by the government each year through biodiesel mandatory program. For example, the ministry of energy and mineral resources will allocate 9.6 million kilo liters of biodiesel production in 2020 (www.esdm.go.id). The mandatory biodiesel policy in Indonesia provides long-term customer demand projections up to 2025. Therefore, biodiesel production systems can be categorized as push supply. As discussed earlier, characteristics of the product (functional product) and manufacturing types (MTS and push supply) reflect the type of lean supply chain strategy [47].

The decision drivers reflect many sources of uncertainty in the biodiesel supply chain. Although biodiesel is produced using raw materials derived from agricultural products, in particular from oil palm, that is affected by seasonality, disease and pests, and land availability so that biodiesel has unique characteristics compared to fossil oil as fuel. Some sources of uncertainty, such as production and operations, can be reduced by implementing lean operating strategies. Arranging less frequent shipping schedules by using large capacity vehicles at lower prices can be applied to transportation and logistics uncertainty. And also, the development of infrastructure networks is carried out in an integrated manner between roads and rails for access to the port. Therefore, in the future, strategies that lead to a lean supply chain with a focus on efficiency from plantations as a source of raw materials to dispensing stations should be able to boost biodiesel into high-value biofuel at affordable prices. Furthermore, it will have implications for energy security in the future.

It has been discussed that supply chain management strategies have an impact on supply chain performance [32]. In transportation uncertainty, this study has identified two performance measures, i.e., cost and time (see in Table 2). How well these performance

measures will be achieved depends on the strategy adopted. We cannot rule out the existence of a hybrid strategy (the combination of lean and agile strategy), which may be more appropriate to the situation of the transportation problem. This strategy, besides focusing on the low cost (lean strategy), also focuses on transportation mode flexibility to transport palm oil, CPO, and biodiesel so that it is on time (agile strategy). Therefore, to formulate a precise strategy, whether a lean, agile, or hybrid strategy requires a systematic framework that can guide researchers by providing measurable parameters.

In addition to the strategic management approach, the system thinking approach can be applied to biodiesel supply chains. However, the systems thinking approach has a scope on a macro perspective that discusses the system more broadly [48]. The characteristics of the biodiesel supply chain are described by (1) a large and complex system consisting of five layers that are connected; (2) have many actors; (3) and are identified with sources of uncertainty in the network. These sources of uncertainty will affect supply chain performance, as discussed. Therefore, combining a strategic management approach with thinking systems will provide research opportunities in the future.

4. CONCLUSION

The primary contribution is that, this study has identified sources of uncertainty along the biodiesel supply chain based on palm oil feedstocks with three streams, i.e., upstream, midstream, and downstream. In this study, a combined cause-effect analysis with SCOR model (plan, source, make, deliver) is employed. The result of the analysis is documented through a Fishbone-SCOR diagram that outlines various sources of uncertainty such as oil palm supply, oil palm price, land farming, CPO price, CPO supply, production and operation, technology, policy and regulation, transportation and logistics, biodiesel price, and biodiesel demand. Uncertainty becomes a critical issue in the context of biofuel because if it is not managed appropriately, its existence can disrupt the performance of a supply chain system that is quite large and complex. In addition, this study also provides insights for all stakeholders regarding performance measures and how uncertainty-based strategies are provided. It is believed that supply chain performance will be improved through the implementation of strategies that are relevant to the conditions encountered. The strategy is to reduce uncertainty at the source that leads to a lean supply chain strategy. However, this research has a limitation that in aligning strategy with sources of uncertainty, a measurable and structured framework is not yet provided. The strategies formulated should be aligned with the situation at hand. Therefore, further research to provide a structured and measurable strategy alignment framework is a challenge. Besides, based on the characteristics of the biodiesel supply chain, a systemic thinking approach will also be identified as a research challenge in the future. This approach is claimed to provide a macro and comprehensive perspective.

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Determination Factors in Supply Chain: Salt Problem

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ABSTRACT
The salt supply chain consists of a complex pattern. In this case, salt farmers, as a significant part of the salt trade, need careful trade channels to get optimal profits. Determination of supply chain channels on a salt commodity is not lonely affected by the price but driven by many external factors. Identify the most significant contributor to the decision making of it, and the Delphi-based approach becomes a promising way. This study designed using qualitative with two rounds of Delphi method, namely to determine the factors that influence the salt supply chain system and the second stage to establish consensus based on the factors obtained in the previous stage. Using a purposive sampling method, the subjects of the study were seven respondents from salt supply chain players in Indonesia. The questionnaire was arranged based on factors affecting the salt supply chain system. As a result, the consensus with the experts was achieved after the 3rd interview, related to factors: number of family members, income rate, salt quality, salt production, price, payment system, price information, capital, and transaction cost. Factors that influence the choice of supply chain systems will have an impact on the amount of income of farmers.

CCS Concepts
•Software and its engineering •Social and professional topics

Keywords
salt supply chain; Delphi method; affect factors

1. INTRODUCTION
Salt is a valuable food commodity for the community. Thus, availability must be maintained. Indonesia is a salt-producing country. However, Indonesia has not been able to fulfill all the needs of salt in the state. It causes salt import. The ratio of production capability to consumption salt needs in Indonesia in 2014 - 2018, on average, was 0.357 [1, 2]. This condition shows that the ability of Indonesian consumption salt production has not met the national salt consumption needs. To meet the needs of domestic salt is conducted by export.

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The demand and fulfillment of salt were not only determined by production but also the salt distribution chain from producers to consumers and the scarcity between needs and satisfaction. The supply chain is a business activity in which there is a flow of goods and services from the point of production to the end of consumers [3]. The salt supply chain can not only saw from the economic side but also from the social side. From the social side, the supply chain can be considered as one of the results of the interaction of the parties involved. From an economic standpoint, an efficient salt supply chain is an indispensable condition. An efficient supply chain system will create fair conditions for farmers as producers and the population in general as consumers. According to [4][5][6][7] stated that the national salt supply chain system shows an intricate pattern, which is: salt farmers, PT. Garam, importers, collectors, wholesalers, iodized salt producers, distributors, sub-distributors, retail traders, and consumers.

Supply chain system will determine the price which will be obtained by salt farmer and the price which consumers will pay to get the product. Each trading institution will certainly determine the selling price for the next trading institution. The price is a combination of the purchase price of the previous trading agency, the costs incurred, and the profits to be taken. The benefits obtained are expected to be in accordance with the role of each trading agency, so that the final price that must be paid by consumers is the price that should be paid. The choice of salt trade by the farmer will determine the amount of profit he gets [8, 9]. In general, farmers do not get a fair price for their products due to the need for money immediately after harvesting [10]. Therefore, the farmer must make the right decision on the choice of salt supply chain system that affects the level of income of farmers.

The behavior of salt farmers is crucial in making the salt trade decision making. Research about factors affecting paprika farmers determines their trade channel based on cooperation contracts with supply chain channels [11]. Other researchers use factors such as infrastructure availability, marketing facilities, access to credit, and market information that determine farmers' decisions in the trading system [10]. For coffee farmers, the factor which determines the choice of supply chain system is that the characteristics of the trader are more critical than the price offered by the trader at the time of the transaction [12]. Whereas, [13] finding the factors associated with the choice of each channel are payment time, method of payment, product price, distance from land, transportation costs, and product valuation. The choice of farmers on the supply chain system through cooperatives is due to the factors of production and

marketing processes. They have a significant effect on farmers' income [9]. According to [10,14], it is necessary to consider transaction costs and marketing costs of each element of the trading system as determining the choice of the trade channel. In this salt trade transaction, values are the cost of packing salt in a sack, the process of raising bags onto a truck, the cost of renting a mode of transportation for transportation to a processing plant. Whereas, [15][16] explain that the price and type of service variables need to be taken into consideration in the choice of supply chain system. Price variables determine the choice of supply chain system because the price offered by the buyer will determine the amount of income that will be received by farmers while the factors determining farmer income are the price of salt, capital, land ownership, income, supply chain channel, and salt production technology [17, 18]. The level of income of farmers is influenced by choice of farmers in the supply chain system, so it is necessary to comprehensively identify the factors that influence the choice of the salt supply chain — referring to several studies on factors which influence farmers' decision making in conducting a supply chain system. It can be used as a reference to determine the decision-making factors in the salt supply chain system.

Some considerations are used to discuss the determinants of decision making in the supply chain, namely: descriptive valuation analysis, logit model, probit model, regression model, and Tobit model. Some researches on determining the factors which influence trade management are the multinomial regression model [19], the probit model [16, 20]; the multinomial logit regression [21,22,23,24,17], the Tobit limit model [21], Analytical Hierarchy Process (ANP) [18] and descriptive statistical methods [22]. Some researchers who conducted research on behavior farmers on supply chain choices and influencing factors, in general, the reference is only focused on one aspect only and do not conduct a comprehensive study. Some studies identify the main factors with a statistical description analysis approach rather than an econometric model in order to obtain inaccurate results due to ignoring the relationship between the factors. However, some references about the main factors which influence other factors in decisions with the approach of logit, probit, and other econometric models, but only a few factors are chosen. Likewise, it is difficult to determine the most important factor among several other factors. These approaches can't identify factors other than those previously identified. To determine the factors which influence the salt supply chain system, you can also use the Delphi method. Delphi technique is a qualitative method to process for gathering opinions among experts about the social phenomenon, which affects salt stakeholders [23,24,25]. The Delphi method does not determine the number of experts involved because the emphasis is on the experts representing the parties involved in the supporting system. The Delphi method carried out to supplement the current opinions of the respondents or to combine the views of respondents on a problem or event. The step taken by the Delphi method is to conduct interviews with experts to get information about the consumption of salt supply chain systems in Indonesia. Analysis of expert opinions is done by summarizing the opinions of several experts and compared to get responses until reaching a consensus [26]. The Delphi method will be able to explore expert opinion on the factors which the consumption of salt supply chain system. Collecting information from respondents does not require respondents to meet, so opinions between respondents do not influence and dominate one another. It needs to avoid so that views are not biased. Based on this, this study aims to obtain information about factors that influence salt trade. It expected that the results of this study could help policymakers determine the directed strategy in the salt trade system that benefits farmers.

2. RESEARCH METHODS

This research is a qualitative study using the Delphi method. The aim is getting consensus from experts regarding influential factors in farmers' decision making in the salt trade system. Method Delphi has done in two rounds using a questionnaire as an instrument. The stage of study begins by discussing the problem of the decisive factors in the decision on the selection of the salt supply chain. Identification of factors that influence the choice of trade is done with a literature study not limited to the salt trade system but expanded to the supply chain system of products that have characteristics of perishable products. Respondents selected are experts in their respective fields and willing to participate in this research. Respondents' criteria are personal questions about salt trade matters. The selected respondent is a salt trade safety advisor who has a minimum of 10 years of experience. The respondents are farmers as workers and owners of ponds, farmers as owners of lakes, and salt traders. The number of respondents was seven people. Respondents' locations are in salt production centers are Sampang Regency and Pamekasan Regency, East Java Province, Indonesia. The size of respondents varies depending on the expertise and purpose of the study [24,27,28]. The choice of the respondent's location based on two sites that have the most extensive pond area in East Java Province [29].

The stages of questionnaire distribution carried out in several steps. Questionnaire stage I is made to determine determining criteria for decision making on the salt supply chain based on the results of literature studies and interviews with experts. The factors which were made statements in this stage questionnaire were 21 factors. Respondents expected to fill out a questionnaire using a Likert scale, namely: 1 (strongly disagree); 3 (disagree); 5 (undecided); 7 (agree); and 9 (strongly agree) to each of the factors identified. The result of distributing the questionnaire stage I analyzed by using some criteria, which were mean, median, and standard deviation. Data analysis used to summarize many data in such a way as to achieve results according to the respondents' representation [30]. Questioner II redistributed to respondents who are the same as the previous stage. The results of the distribution of questionnaires conducted II were analyzed to obtain consensus. If consensus has not received, then proceed with distributing questionnaires to get consensus. Consensus used criteria: mean median, standard deviation, interquartile range (IQR), and consensus percentage. If a consensus had not yet obtained, it is necessary to disseminate the next stage of the questionnaire to reach a consensus on the factors that influence the choice of the salt supply chain system.

3. RESULT AND DISCUSSION

3.1 Questionnaire Stage I

Based on interviews with salt supply chain experts and literature study were as follow age (F1); farmer's education level (F2); experience of farmer's (F3); number of family members (F4); income level (F5); salt quality (F6); total salt production (F7); price (F8); payment system (F9); market information (F10); bargaining power (F11); scale of production (farm area) (F12); total capital (F13); access to credit (F14); risk of damage (F15); farmer membership (F16); transaction costs (F17); distance to markets (F18); transportation mode ownership (F19); kinship with traders (F20); pond ownership status (F21). The results of the recapitulation of the distribution of the questionnaire stage I can be seen in Figure 1.

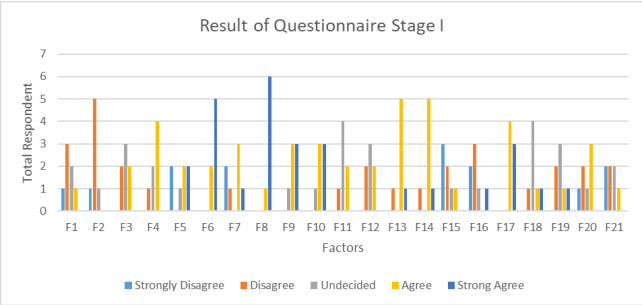

Figure 1. Result of Questionnaire Stage I

In this research, the questionnaire analysis stage I was conducted by calculating mean, median, and standard deviation (Figure 2). Based on the results of the questionnaire, the respondent's tolerance as those who had a median value of more than 3. Thus, age, farmer's education level, risk of salt damage, farmer group membership, and pond ownership status were removed from the questions on the next questionnaire. This was because the Likert scale of less than 3 indicated that the opinions of respondents did not agree with a factor which influenced the salt trade system. In contrast to the opinion [31, 32], they stated that the characteristics of farmers (age and level of education), and the risk of damage to crops affect the choice of trade. Cooperatives can contribute to increasing agricultural productivity and increasing farmers' incomes by producing products according to market standards [33]. Thus, cooperative membership could be used as a reason for making trade choices through cooperatives. Cooperatives provided a very significant economic impact of cooperatives, cooperative services to members, and non-members that are not distinguished. Therefore, it could be ensured that cooperatives could provide long-term benefits of membership [34]. Non-marketing services provided by cooperatives in the form of training in production technology, market information, and access to credit could be received by the members [35, 36, 37]. This condition differed from the opinion of the salt trade system. Farmers did not utilize the membership of the salt cooperative as one of the determining factors in the decision to select the salt trade channel. This was due to the fact that salt cooperatives only acted as savings and loan units, channeling aid from the government, and conducting training to increase productivity in salt production. It had not been able to determine salt prices, which were higher than prices on the market [5, 6, 38].

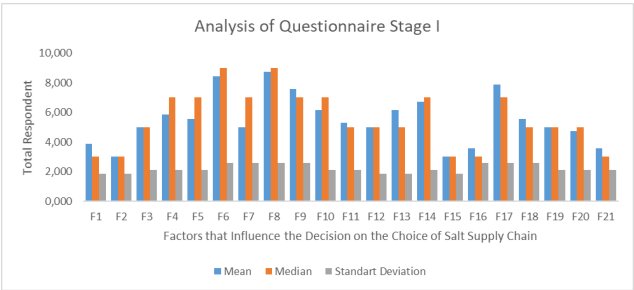

Figure 2. Analysis of Questionnaire Stage I

3.2 Questionnaire Stage II

The questionnaire stage II, the expert was conducted by providing priority for each factor. Whereas the order given by all respondents was used, then a certain level of consensus needed to be determined. The consensus level uses the Delphi method were of 51%, 55%, 70%, 75%, and 80%. However, a 70% consensus rate is often the most preferred measure [39]. "High-level consensus" occurs when the standard deviation is between 1 and 2, whereas "low-level consensus" occurs when the standard deviation is greater than 2. Quartile values indicate that width is low, and height is the absence of consensus. Median values are considered more useful and superior to other centralized aggregate measures because they are not influenced by extreme values in the distribution of measurement results. With increasing median values, the level of consensus increases. The results of the questionnaire distribution can be seen in Table 1.

From the calculation, it was obtained priority order which could be seen from median value with order from priority 1 to 16 which are price, payment system, access to credit, market information, amount of salt production, bargaining power, amount of capital, distance to market, ownership of transportation modes, number of family members, income level, kinship with traders, and farm manager experience. At this stage, the results of each respondent on the factors that determine the salt supply chain decision making by farmers have not produced consensus. This can be seen from the greatest standard deviation of 3.742; 3.185; 2.610; 2.545; and 2.035. The value of deviation standard showed that the distribution of answers from each respondent tended to be large, which means that from the existing respondents, they had not agreed with the priority determining factors in determining the salt supply chain decision making.

Table 1. Tabulation and analysis of questionnaire stage II

Factors	Mean	Median	Standard Deviation	Consensus Level	IQR
F3	14.714	15	1.254	43%	1
F4	13.143	13	2.035	14%	3
F5	11.143	14	3.185	43%	6
F6	4.571	5	0.535	57%	1
F7	7.000	7	1.915	29%	4
F8	1.286	1	0.488	71%	1
F9	1.857	2	0.690	57%	1
F10	5.143	6	1.069	57%	2
F11	8.286	8	0.488	71%	1
F12	13.286	12	1.976	43%	3
F13	10.286	10	0.951	57%	1
F14	6.429	7	0.787	57%	1
F17	2.857	3	0.378	86%	0
F18	11.857	11	2.610	43%	5
F19	11.143	12	2.545	14%	4
F20	13.000	14	3.742	29%	3

3.3 Questionnaire Stage III

This stage was a continuation stage of the next stage. The following is tabulate of the results of the stage III questionnaire. The results of questionnaire distribution can be seen in Table 2.

Table 2. Tabulation and analysis of questionnaire stage III

Factors	Mean	Median	Standard deviation	Consensus Level	IQR
F3	14.571	13	1.272	29%	3
F4	11.714	12	0.488	71%	1
F5	5.286	6	0.951	57%	2
F6	7.714	8	0.488	71%	1
F7	1.286	1	0.488	71%	1
F8	1.714	2	0.488	71%	1
F9	5.571	5	0.976	71%	2
F10	9.286	9	0.488	71%	1
F11	7.857	7	2.795	29%	5
F12	5.286	4	1.704	57%	3
F13	11.000	11	1.000	57%	1
F14	15.143	15	0.900	29%	2
F17	3.000	3	0.000	100%	0
F18	9.429	10	3.101	29%	7
F19	14.000	14	0.816	43%	2
F20	13.143	14	2.854	14%	6

As the questionnaire stage II, questionnaire stage III was also analyzed using mean, median, standard deviation, interquartile range, and percentage of the median for each factor. Determining consensus on each factor by using a value of more than 50% at the consensus level, the standard deviation was less than 1, and the interquartile range was less than 2. Data analysis revealed that consensus was reached on 9 of the 16 factors in the questionnaire stage III. On the other hand, no consensus was reached on 7 of the 16 factors: the experience of the farmer manager (F3); bargaining power (F11); production scale (F12); access to credit (F14); distance to market (F18); transportation mode ownership (F19); and kinship with traders (F20).

3.4 Evaluation of Factor Results that Influence the Choice of Salt Supply Chain

Based on questionnaire stage II, it was obtained the consensus that number of family members (F4); Income level (F5); Salt quality (F6); Total salt production (F7); Price (F8); Payment system (F9); market information (F10), total capital (F13), and transaction costs (F17) were factors which influenced the decision making of the salt supply chain choice.

The number of family members and the level of income of farmers will describe the economic level of farmers. The high number of family members and low household head income will cause farmers to sell their salt immediately after harvest without considering other factors. This is due to an urgent need to meet the needs of family life. In line with research conducted by [37, 40], which states that the number of family members and income levels determines the supply chain choice.

Price is the main factor that is used as a supply chain system consideration [41]. However, some farmers considered risk more than the price [13]. Price is the financial value of an item or service. The payment system is the method used in obtaining cash in the supply chain system. There are two payment systems, which are cash payment at the beginning of the transaction and the postponement payment system. In the salt trade system, farmers wanted a fair price and a cash payment system. The cash payment system was needed by farmers because they needed cash immediately after harvest. In line with the opinion [42, 43], factors that had a significant effect on sales prices, the speed of payment had a significant influence on the selection of marketing channels.

The price expected by farmers was an accumulation of production costs, transaction costs, and desired profits. Transaction costs include information retrieval costs, packaging costs, transportation costs, and marketing costs. In this salt trade transaction, costs were the cost of packing salt in a sack, the process of raising sacks onto a truck, the cost of renting a mode of transportation for transportation to a processing plant. Transaction costs are components that determine the number of profits received by farmers. Although the price offered by the seller was high, the farmer still had to bear other transaction costs so that the financing for this is charged to the price received, which causes the profit to be received low. In line with research [10, 38, 40, 44], the transaction costs must be in accordance with the selection of trade systems. Market information is needed to get information about prices offered by several different marketing channels. Market information can be used as a strength for bargaining. Market information has a significant effect on supply chain choice [19].

The attribute of the product that affects trade is the quality and quantity of harvested products, which are crucial in conducting transactions. Product quality levels will give different prices in each market. Some marketing channels set certain quality and quantity standards that can be accepted by the market. Decisions on the number of products sold in a trade channel would determine the amount of farmer's income [19, 31, 45]. In salt commodities, the salt production process technology determined the quality of the salt produced. Salt processing companies set standards regarding NaCl content, color, and level of cleanliness of salt. Thus, not all salt produced by farmers could be accepted by processing plants.

Often farmers have difficulty under challenging choices that must accept the price offered by traders. Very unprofitable. By knowing the factors that influence the decision of farmers in conducting the salt trade system will have an impact on the amount of farmers' income. These factors influence each other. The income level will determine salt production techniques that produce good quality salt. The level of salt prices that will be obtained by farmers by the quality of salt provided. Market information about salt prices will enable farmers to bargain with traders. In general, farmers want a cash payment system. Middlemen can only make cash system payments. For factors that can increase farmers' income based on these factors, the government must provide a supporting component of a conducive salt trade system. One of the trade system factors that can increase salt production can stabilize the price and welfare of farmers.

4. CONCLUSIONS

Factors which affect the decision of supply chain based on interview with experts and literature study are age, farmer education level, farmer manager's experience, number of family members, income level, salt quality, amount of salt production, price, payment system, market information, bargaining power, production scale, amount of capital, access to credit, risk of damage, group membership farmers, transaction costs, distance to market, ownership of transportation modes, kinship relations with traders, and pond ownership status.

Consensus toward affecting factor is obtained from distributing questionnaire stage III using standard deviation criteria less than 1, interquartile range value less than 2 and percentage of consensus level of more than 50%, namely factor number of family members, income level, quality of salt, amount of salt production, price, payment system, market information, capital amount, and transaction costs.

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Session II

Management Science and Engineering

Environmental, Social and Governance Risk in Public and Private Financial Systems: Fuzzy Cognitive Mapping Comparative Analysis

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ABSTRACT
Environmental, social, and governance (ESG) risk is relevant for the public and private financial sectors and it has an impact on financial performance in both sectors. The aim of this study was to diagnose the impact of ESG risk on public and private financial systems and to determine the sector-specific significance of ESG risk attitudes. Fuzzy cognitive maps were used to diagnose ESG risk in the Polish public and private financial systems. Eight independent experts were asked to evaluate a total of 62 factors, of which 21 were environmental related, 25 were social related, and 16 were governance related. The results of the study revealed that the number of ESG factors and the sustainability pillar they represented differed between the financial systems. As a result, different ESG risk attitudes were observed in public and private financial systems due to the sector-specific influence. The public financial system was found to be more responsive to environmental factors, while the private sector is more likely to take into account factors representing social sustainability. These findings have practical importance and should be considered when designing ESG risk policy and management systems in public and private financial systems.

CCS Concepts
• **General and reference→ Cross-computing tools and techniques→ Empirical studies**

Keywords
Sustainability; finance; risk management; non-financial factors; fuzzy cognitive mapping.

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1. INTRODUCTION
Due to the fact that environmental and social changes are gaining momentum, and that the financial consequences of these changes are increasingly evident, there is a growing interest in and need for research on the impact of environmental, social, and governance (ESG) risk on financial systems.

While operational risk and its management in public and private financial systems is a well-recognized issue, ESG risk remains insufficiently investigated and recognized, especially in the public financial system. Faced with the challenges of ESG risk management, financial institutions have found it necessary to review the current approach to risk analysis and assessment in both the public and private sectors.

The impact of ESG factors on performance of financial sector can be observed in change of financial and non-financial indicators, e.g.: leverage, liquidity, size, risk, asset valuation, RoA, RoE, TQ, management quality, etc. ESG factors may have positive or negative impact on financial performance. For example, reputational damage caused by pollution emission may lead to loss of company's revenues. Also not respecting human rights by companies has negative impact on their reputation which results in decreasing their share price. Reducing pollution require investment in new technologies which leads to higher CapEx in short-term but also decrease production cost (long perspective). Introduction of environmental taxes encourages companies to eco friendly operating and provide income for govenment. Conducting empirical studies Buallay (2018) found that environmental disclosure positively affects the ROA and TQ. However, the corporate governance disclosure negatively affects the ROA, ROE and positively affects the Tobin's Q. Positive association of CSR with financial performance in terms of RoA, RoE, net interest income, and non-interest income showed Wu and Shen (2013). They also revealed negative CSR association with non-performing loans. Fahrurrazi (2018) revealed that only management quality and CSR-ESG have direct negative impact towards financial performance of banks in U.S.

The new approach requires identifying ESG factors that have the strongest impact on the public and private financial systems, increasing the risk of system functioning, and incorporating ESG factors into the risk management process. In this context, the

approach to estimating risk ratings and risk assessment methodologies needs to be changed. Regarding private finance, discussions of these issues are already advanced. Sustainable rating agencies include ESG risk in their credibility assessment methodologies and issue a sustainable rating. However, in relation to the public financial system, there is a lack of experience and discussion in this regard.

The aim of the study was to fill the gap in research on ESG factors by conducting a comparative analysis of such factors that affect the public and private financial systems and to diagnose differences in the approach to ESG risk management by public and private finance managers.

The following research questions were posed in this work:

- What ESG factors affect the public and private financial systems?
- Which factors affecting the public and private financial systems have the greatest impact?
- How does ESG risk management differ between financial managers in the public and private sectors?

The paper comprises the following sections: Section 2 presents a literature review related to ESG risk and factors in the context of financial system impacts. The methodology of the study is highlighted in Section 3. Section 4 presents the results and discussion, and Section 5 concludes with the pertinent recommendations.

2. LITERATURE REVIEW

In recent years, Environmental, Social, and Governance issue has been the subject of many researches. This phenomenon is mainly analyzed from the following points of view: cost of capital, valuation of firm, future returns, economic performance and ESG reporting.

One of areas of research is relation between ESG and cost of capital. Cajias et. al (2014) showed that financial market value investment in corporate social responsibility activities through lower cost of capital. Sharfman and Fernando (2008) revealed that improved environmental risk management provides a lower cost of capital. Eliwa et al. (2019) found that lending institutions consider ESG performance and disclosure and integrate ESG information in credit decisions and that firms with stronger ESG performance have a lower cost of debt, and both of ESG performance and disclosure have an equal impact on the cost of debt. Chava (2014) showed that banks charge a significantly higher interest rate on loans issued to firms with environmental concerns. They also have lower institutional ownership and fewer banks participate in their loan syndicate than firms with worse ESG. Nowadays ESG factors are more often taken into consideration in the assessment of countries. Crifo et al. (2017) showed that ESG ratings significantly decrease government bond spreads.

Another research direction is the relationship between ESG and valuations of firms. The hypothesis that better ESG companies, which have lower financing costs have higher valuations, has been confirmed by Konar and Cohen (2001), Jiao (2010) Deng et al. (2013). Fatemi et al. (2018) noted that ESG strengths increase firm value and weaknesses decrease it.

Escrig-Olmedo et al. (2017) and Achim and Borlea (2015) pointed out that the integrated ESG criteria are used for the evaluation of the assets, which affects the value of firm.

There are several approaches to the impact of ESG on future returns in the literature. According to the first of them, the performance of conventional and SRI funds is similar (Bauer et al. 2005). The performance of SRI indices and conventional indices are comparable (Lee et al. 2013). Findings of other research show that better ESG companies have higher returns (Van de Velde et al. 2005). Russo and Fouts (1997) noted that SRI funds positively influence ESG scores to a greater extent and outperformance. Kempf and Osthoff (2006) found that the performance of the socially responsible firms is never significantly negative. However, the companies with low social responsibility suffer a significant performance loss for the following screens: diversity, community, relations of employee, a combination of all qualitative screens and all qualitative plus exclusionary screens.

There are also some studies that didn't clearly show the impact of ESG on returns. Gerhard et al. (2015) didn't find significant differences in return of companies with high and low ESG ratings. Similarly, Manescu (2011) also was unable to show that ESG affect stock performance.

Tarmuji et al. (2016)., pointed out that companies disclosing ESG practices were reported to have reputation gains, increased investors' trust and confidence, efficient and competitiveness. Fatemi et al. (2017) showed that disclosure plays a crucial role by mitigating the negative effect of weaknesses and increasing the positive effect of strengths. The last research group concerns the relationship between ESG and economic performance. Russo and Fouts (1997) reveal that environmental performance and economic performance are positively linked. Orlitzky et al. (2003) also posited that environmental and social responsibility pay off in financial effects.

Brooks and Oikonomou (2018) showed that the positive impact of ESG results is lower than the negative impact of ESG negligence on economic performance. In this way they confirm the need to analyze various ESG factors. Better ESG companies benefit from good management of operational, reputational, legal and supervisory risks enhanced relationships with business partners, customers, and employees, better management quality (Amel-Zadeh and Serafeim 2018, Koehler and Hespenheide 2013).

Despite a large number of studies about the relation between ESG criteria and company financial performance (CFP), most of them show only overall relation (positive or negative), without presenting the impact of particular criteria. The impact of particular ESG factors on the market performance of firms was analyzed by Sahut and Pasquini-Descomps (2013). They revealed that the changes in ratings in the categories (governance, economic, environment, labour, human rights, society, and products) show a small but significant influence over the stock's performance, however only during limited periods or on limited sectors, which varies among the countries.

Peiris and Evans (2010) found the relationship between ESG ratings and stock return but also wider measures of financial performance, namely valuation and operating performance. ESG criteria from different categories were used for the analysis, for example, Transparency Corporate Governance policy, Human Capital performance indicators, Personal and organizational learning, and development. One of the conclusions was that ESG factors contribute to the financial performance of firms.

Analyzing the Sustainability Accounting Standards Board (SASB) Material Map, some relations between ESG related issues can be found. The SASB Material Map identifies sustainability issues

that are likely to affect the financial condition or operating performance of companies within an industry (SASB). Looking at environmental issues it can be noticed that greenhouse gas emissions in several sectors are one of the most important issues together with energy management and water and wastewater management. The existence of the relationship between these three issues is consistent with the results of the authors' research.

The above review applies to the private sector of companies. For the public sector there are very few studies because ESG risk is a new issue for public organizations. According to a paper titled "Pensions and ESG: The Evolving Legal and Regulatory Landscape. A Practical Guide" (2019) new legislative measures which were to be introduced from 1 October 2019, require pension scheme trustees to take into an account of ESG factors, in their investment decision making.

The OECD paper (2017) presents the findings of an international stock-taking of the regulatory frameworks that apply to institutional investment and how institutional investors integrate ESG factors in their governance processes. Authors of the paper presented some ESG related issues affecting company value, such as carbon emissions, climate change, air and water pollution, waste management, health and safety record, labour standards, and community relations.

A survey conducted by Krueger et al. (2019) regarding climate-risk perceptions, showed that institutional investors believe that climate risks have important financial implications for their portfolio firms and these risks have impact on their finance, particularly regulatory risks. Many investors, especially ESG-oriented ones, consider risk management and engagement, as a good approach for addressing climate risks.

Also Bailey et al. (2016) pointed out that ESG risks have to considered by institutional investors when making investment decisions. New regulations in this area appeared recently, for example US Department of Labour recommends consideration of ESG concerns should be a part of the pension plans' fiduciary duty. French Ministry of Finance announced new rules that require investors to measure their portfolios' exposure to carbon and other ESG considerations.

3. METHODOLOGY AND VARIABLES

Fuzzy cognitive mapping (FCM) was used in this study. A multistep fuzzy cognitive mapping approach was implemented to analyze the many types of environmental and ecological problems or, generally, the problems related to research based on people's knowledge. Cognitive maps are qualitative models of a system that consist of variables and the causal relationships between those variables [Ozesmi&Ozesmi 2004].

Fuzzy cognitive mapping was applied because of its advantages compared to other modeling methods. The most important for the purpose of the study advantages of FCM are: The ability to deal with many variables, even if they are not well-defined (Kosko, 1986), the ability to model relationships between variables that can be described in degrees such as a little or a lot (Kosko, 1986), the ability to provide models when scientific information is limited but expert and/or local knowledge can be used (Özesmi 2004), the ability to obtain model with ease and speed (Kosko, 1992a,b; Taber, 1991) as well as reaching similar results with lower sample sizes comparing to other methods (Özesmi, 2001a).

Among the disadvantages of FCM are: influence of the interviewees' knowledge, ignorance, misconceptions and biases on the shape of the maps (Kosko, 1992b), the inability to provide real-value parameter estimates or inferential statistical tests (Craiger et al., 1996), lack of a concept of time (Schneider et al., 1998) which is the reason why they cannot model transient behavior (Hobbs et al., 2002), the inability to deal with co-occurrence of multiple causes such "and" conditions (Schneider et al.,1998).

The disadvantages of FCM, however do not make other methods more useful for the purpose for the study. Experts systems require building of a knowledge base, which consumes more time than creating a cognitive map (Özesmi 2004). Structural equation modeling (SEM) is based on a statistical model and has the inability to estimate parameters if model or data are insufficient (Craiger et al. 1996) which is not a concern for FCMs providing qualitative information. System dynamic models require a lot of empirical data while FCMs can be used when rich data is not available.

In this study, two ESG cognitive maps were designed based on interviews of eight independent financial experts. The software FCMapper_bugfix_27.1.2016 was used to obtain the maps. The experts are directors and managers with considerable experience (more than 20 years) in financial management and are responsible for financial decision-making regarding ESG risk in the public and private sectors. Some of the experts represented the banking sector, some public companies, and others self-government entities. Every expert was interviewed for about 50 min. The list of ESG factors that was discussed during the interviews was selected based on a literature review, especially considering the work of Escrig-Olmedo et al. (2019). Common stages in the cognitive mapping process include the following:

1. Development of an interview questionnaire.
2. Selection of experts participating in interviews.
3. Establishing a list of criteria for assessing the specificity of a given research problem.
4. Selection of criteria with the greatest impact on the studied phenomenon and model.
5. Development of a correlation matrix between the analyzed criteria.

The density and type of variables included in a map are two categories that are important for analyzing the cognitive map. The density (clustering coefficient) of a fuzzy cognitive map (*D*) is an index of connectivity, which shows how connected or sparse the maps are [Ozesmi&Ozesmi 2004]. The clustering coefficient is calculated based on the following formula:

$$\boldsymbol{D = \frac{C}{N(N-1)}} \qquad (1)$$

or

$$\boldsymbol{D = \frac{C}{N^2}} \qquad (2)$$

A cognitive map is built on three variables types: transmitter variables (forcing functions, givens, and tails), receiver variables (utility variables, ends, and heads), and ordinary variables (means) [Ozesmi&Ozesmi 2004]. These variables are defined by their outdegree (od(vi)) and indegree (id(vi)). Outdegree is the row sum of absolute values of a variable in the adjacency matrix. It shows the cumulative strengths of connections (aij) exiting the variable and is calculated according to formula 3 [Ozesmi&Ozesmi 2004]:

$$\boldsymbol{od(v_i) = \sum_{k=1}^{N} \bar{a}_{ik}} \qquad (3)$$

Indegree is the column sum of absolute values of a variable. It shows the cumulative strength of variables entering the variable. It is calculated according to formula 4 [Ozesmi&Ozesmi 2004]:

$$\boldsymbol{id(v_i)} = \sum_{k=1}^{N} \bar{\boldsymbol{a}}_{\boldsymbol{ki}} \qquad (4)$$

Transmitter variables have a positive outdegree (od(vi)) and zero indegree (id(vi)). Receiver variables have a positive indegree (id(vi)) and zero outdegree (od(vi)). Ordinary variables have both a nonzero indegree and outdegree [Ozesmi&Ozesmi 2004]. The total number of receiver variables can be considered an index of its complexity. If the FCM considers many outcomes and implications that are a result of the system, many receiver variables are represented on the map [Ozesmi&Ozesmi 2004, 121]. A large number of transmitter variables describe the "flatness" of a cognitive map, where causal arguments are not well elaborated [120]. The complexity of cognitive maps may be compared by using the ratios of the number of receiver (R) to transmitter (T) variables: R/T. In more comprehensive maps, these ratios will be larger due to their large number of utility outcomes defined on the maps.

The centrality (immediate domain, total degree (td(vi)); Ozesmi&Ozesmi 2004, 121) of a variable is the summation of its indegree (in-arrows) and outdegree (out-arrows) [Ozesmi&Ozesmi 2004]:

$$c_i = td(v_i) = od(v_i) + id(v_i) \qquad (5)$$

A cognitive map provides knowledge about the impact factors in the decision-making process. Here, the selection of criteria of the highest importance was divided into three aspects: environmental, social, and governance. Experts were asked to evaluate a total of 62 factors, of which 21 were environmental related, 25 were social related, and 16 were governance related. The factors were selected according to the related work, with special emphasis on the ESG factors included in the methodology of sustainable rating agencies. The task of the experts was to assess the strength of the impact of these criteria on financial system risk (both public and private), as well as to provide an indication of the direction of this impact (positive versus negative influence). The experts made their assessments using a 5-point Likert scale, where 1 was the smallest positive influence and 5 was the largest positive impact. Similarly, the value -1 was the least negative impact on the financial system and -5 was the largest negative impact. The result was a list of the most impactful criteria. Only the criteria, for which the average calculated on the basis of the absolute values of the awarded points was the highest, were selected for the next research stage. The results of the selection were presented to the experts for verification. A list of the crucial criteria for public and private finance in every ESG aspect is presented in Table 1.

Table 1. The main ESG factors incorporating by financial institutions in decision making process in public and private sector

Environmental	Social	Governance
Private financial system		
(C1)Control of environmental impacts (C2)Hazardous waste (C3)Travel and transport impact (C4)Waste management reduction (C5)Water use and management	(C6)Customer relationship management (C7)Customer and product responsibility (C8)Human Capital Development & Training (C9)Human Rights criteria (C10)Labour management (C11)Local suppliers (C12)Market ethics (C13)Non-discrimination, promotion equality (C14)Privacy and data security (C15)Protection of children (C16)Exclusion of children labour	(C17)Business ethics and fraud (C18)Corporate government functions and commitments (C19)Prevention of corruption and bribery (C20)Remuneration of members of the executive team (C21)Respect of shareholders rights (C22)Risk and crisis management (C23)Transparency
Public financial system		
(C1)Carbon intensity emissions (C2)Climate change (C3)Energy consumption (C4)Environmental policy management (C5)Environmental reporting (C6)Hazardous waste (C7)Pollution management/ recourses (C8)Travel and transport impact (C9)Waste management reduction (C10)Water use and management	(C11)Human Capital Development & Training (C12)Exclusion of children labour (C13)Respect of trade unions (C14)Responsible investing (C15)Social reporting (C16)Talent attraction / retention (C17)Work – life balance	(C18)Audit and control system (C19)Prevention of corruption and bribery (C20)Respect of shareholders rights (C21)Antitrust policy (C22)Transparency

Source: own elaboration based on: Escrig-Olmedo et al. (2019), p. 11-12

The second research stage was expert evaluation of the relationships among ESG factors and then identification of the strength of the relationships. The assessment was based on an 11-point scale, numbered from -5 to +5, that could describe any kind of relationship between two factors, positive or negative, where -5 means very strong negative impact and 5 means very strong positive impact. The results were used to design a correlation matrix between the criteria. Finally, fuzzy cognitive maps were employed to present the mutual relations and directions of influence between particular criteria (C1–C22) according to the relationships existing between the 22 criteria selected for the analysis. The two fuzzy cognitive maps for private and public financial systems are presented in Figures 1 and 2.

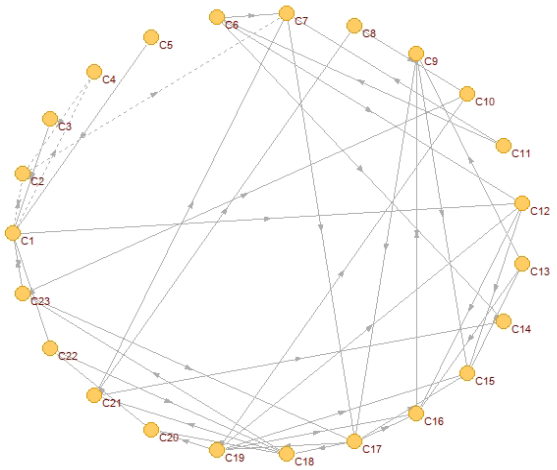

Figure 1. FCM impact ESG on private financial system

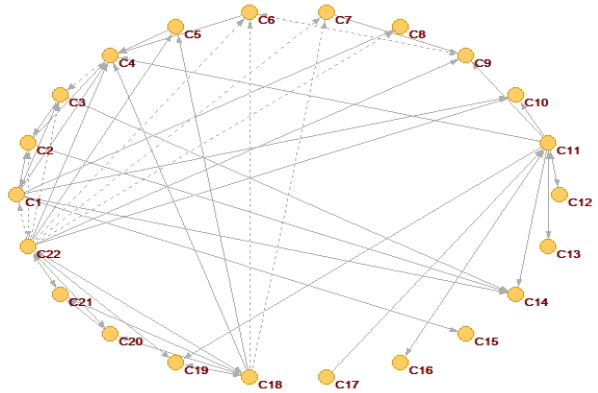

Figure 2. FCM impact ESG on public financial system

4. RESULTS AND DISCUSSION

The patterns in the field of ESG factors and financial system risk were found to vary between public and private systems (more variables explain the impact in the public sector, and environmental impacts are more strongly considered in the public financial system). The specific results for the private financial system are listed below:

1. The social aspect has the greatest impact on the private financial system, followed by the environmental aspect, and, finally, governance.
2. For the private financial system, risk related to social factors is most responsible for nonfinancial risk exposure (11 risk factors in the private financial system compared with 7 factors in the public financial system).
3. Regarding the social aspect (C6–C16), variables that impact the private financial system may be divided into groups related to customers (C6, C7, C12, and C14), suppliers (C11), human rights (C9, C13, C15, and C16), and the labor market (C8 and C10).
4. For the environmental aspect (C1–C5), the crucial and most impacting variable was found to be variable C1 (control of environmental impacts), which showed a positive relationship with variables C3 and C5; these relations were negative in the case of other variables (dashed line).
5. Regarding governance (C17–C23), only positive relationships were found.
6. Positive relationships were observed mainly between variables in the social aspect (e.g., C6 and C7, C6 and C14, C11 and C6, as well as C12 and C15) and the governance aspect (e.g., C17 and C18, C18 and C20, as well as C20 and C22).
7. A negative impact was observed mainly in the environmental aspect. There was a strong negative relationship (-1), for example, between the variables C1 and C2, C1 and C4, C1 and C3, as well as C4 and C2.

The specific results of the study for public financial system were as follows:

1. Environmental factors were found to have the greatest impact on the public financial system, followed by social factors, and, finally, governance.
2. The significance of environmental factors (C1–C10) for generating risk is greater in the public financial system (10 risk factors) than in the private financial system (5 risk factors).
3. Regarding the environmental aspect (C1–C10), "carbon emissions" is the variable that was found to have the strongest impact on the public financial system. A negative relationship was observed between "environmental policy management" and "energy consumption", and "waste management reduction" and "hazardous waste" (Fig.2).
4. For the social aspect (C11–C17), only positive relationships were observed between variables. The leading factors was "human capital development and training" and its relationship with five other variables (Fig. 2).
5. For governance (C18–C22), the relationships were positive only (Fig. 2).
6. A strong relationship was found to exist between the variable "carbon intensity emissions" (environmental) and two variables from the social area (C14 and C15), which was a positive relationship (solid line in Figures 1 and 4). Strong relationships were also observed between variables C4–C10 (environmental) and variable C14 (social) and "human capital development and training" (social), after the variable "prevention of corruption and bribery" (governance).
7. The variable "transparency" (C22 and C23) positively, and in most cases, strongly affected all variables considered in the study.

The differentiation of the impact of ESG factors on public and private financial systems is justified by the specificity of both systems. For the public financial system, the leading role is played by factors from the ESG "macro" group (e.g., carbon emissions), while for the private financial system, they are from the ESG "micro" group (e.g., customers). The leading impact of environmental factors on nonfinancial risk in the public financial system is not surprising, since environmental factors, including combating climate change, are the subject of political and international agreements, especially after the 2015 United Nations Climate Change Conference. In turn, the role of social factors and their growing impact stem from the implementation of policies and goals for sustainable development (the 2030 Agenda for Sustainable Development), especially through socially responsible business. While analyzing the role of governance factors, OECD reports and recommendations are crucial for ensuring transparency and fighting against corruption and bribery. Transparency and antibribery and anticorruption mechanisms are regulated by law, are a part of every state policy, and are within the scope of interest of public authorities.

The different impact of ESG factors on the public and private financial systems is also due to the fact that the private financial sector may exclude itself from selected risk-creating activities, while the public financial sector cannot do so. This applies to environmental risk, where financial institutions may decide to not cooperate with environmentally unfriendly businesses, thereby reducing this risk, and while the state cannot eliminate environmental risk, it can minimize it through environmental policy, mainly through environmental taxes.

In turn, the greater impact of social factors on the private financial system compared with the public financial system results from national and international regulations that are imposed on employers regarding human and employee rights. The public financial system operates a redistribution mechanism that counteracts inequality, exclusion, and similar phenomena, while democratic public institutions, being transparent and under the control of citizens, are obliged to outlaw human and employee rights violations. Therefore, in the private financial system, due to the greater risk of abuse regarding social factors, there is greater pressure to ensure social standards and greater risk related to control and penalties in the event of noncompliance with standards.

In the public financial system, there are no operations based on profit and sales, which shapes relationships with suppliers, and their selection for cooperation is not a risk factor, just like market risk.

In turn, from the perspective of enterprises, cooperating with environmentally unfriendly or unethical entities that do not meet the criteria of corporate social responsibility results in increased reputational risk and, as a consequence, loss of sales revenues or increased costs due to penalties and fines.

The positive impact of the "human capital development and training" factor was observed for both financial systems. Raising competence through training results in increased awareness, including for ESG risk management.

The differences between the private and public financial systems result in different approaches to managing ESG risk. "Environmental policy management" turns out to be a useful tool in reducing the negative impact of environmental factors on the public financial sector, as is "waste management reduction" and "hazardous waste". One of the elements of "environmental policy management" in the public financial system is environmental taxation. In the private financial system, on the other hand, environmental risk is minimized through "control of environmental impacts".

Similarly, social risk management in the public financial system is carried out in close connection with social reporting and responsible investment. The state has an impact on shaping policies and incentives for responsible investment, and it also has the option of spending public funds to finance or cofinance projects in the field of responsible investing. In turn, private sector entities implement best practices and codes of ethics to minimize social risk and the associated reputational risk.

The impact of the governance aspect is comparable for private and public financial systems. In particular, this concerns common factors such as transparency and antibribery and anticorruption activities. In the case of the public financial systems, audits and antitrust policies are the elements that distinguish this system from the private financial system. For the private financial system, executive members, corporate government functions, and risk management dominate. In sum, the impact of governance is similar for private and public financial systems, but the manner in which governance risk is reduced is different.

To the best of our knowledge, no study has analyzed ESG factors from the risk perspective in private and public financial systems, so it is difficult to compare our findings with similar research results or to discuss related works. Regardless, we can state that our findings are in line with Orlitzky et al. (2003), who found that environmental and social responsibility affect financial effects, and Brooks and Oikonomou (2018), who argued that the positive impact of ESG effects is lower than the negative impact of ESG negligence on economic performance. Based on a literature review concerning environmental factors, our findings are in line with research results that have proved the positive impact of economic and financial development on greenhouse gas emissions (Atalla and Bean, 2017; Kabaklarli et al. 2018).

5. CONCLUSION

Currently, ESG factors are vital to the risk impact of both private and public financial systems. Therefore, a question arises about the impact of these factors on the private and public financial systems and about the awareness and knowledge of financial managers regarding the impact of nonfinancial factors on finance. Recognizing such impacts allows for diagnosing and managing ESG risk in the private and public financial sectors.

This study was one of the first to attempt to comprehensively analyze the impact of ESG factors on the private and public financial systems, to determine the relationships between factors, and to answer questions about how to manage ESG risk and the differences in the approach between the private and public financial systems. The originality of our research approach and its results lies in including in the analysis of ESG factors the perspectives of financial managers in both the private and public financial systems. In particular, for the public financial system, no such research has been done so far. In this work, using cognitive maps, ESG factors acting on the private and public financial sectors were examined to discern the strength and direction of impact.

This study was conducted on the basis of interviews with 8 experts asked to assess the impact of ESG factors on the private and public financial systems in terms of risk created. 62 factors, of which 21 were environmental related, 25 were social related, and 16 were governance related, were examined. The analysis considered ESG factors taken into account in the literature as well as methodologies of sustainable rating agencies. As a result, a list of the most important ESG factors that are included in financial decisions by financial managers in private and public financial systems was created. In the next step, the directions and strength of interactions and relations between factors were determined.

As a result, ESG factors affecting the private and public financial systems were diagnosed, the differences between the systems were pointed out, ways of minimizing ESG risk in both systems were determined, and the factors with the greatest impact were identified. The research showed that the public financial system is most exposed to the negative impact of environmental factors, the private financial system is most exposed to the negative impact of social factors, and the impact of governance factors is similar. Detailed study results show that

- the "carbon emission" has the greatest impact on the public financial system;

- "control of environmental impacts" most greatly affects the private financial system from the environmental perspective;
- the variable "human capital development and training" and its relationships have a similar positive impact for the both financial sectors;
- variables affecting the social risk of the private financial system focus on the client, market, and suppliers;
- social reporting and responsible investing are popular for mitigating social impacts on the public financial system.
- The impact of governance was found to be comparable for the private and public financial systems, but the approach to reducing governance risk is different in both systems.

Our research confirms that the strongest impact on public decisions comes from the group of environmental factors, followed by the group of social factors, and, finally, governance factors. On the contrary, the strongest impact on private decisions comes social factors, followed by environmental and governance factors.

Decision makers in the public financial system perceive ESG risk more comprehensively and at the macro level compared with those focused on the micro perspective in the private financial system. This is expressed in the ESG risk management method, which takes place at the level of public policies and system solutions in the case of the public financial system and at the level of tools dedicated to enterprises in the case of the private financial system. Hence, effective tools in the public financial system correspond to the variables "environmental policy management", "waste management reduction", and "hazardous waste". In private financial system, the focus is on controlling single-level actions at the enterprise level ("control of environmental impacts", e.g., the choice of a low-emission mode of transport, transport of hazardous waste including safety measures, etc.).

Differences in the perception of the impact of ESG factors in private and public management systems also result from the type of goods financed in both systems. Public good, social good, and their combination are not determined by creating an individual demand for such goods, so reputational risk does not affect demand. In the case of commercial goods, the opposite is true. Competition and satisfying individual needs determine the impact of ESG reputational risk on demand and private finance.

We are aware of the limitations of the study resulting from the specifics of research using cognitive maps. In the future, our research will focus on an international perspective and compare the attitudes of financial decision makers towards ESG risk between countries.

The results of this study allowed us to formulate the following recommendations:

- Public policies enabling effective environmental management should be strengthened.
- Reporting, auditing, and control of nonfinancial factors should be developed.
- The role of good practices and codes of ethics in business operations should be strengthened.
- ESG risk management systems should be implemented and developed in enterprises.

The public financial system's greater impact on ESG factors from a macro perspective affects the private financial system, such as through environmental taxation. There are, therefore, relationships between both financial systems.

6. ACKNOWLEDGMENTS

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Mathematical Modeling and Analysis of Factors Affecting Medical Errors in Emergency Department of Government Hospitals in Province X

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ABSTRACT
JCI established a standard for common medical errors in hospitals known as IPSG. This study focused on the emergency departments of government hospitals A to C and a private hospital D. The objective for this study is to know and determine which among the factors must be considered in constructing an emergency department (ED), which lessens medical errors, and to be able to create a mathematical model among the factors. This research used a combination of quantitative correlational research and quasi-experimental research. The data were tested for reliability using the Attribute Agreement Analysis (3A) method in MINITAB v.17 then it proceeded to factor analysis using SPSS, which yields the result of interdependence of the factors to each presence. SEM can be performed to see the partial correlation and multi collinearity of the variables. All of the measurements used were incorporated to create a mathematical model, which aims to analyze the factors. Among the three major factors that were cited, environmental-related (ER) factors ranked the highest correlativity to medical errors or International Patient Safety Goals (IPSGs) with a value of 0.82 versus the other factors of 0.59 and 0.68. Noise and illumination were the two highest contributors of medical errors from ER factors with a value of 0.93 and 0.82, respectively.

CCS Concepts
•General and reference→ Document types→ General conference proceedings

Keywords
Structural equations modelling; medical errors; attribute agreement analysis; HFMEA; emergency department

1. INTRODUCTION
World Health Organization defined emergency department (ED) as a medical treatment facility specializing in emergency medicine, the urgent care of patients who express without previous appointment; either by their own methods or by that of an ambulance. Due to the unplanned nature of patient attendance, the department must provide initial treatment for a broad spectrum of illnesses and injuries, some of which may be life-threatening and require immediate attention. In some countries, emergency departments have become important entry points for those without other means of access to medical care (GL Hospitals, n.d.)

Nurses, physicians, and other healthcare employees work under extremely stressful physical conditions. Several studies deal with healthcare employees' risk of contracting infectious diseases from patients due to airborne and surface contamination (Jiang et al., 2003; Kromhout et al., 2000; Kumari et al., 1998; Smedbold et al., 2002). Nursing staff members are also open to risk of injury from medical equipment such as high-intensity surgical-light sources. One study found that a light source used during surgery could potentially cause retinal damage in surgical staff (Fox & Henson, 1996).

Much research has examined the effects of noise on patients, but comparatively few studies are available for healthcare staff. There is evidence that staff perceive higher sound levels as stressful (Bayo, Garcia, & Garcia, 1995; Norbeck, 1985). Importantly, noise-induced stress in nurses correlates with reported emotional exhaustion or burnout (Topf & Dillon, 1988). A recent study by Blomkvist et al. (in press, 2004) examined the effects of higher versus lower noise levels on the same group of coronary intensive-care nurses over a period of months. Lower noise levels were linked with a number of positive effects on staff, including reduced perceived work demands, increased workplace social support, improved quality of care for patients, and better speech intelligibility. Other aspects of the environment, such as lighting levels and auditory or visual distractions, can also affect staff effectiveness while performing critical tasks such as dispensing medical prescriptions.

The objective for this study is to be able to know what are the factors greatly affect medical errors in ED of government hospitals in Province X; to determine which among the factors must be considered in constructing ED which lessens medical errors, and to be able to create a mathematical model and analysis among the factors affecting the medical errors in emergency department of government hospitals in Province X.

This study will focus on the emergency departments of government hospitals namely: (1) Hospital A; (2) Hospital B; (3) Hospital C and- (4) Hospital D - a private hospital. This study will be a significant endeavor in building and identifying factors which focus on medical errors. This study may contribute to the researcher, students, readers, journalists, and other writers that show a great fundamental and broad view of knowledge about

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mathematical modeling and analysis of workplace design. This would motivate the readers and researchers to gain intellectual strategies and other presentations that could help their study as well. Moreover, this research will provide recommendations on how to improve workers' performance of an emergency department of government hospital in Province X.

Furthermore, this study will be useful to the other private hospitals and informing them in the area of mathematical modeling and analysis of factors affecting medical errors in emergency department. It will also serve as a future reference for researchers on the subject of facilities planning and design, multivariate statistical analysis and workplace design and analysis. And most importantly, this research will educate hospitals in deciding on

- what particular factor they should have in order to decrease the medical errors in emergency department.

2. METHODOLOGY

This research will be using a combination of quantitative correlational research and quasi-experimental research as shown in figure 1, which aims to systematically investigate and explain the nature of the relationship between multiple dependent variables to multiple independent variables.

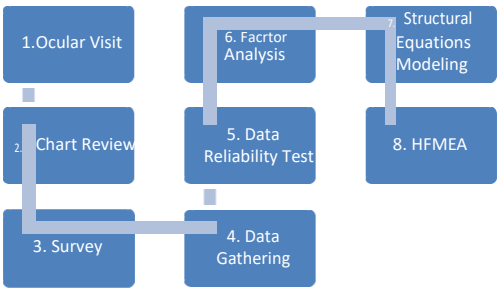

Figure 1. Research Methodology

The research started in an ocular visit which was endorsed by the DOH to respective hospitals and from there, a chart review which corresponded to the Global Trigger Tool (See Appendix C) to identify the medical errors in the chart. Then, an approved survey questionnaire was filled out through an interview by the medical practitioners per corresponding emergency department. Tools such as thermometer, sound meter, lux meter and HAV tool were used to get the data for environmental and facility related-factors.

The gathered baseline data was tested for reliability using Attribute Agreement Analysis (Attribute) in MINITAB v.17. If the data gathered passed the reliability test, then it will proceed to factor analysis using SPSS, which yields the result of interdependence of the factors to each presence. Lastly, if all the tools used were uniformly interpreted (if not, investigated), SEM can be performed to see the partial correlation and multi-collinearity of the variables. All of the measurements used was incorporated to create a mathematical model that aims to analyze the factors affecting medical errors in emergency department of government hospital in Province X.

3. RESULTS

The study was conducted in the emergency departments of three (3) government hospitals in Province X and one (1) JCI accredited private hospital. A total of five hundred seventy-seven (577) charts were reviewed for medical errors in a total of one hundred sixty-eight days of observations in parts of the emergency department like triage, resuscitation area, major trauma/medical areas/consultation rooms, minor procedure rooms, observation units, injection rooms and 24-hour pharmacy. Various methods were used to determine the data needed for the study such as ocular visit, chart review, interview, and observation using environmental factor tools like thermometer, sound meter, light meter, and HAV tool. By the combination of these techniques, several gaps were identified in the work environment and facilities provided to the medical workers. Based on the study, several interventions have been suggested, which will eventually help to improve the work environment and also to overcome the factors affecting medical errors.

3.1. Structural Equation Modeling

Structural Equation Modeling (SEM), as a concept, is a combination of statistical techniques such as exploratory factor analysis and multiple regression. SEM, as a concept, is a combination of statistical techniques such as exploratory factor analysis and multiple regression. The purpose of SEM is to examine a set of relationships between one or more independent variables (IV) and one or more dependent variables (DV).

Merging all the factors and their categories is shown in figure 2, It shows that the ER2 and ER3 have a clear impact with the facility-related factors of 0.89 and 0.72, respectively. While ER2 has a bigger impact on facility-related factors of 0.89 and 0.93 on the medical errors. There is a 0.9 correlation between ER1 and ER2, which states that medical errors are evident when the noise is above the standard.

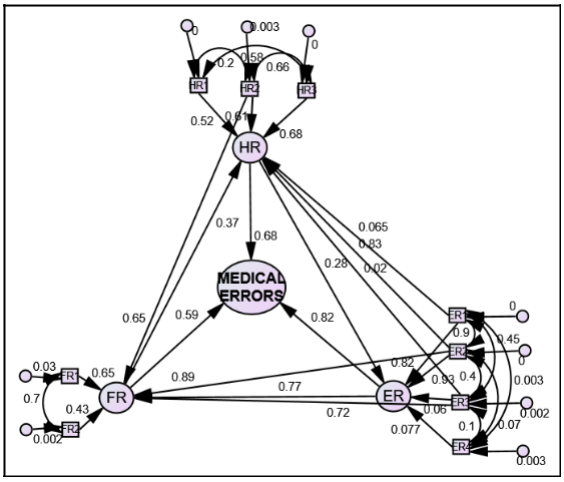

Figure 2. SEM for all factors with correlations, covariance and p-value

3.2. SEM Summary

The summary for regression weights as computed using AMOS plug-in in SPSS is shown in table 1. It shows that the environmental-related factors are linked the most to other factors and their sub factors as well with values from 0.077 to 0.93 in which ER2 (noise) has the highest contribution factor of 0.93 to the total ER factor.

Table 1. Regression weights of the SEM from AMOS of overall factors

DEPENDENT	INDEPENDENT	PARAMETER
ER	ER1	0.82
ER	ER2	0.93
ER	ER3	0.06

ER	ER4	0.077
ER	HR	0.28
ER1		0.00
ER2		0.00
ER3		0.002
ER4		0.003
FR	FR1	0.65
FR	FR2	0.43
FR	ER	0.77
FR	ER2	0.89
FR	ER3	0.72
FR	HR2	0.65
FR1		0.03
FR2		0.002
HR	HR1	0.52
HR	HR2	0.61
HR	HR3	0.68
HR	ER1	0.065
HR	ER2	0.83
HR	ER3	0.02
HR	FR	0.37
HR1		0.00
HR2		0.003
HR3		0.00
Medical Errors	FR	0.59
Medical Errors	ER	0.82
Medical Errors	HR	0.68

3.3. HFMEA

The HFMEA took place after the data analysis of several factors that affect the medical errors in selected emergency department of government hospitals in Province X.

Table 2. Recommended action for failure modes of some high-risk failure modes in selected emergency processes

Failure Mode	Potential Causes	Recommended Actions
Recording The incorrect information in triage sheet	Giving false information from the patient or not having knowledgeable person	Assessing the patient's ability to communicate effectively with healthcare providing; Detailed examination of the patient and not limited to what patient said
	Lack of a correct communication of physician with patient.	Assessing the patient's ability to communicate effectively with healthcare providing; Developing the criteria of performance evaluation and monitoring clinical process; Training course of effective communication and respect to the rights of service recipients
	Lack of confidence of the patient and patient's caregiver to the nurse	Catches the patient's desire for giving information; Implementation of the ethics nursing codes in the hospital for better interaction with the patient Correct communication with patient;
Error in patient transfer to the emergency surgery (incorrect refer of patient)	Incorrect decision by the physician	Detailed examination and complete knowledge of the patient's clinical condition; Correct history taking from the patient;
	Lack of a good protocol to determine the correct situation of patient	Taking into account the advice of other clinicians by the service provider if necessary; Assessing the patient's ability to communicate effectively with healthcare provider; Detailed examination of the patient and not limited to what patient said
	Absence of nurse aid or the intern	Coordination in medical team; Sharing information in medical team; Responsibility about patient safety
	Lack of cooperation of patient and being unstable of the patient	Cooperation for receiving information and consequences of each method; Awareness of patient about the need to do radiology; Monitoring the work process; To pass information sharing between the medical team
Delay to refer patient to the radiology	Lack of cooperation, coordination and team problems between radiology and emergency surgery	Sharing the information between medical team; Training courses of team work; Continuous monitoring of doing process; Coordinated acting of medical team Supply of additional power; Supply of additional power; Fitting the work volume with number of human resources;
	Overcrowding in radiology and or emergency surgery	Coordination of medical team and establishment of stress management; Determination of standard range and keeping client data in the standard range; Coordination between radiology and surgery wards
Unnecessary graph for patient is requested by the physician	Lack of correct communication of physician with the patient	Assessing the patient's ability to communicate effectively with healthcare provider; Developing criteria of performance evaluation and monitoring the clinical process; Training course of effective communication and respect to the rights of service recipients
	Lack of knowledge and enough skill by physician	Encourage physicians to ask about the ambiguity (taking into account the comments of other experts); Periodic training for clinical staff Reducing the workload and arranging the tables of work shifts and avoid of row shifts;
Delay in the beginning of the test on the intended sample in laboratory	Overcrowding of the laboratory	Supply of additional power; Fit the work volume with the number of human resources; Coordination of medical team and establishment of stress management
	Lack of awareness of the importance of the subject	Performing a justification course at the beginning; Determination a leader or supervisor for the team; Sharing information with medical team; Continuous monitoring of healthcare providing

Failure Mode	Potential Causes	Recommended Actions
Failure (error) in entering test answer in the system through laboratory	Lack of monitoring of a technical responsible on the process of doing work	Periodic monitoring and evaluation of laboratory;
		Checking the competence of the team leader and responsible person;
		Continuous monitoring of doing processes
	High work volume and staff fatigue	Programing and management of actions during the shift;
		Work division;
		Setting shift tables and lack of giving ling shifts
	Lack of enough experience	Evaluation and control of activity and checking the final test answers by technical manager;
		Developing the careers of introduction of new personnel to the ward's criteria

4. CONCLUSION

This study aims to achieve objectives such as; (1) to be able to know what are the factors greatly affect medical errors in ED of government hospitals in Province X; (2) to determine which among the factors must be considered in constructing ED which lessens medical errors; (3) and to be able to create a mathematical model and analysis among the factors affecting the medical errors in emergency department of government hospitals in Province X. Joint Commission International has standardized the common medical errors in hospitals which were grouped as International Patient Safety Goals (IPSG). IPSGs were subdivided into six (6) categories or goals; (1) correct patient identification (IPSG 1); improve effective communication (IPSG 2); improve the safety of high-alert medications (IPSG 3); ensure correct-site, correct-procedure, correct-patient surgery (IPSG 4); reduce the risk of health care–associated infections (IPSG 5); and reduce the risk of patient harm resulting from falls (IPSG 6). The research team identified three rigorous studies that link environmental factors, such as lighting, distractions, and interruptions, with errors in prescribing or dispensing medications (Booker & Roseman, 1995; Buchanan, Barker, Gibson, Jiang, & Pearson, 1991; Flynn et al., 1999). According to the SEM model of overall factors explained, ER2 (noise) ranked the highest factor that greatly contribute to the medical errors of emergency department. Next to it is ER1 (Illumination) with a regression value of 0.82 to the total ER factors. Then the HR3 (Ward-environment) sub-factor ranks the third with a regression value of 0.68 with the total HR (Human-Related Factor; regression value – 0.68). Hend and Barber (2000) classified the causes for medication errors into three categories of personal, contextual and knowledge-based factors, personal factors include, stress, tiredness, confusion, the physician prescription, errors of orders implementation, inadequate attention to details, lack of job-satisfaction, unpleasant workplace, decreased sense of commitment and career conscience and so on.

The next objective is to determine which among the factors must be considered in constructing ED, which lessens medical errors. This means that the factor with the most correlation and covariance with the other factor must be taken into consideration as shown in figure 2. The SEM of all the factors with specific correlations and covariance show the specific relationship of a certain factor to other as well. ER2 and ER3 have a clear impact with the facility related factors of 0.89 and 0.72, respectively, while ER2 has a bigger impact on facility-related factors of 0.89 and 0.93 on the medical errors. There is a 0.9 correlation between ER1 and ER2, which states that medical errors are evident when the noise is above the standard. Noise and temperature contribute to the medical errors that are attributed in the facility related factors as shown in figure However, noise and illumination are the highest contributors for the totality of the environmental factors (0.93 and 0.82 respectively; p-value = 0) using the embedded Chi-square methodology in SEM as a method of analyzing factorial metrics. HR has a 0.28 correlation to ER and 0.68 to total medical errors. ER has the highest impact to the medical errors with a value of 0.82 and 0.77 to FR as shown on Figure 2.

Therefore, when creating an emergency department, it is better to take into account the noise factor next is the proper illumination and airflow for temperature and humidity as these factors were correlated to other factors such as human-related factors and facility-related factors. Overall factors under human-related factors, which affect the medical errors according to the seven (7) groups of medical practitioners, were (1) inadequate attention, (2) tiredness due to excessive overwork time, and (3) no assessment before drug administration under nurse-related factors. Other factors such as (1) incorrect transfer of doctors' order from the patient's file to kardex, (2) incorrect transfer of doctors' order from kardex to medical card, (3) illegibility of physician's order in patient's file, and (4) illegibility of patient's chart are the most contributing factor for medical errors under management-related factors. Heavy workload in the ED, noisy ED environment, and similar drug name and label are the most contributing factors for medical errors under management-related factors.

Applying the SEM analysis on human-related factors with categories of (1) HR1-Worker's Fatigue; (2) HR2-contextual and knowledge-based factors, personal factors; and (3) HR3-Stress and Fatigue gives an insight to the overall correlation of the factors to the medical errors. Barber (2000) discussed that knowledge-based factors have a moderate effect on environment specifically on the flow of the facility, which is evident on figure 2 that there is a 0.65 correlation of HR 2 to FR. Lastly is to conduct SE model for ER, which is divided into four (4) categories, ER1 for illumination, ER2 for Noise, ER3 for Temperature and Humidity, and ER4 for Vibration. It shows that ER1 has a 0.83 correlation to the medical errors and human-related factors, while ER2 has a bigger impact on facility-related factors of 0.89 and 0.93 on the medical errors. There is a 0.9 correlation between ER1 and ER2, which states that medical errors are evident when the noise is above the standard.

Figure 2 shows the summarized correlation in SEM of the three (3) major factors; (1) human-related factors; facility-related factors; and (3) environmental-related factors. HR has a 0.28 correlation to ER and 0.68 to total medical errors. However, ER has the highest impact to the medical errors with a value of 0.82 and 0.77 to FR.

Based on the analysis of this research paper, a number of conclusions for the analysis of factors affecting medical errors in emergency department are generated:

- Among the three (3) major factors that were cited, environmental-related factors rank the highest correlativity to medical errors (IPSGs) with a value of 0.82 versus the other factors of 0.59 and 0.68 for facility-related and human-related factors, respectively.
- Noise and illumination are the highest contributors of medical errors from environmental-related factors with a value of 0.93 and 0.82, respectively. The average noise level in emergency department is 68.63 dba, which is higher that

the prescribed 45 dba level for best reading performance (Liu, 2016).

- There is a significant relationship between human-related factors and environmental factors (p-value = 0.003); There is a significant relationship between human-related factors, and facility-related factors (p-value = 0.03).
- Noisy environment contributes to fatigue and stress among medical workers inside the emergency department with a correlation of 0.83 and p-value of 0.000, which proves significance.

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A System Dynamics for Financial Strategy Model Assessment in National Health Insurance System

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ABSTRACT
The National Health Insurance System (NHIS) was established by the government to provide health insurance to its people. However, some obstacles will be faced by NHIS. For example, when not having proper financial management, the fiscal budget sector will experience a deficit. The issue is happening in Indonesia. The purpose of this research is to develop and evaluate problem models so it can be used for consideration in determining relevant proposed policies. This research uses NHIS data in Indonesia from 2014 to 2018. The method used is a system dynamics approach. The validation of the SD model uses the mean comparison test and t statistic. Next, the model is tested for sensitivity under extreme conditions of low, basic, and high. Patient variables generate low and high states of 34.34% and 33.24%, respectively, which affect the variable fund inventory about 49.3 trillion and -93.46 trillion, respectively. Otherwise, participant variables affect the supply of funds in low and high conditions were about -19.60 trillion and -26.19 trillion, respectively. It can be concluded variable have a direct influence on the expense variable (patient variable) gives a more dominant effect than the variable gives the overall impact (variable of expense and income) such as participant variables. Therefore, strategies related to patient variables are used as short-term strategies, while those related to participant variables are used as long-term strategies.

CCS Concepts
•Social and professional topics→ Medical information policy •Computing methodologies→ Model verification and validation •Computing methodologies→ Modeling methodologies •Computing methodologies→ Simulation evaluation

Keywords
system dynamics; simulation; NHIS; patient referral mechanism; financial strategy

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1. INTRODUCTION
The National Health Insurance System (NHIS) is a program established by the government to provide comprehensive health insurance to its people. Health service packages offered by NHIS are carried out in stages so they can monitor the quality and cost of health. The first year (2014) was launched, NHIS experienced problems such as a financial budget deficit of 1.94 trillion [11]. These constraints continue to occur and increase every year until 2018 [2]. These obstacles have arisen at NHIS in Indonesia.

NHIS problems are complex and dynamic so it is suitable to use a system dynamics approach. SD is a method for studying system behaviour has complexity from time to time. SD is usually used to investigate systemic interactions and the effects of feedback [4]. In addition, the SD approach is an approach based on real conditions in a system to study the behaviour of the system experimentally [5]. The purpose of using this approach includes solving problems by designing more effective policies by observing the behaviour of real complex systems.

SD has been implemented in several complex problem sectors, such as in the health sector, especially those discussing financial budgets. For example, Stammer [6] established policies to reform health services in the US. Another researcher, Thompson [7], observed behaviour dynamically in the health sector in the US.

An SD approach is needed to resolve the problem of a deficit NHIS financial budget [1]. In research [3], the health service cost sector and the participation sector do not have a relationship with each other. Meanwhile, participants who request health services at a health facility will generate health service costs. Changes in the relationship between participants and health service costs will change the validity of the existing model. These will create a behavioural relationship so it forms a loop between one variable and another.

Based on the review described earlier, this study will develop a model in the literature [3]. The development of this model is carried out so the existing NHIS model is in line with the system being observed at present. Therefore, this research is vital because it contributes to developing and evaluating the model so it can be considered for planning appropriate policies towards NHIS.

2. SIMULATION MODEL
2.1 The Case Study
This research developed a problem model in the literature [3]. Problems are modelled and evaluated are financial budget problems. The model to be developed in the sector of Participant, Benefit cost, Premium income, and Financial budget. The fiscal

budget sector represents the income and expense flow affects fund inventory. Income is obtained from premium income and other income. Meanwhile, the expense comes from benefit costs and other costs. Benefit costs are influenced by costs generated by Primary care (capitation costs and non-capitation costs) and costs caused by Advanced care (Claim costs).

The Participant Sector illustrates the membership relationship affects the sector of benefit cost and premium income. NHIS membership is categorised into three types, including Dues Assistance Recipients participants (PBI), Paid Workers Participants (PPU), and Individual participants. PPU is divided into two types, namely government employees (PPU-PN) and participants company (PPU-BU). The total number of participants affected the number of patients requesting health services at Primary care (PC) and Advanced care (AC). The amount of the premium determined varies according to the participant category. These affect the income represented in the premium income sector.

2.2 Model

The base approach teaches us to think systemically. The process of building an SD model begins with identifying NHIS problems and then determining the variables to form a loop. The loop occurs because of a causal relationship will create a causal loop. SD has two types of causal, namely negative loop and positive loop, uses STELLA tools (Figure 1). The linkages loop is explained below by using italics for variable writing.

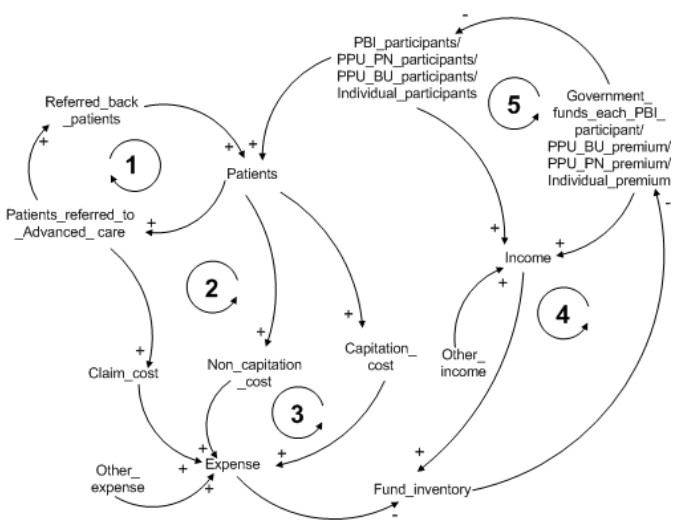


Figure 1. Causal loop model in main system

In loop 1 it is explained *Patients*, *Patients_referred_to_Advanced_care*, and *Referred_back_patients* influence each other. Increased *Patients* causes *Patients_referred_to_Advanced_care* and *Referred_back_patients* to increase. *Referred_back_patients* increases, then *Patients* also increase.

Then loop 2 shows *Claim_cost* has increased, so *Expense* has also increased. Increased *Expense* causes *Fund_inventory* to decrease. *Fund_inventory* decreases, *Premium* (*Government_funds_each_PBI_participant*, *PPU_PN_premium*, *PPU_BU_premium*, and *Individual_premium*) increases. An increase in *Premium* causes *Participants* (*PBI_participants*, *PPU_PN_participants*, *PPU_BU_participants*, and *Individual_participants*) and *Patients* to decrease. These caused *Patients_referred_to_Advanced_care* to decrease, so *Claim_cost* also decreased.

Loop 3 explains an increase in *Patients* affects growth in *Capitation_cost* and *Non_capitation_cost*. This increase affects *Expense*. *Expense* increases, then *Fund_inventory* decreases. A decrease in *Fund_inventory* causes *Premium* to increase and *Participant* to decrease. This decrease resulted in decreased *Patients*.

Furthermore, loop 4 shows *Fund_inventory* is increasing, so *Premium* and *Income* are decreasing. This decrease resulted in *Fund_inventory* also declining.

Then in loop 5 explains the increase in *Participant* causes *Income* increases. This increase affects *Fund_inventory* growth. *Fund_inventory* increases, so *Premium* decreases. *Premium* decreases, so *Participant* increase.

Furthermore, the causal loop model is changed to a stock and flow model. The model built is based on literature [3], but there are some developments in the model shown by Figure 2.

2.3 Model Testing

The next step is testing the model. Tests carried out, namely verification and validation. The verification carried out in this research is the same as the literature [3], while the validation test uses the mean comparison (Table 1) and t statistics (Table 2).

The equation formula (1) used to calculate the mean comparison is shown as follows.

$$E = \frac{|\bar{S}-\bar{A}|}{\bar{A}} \quad (1)$$

where,

E : error value
$\bar{S}$: average of simulation result value
$\bar{A}$: average of actual data value

E value <0.1, then the existing model can be said to be valid.Then for the test of statistical t using the following hypothesis.

$H_0: \mu_1 = \mu_2$	; no different
$H_1: \mu_1 > \mu_2$	; *Fund_inventory* in the actual data is higher than *Fund_inventory* in the simulation results.
α	: 5% or 0.05
Decision	: reject H_0 if the value α <0.05 and accept H_0 if the opposite

In the test of statistical t, the value of t must be in the reception area of H_0 so the existing model can be said to be valid.

Based on Table 1, the existing simulated model generates an error of approximately 0.027. It means is the existing model has following the observed system, is represented by calculating the error value < 0.1. Furthermore, testing using t statistics on the simulation results so the existing models are guaranteed validity.

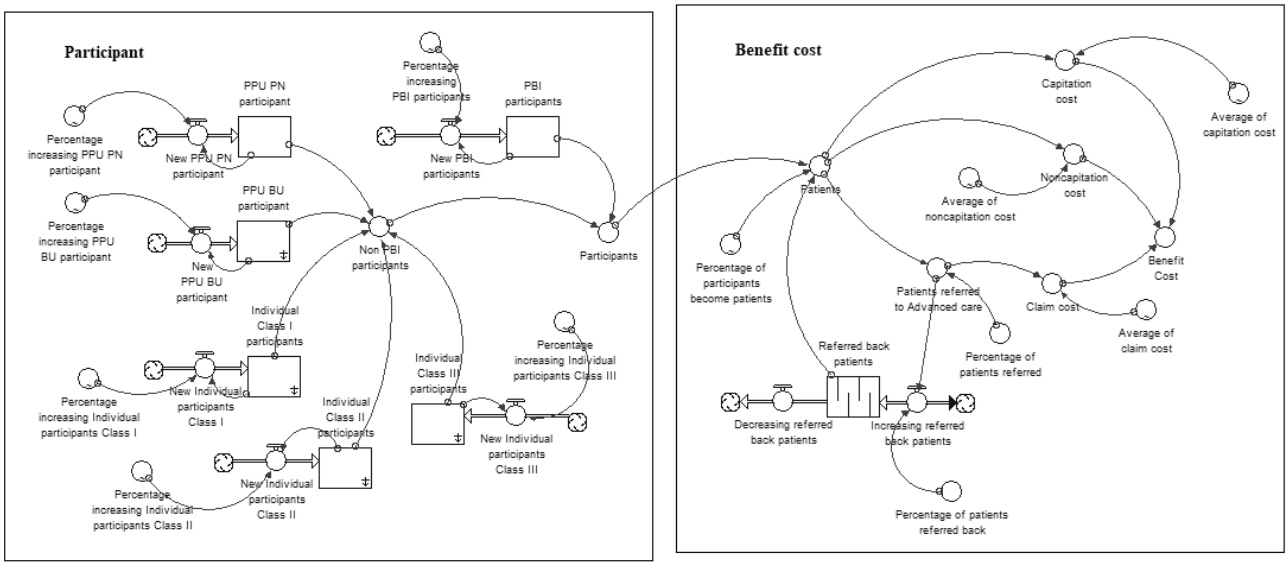


Figure 2. Stock and flow model in *Participant* and *Benefit_cost*

The validation test using the t statistic obtained a value of t about 1.480385908 and value of t of one-tail Critical (0.05; 4) about 2.131846786. Furthermore, the hypothesis test process is carried out, if the t value < value of t of one-tail Critical, then the null hypothesis is accepted. Conversely, the t value > value of t of one-tail Critical, so the null hypothesis is rejected. From the results of hypothesis testing obtained (Table 2), the value of t is less than the value of t of the one-tail Critical. Hence, the results are in the area of acceptance of a null hypothesis. Based on these tests, it can be concluded the simulation results are the same as historical data. Therefore, the model has been built can be declared valid according to the test of t statistical.

Table 1. Mean comparison test result

Years	*Fund_inventory*		
	Actual data	**Result of simulation**	**Mean comparison**
2014	(3,309,144,000,000)	(3,033,871,756,803)	0.083185332
2015	(9,069,216,000,000)	(8,995,475,608,327)	0.008130845
2016	(8,560,782,000,000)	(8,379,651,084,125)	0.021158221
2017	(23,025,252,000,000)	(23,435,889,320,000)	0.017834216
2018	(34,712,814,000,000)	(34,941,774,005,132)	0.006595835
Average of mean comparison			0.02738089

Table 2. t-statistic test result

	Actual data	Result of simulation
Mean	-1.57354E+13	-1.57573E+13
Variance	1.65902E+26	1.72261E+26
Observations	5	5
Pearson Correlation	0.99993083	
Hypothesized Mean Difference		0
df		4
t-Stat		0.169733893
P(T<=t) one-tail		0.436728952
t-Critical one-tail		2.131846786

3. RESULT AND DISCUSSION

The results obtained from simulating the SD (Figure 3) are the NHIS financial sector has a deficit from 2014 to 2018. If a long-term simulation is conducted, the results show the deficiency will occur until 2022, with an average increase of about 33.02% (Figure 4).

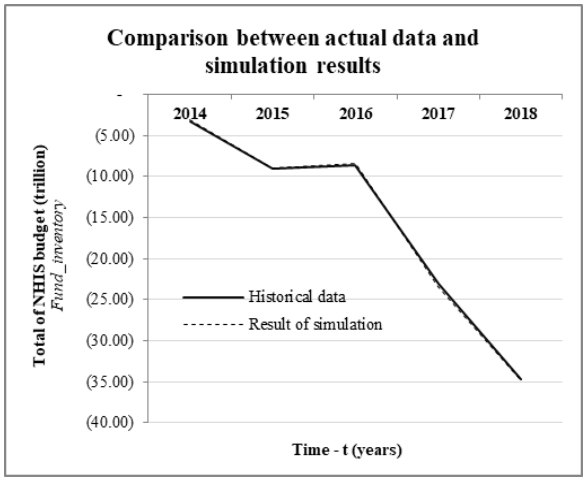


Figure 3. Comparison of simulation results and actual data

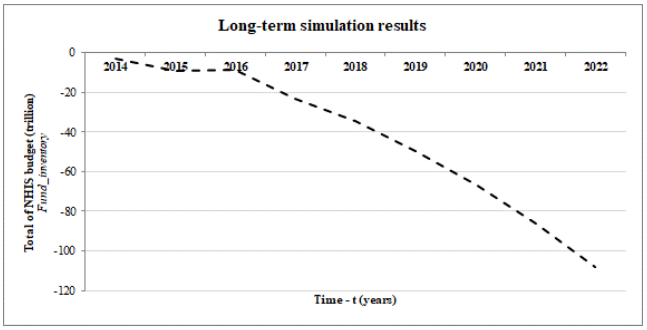
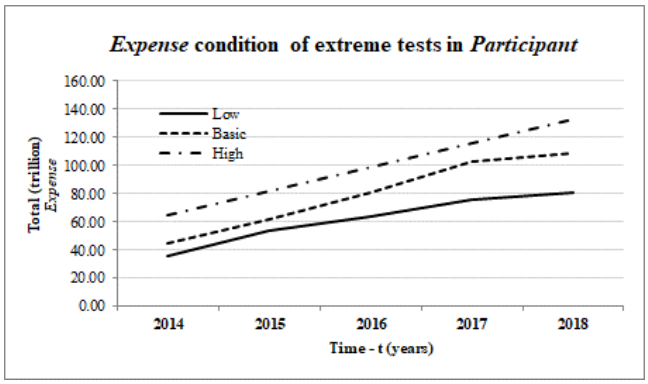
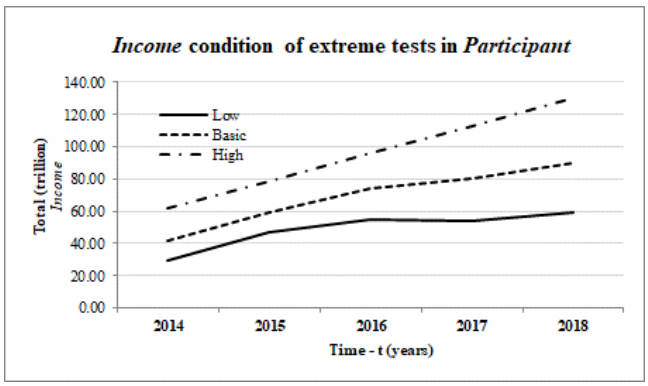


Figure 4. Result of long-term simulation

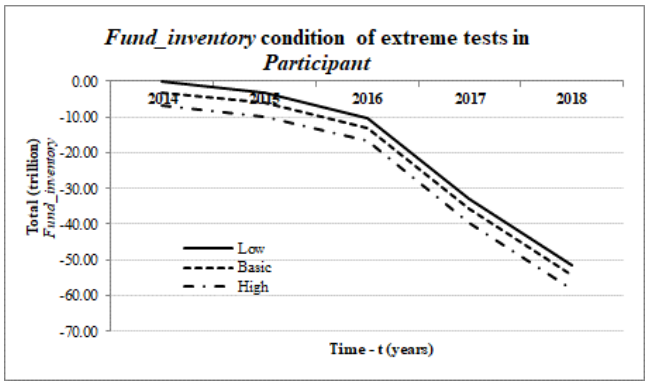
Sensitivity analysis is needed to investigate influential variables. This analysis is done so it can be used as a basis for planning the right policy. The analysis is done by testing the model in extreme conditions. Extreme values are obtained from the calculation of 95% PI Lower Bound (LB) and Upper Bound (UB). LB values are used as input values in Participant under extreme conditions. A low condition will represent this condition. Meanwhile, the UB value is used for the input values of extreme conditions above on Participant. A high state will represent this condition. Basic conditions indicate the existing conditions in the observation system.



(a)



(b)



(c)

Figure 5. Simulation results with *Participant* in Extreme Condition

Based on Figure 5, *Fund_inventory* continues to experience a deficit when there is a change in the number of *Participant* in Low (solid line), Basic (dotted line), and High (point line) conditions. The means is an increase in the number of *Participant* resulted in total *Income*, also experiencing an increase in *Income* and *Expense* on average about 39.14% and 26.37%. An increase in *Income* cannot balance the *Expense* must be borne as indicated by an average *Fund_inventory* deficit of approximately 26.19 trillion. From these results, changes only in the *Participant* sector did not have a significant effect on the financial budget, as evidenced by Figure 5. These need to combine several sectors to obtain better results.

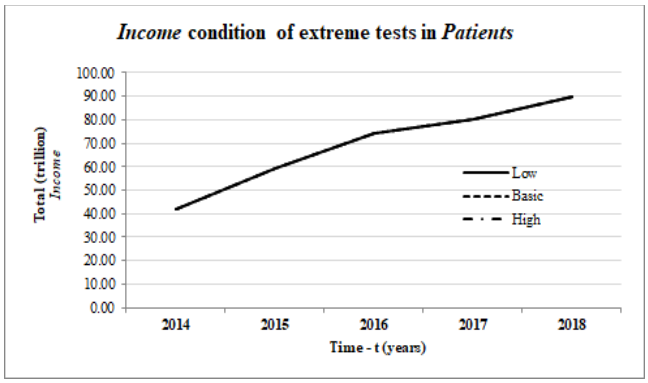
Next extreme conditions test is on the *Patients* variable. This test will significantly affect *Expense* and *Fund_inventory*. However, it does not affect *Income*, shown in Figure 6 when the number of *Patients* is low (solid line), *Fund_inventory* will not cause a deficit. Conversely, the number of *Patients* in the High condition (point line) causes *Fund_inventory* to experience a deficiency. The value generated by *Fund_inventory* in the High condition is an average increase of about -71.03 trillion from the Basic state. It can be seen *Expense* in the High condition experienced an average growth of approximately 33.24% from the Basic state.

Test extreme conditions conducted on both factors (*Participant* and *Patients*) it can be concluded the *Patients* variable has an influence on *Fund_inventory* rather than the *Participant* variable. The *Patients* variable only affects *Expense* but has a very significant effect. The average increase and decrease generated by *Patients* amounted to 34.34% and 33.24%, respectively, which affected *Fund_inventory* of 49.3 trillion in Low conditions and -93.46 trillion in High conditions. Unlike the case with the *Participant* variable affecting *Fund_inventory* in the condition of Low and High, an average of about -19.60 trillion and -26.19 trillion. The findings obtained from the variables sensitivity analysis have a direct influence on *Expense* (*Patients* variables) have a more dominant impact than the variables give overall effect (*Expense* and *Income*) such as the *Participant* variable. Changes to the *Patients* variable can be used as a short-term strategy, while the *Participant* variable is a long-term strategy.

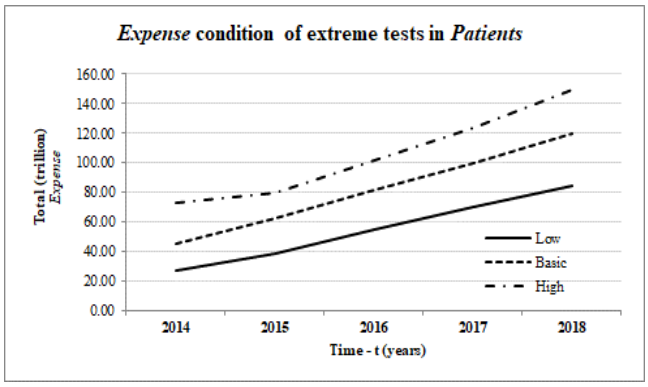
4. CONCLUSION

This research was conducted to develop and evaluate problem models so they can obtain consideration for planning appropriate policies so the NHIS financial budget does not experience a deficit. The approach used is SD.

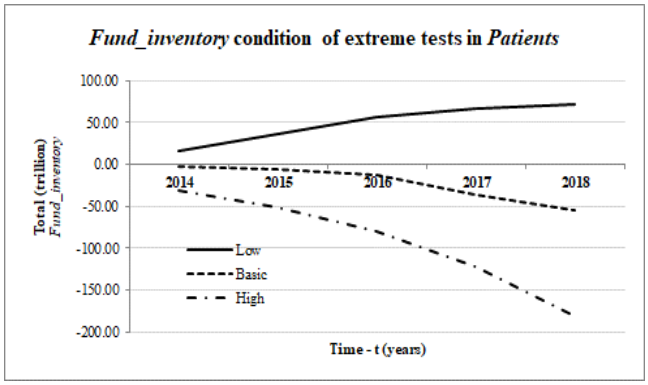
Several steps are carried out to build the existing model. First, identify the variables of the NHIS problem. Second, create a CLD to find out the interrelationships between variables so it can study the behaviour of variables in the model. Third, transforming CLD into SFD by using input data from the actual data has been obtained. Next, do verification and validation testing on the model has been built. Verification testing is done by checking the unit variables in the model. Then, validation testing uses mean comparison and t statistics.



(a)



(b)



(c)

Figure 6. Simulation results with Patient in Extreme Condition

Existing models have been declared valid will be tested in extreme conditions. The key variables used for testing are *Participant* and *Patients*. The results obtained are variables directly affect the *Expense* sector, such as *Patients*, which have a significant influence on *Fund_inventory*. Changes to the *Patients* variable can be used as a short-term strategy, while the *Participant* variable is a long-term strategy.

This model can be used as a material for practitioners and policymakers to determine the right policy. So, further research is needed to plan sustainable NHIS policies.

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Service Quality Assessment of Theme Park

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ABSTRACT
Theme park is one of the most important assets in tourism industry. To maintain its existence, one of the most important things is by considering customer satisfaction. Since service quality is regarded vital due to its close connection with customer satisfaction, assessing it would be beneficial for service providers. The objective of this research is to assess the service quality of a theme park. The weighted SERVPERF combined with importance-performance analysis were used to accomplish the objective of the research. However, since the attributes in the SERVPERF are intended for assessing "general service", the attributes of THEMEQUAL—which was developed in theme park setting—are utilized instead. To show the applicability of the proposed method, a case study was conducted to assess the service quality of a theme park located in Jakarta, Indonesia. Result shows that the performance of the object of the research is 3.009 (of 5.000), or in the "average" state. It means that improve-ment must be made to enhance the service quality.

CCS Concepts
• **Applied computing→ Law, social, and behavioral sciences.**

Keywords
Importance-performance analysis; service quality; SERVPERF; THEMEQUAL; theme park.

1. INTRODUCTION
Theme (or amusement) parks industry is considered as one of the most promising businesses in the world and has consistent growth from year to year. According to the report from Themed Entertainment Association, there was a growth of 8.1 million visitors in the top 25 theme parks in the world in 2018, an increase of 3.3% compared to 2017 [1]. Attendance at themed attractions also has exceeded half a billion visits for the first time in history [1]. These show that this industry is growing better and better. From an economic point of view, economic growth from theme parks shows a promising increase, global income gained from the theme parks worldwide reached 44.8 billion US dollars in 2017 [2]. This evidence shows that there is still a broad market and potential for promoting theme parks throughout the world.

In Asia, such industry is showing steady growth, fueled by not only large populations but also with their rising middle-class population [3]. Asia is the second-fastest-growing segment of the worldwide theme park industry [4]. Overall attendance growth was 3.6% in 2018 for the top 20 Asian theme parks, compared to 2017. It contributed to 11 theme parks that were included in top 25 theme parks of a total attendance in 2018, the most compared to other continents in the world. In Southeast Asia, Universal Studio of Singapore is included in top 20 theme park in Asia.

Indonesia, as the largest country in Southeast Asia, has several large theme parks, among which the largest are Dunia Fantasi, Jungle Land Adventure Park, Jatim Park, The Jungle Water Adventure, and Taman Mini Indonesia Indah. Indonesian government estimates that there is 20 billion US dollars in foreign exchange revenue that comes from the tourism industry [5]. To tackle that, one endeavor could do is Indonesia need to capture the potential and try to develop better theme parks to attract tourists. However, it seems that the development is not growing as expected. For example, in 2018, Dunia Fantasi was visited by 2,247,282 visitors in 2018 but it is a decrease 2.3% compared to 2017 [6]. Another example is The Jungle Water Adventure, a water park located in Bogor, which experienced a 14% decrease of attendance from 2017 to 2018 [1].

Theme park is a powerful revenue generator for the tourism industry [7], which means that people's needs for tertiary entertainment are urgently needed more than ever in the age of experience economy and social media. Moreover, as Indonesia is a populous country in addition with the growing of middle-class economy, are the evidences that there is great potential in theme park business. However, a theme park would not be successful without good service quality [7], [8]. Service quality is vital

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because theme park could benefit from repeat visits and the spread of positive word of mouth from satisfied visitors. In addition, this service quality has to be continuously improved due to its close connection with customer satisfaction [9], [10].

Some scholars have extensively studied and established various scales to assess the service quality; two of the most well-known scales are the classical SERVQUAL [11] and SERVPERF [12] that can be applied for various service settings. Since SERVQUAL has been subjected to a number of theoretical and operational criticisms (see e.g., [12], [13]-[16]), this research adopted the later scale, i.e., SERVPERF, with weight factors. However, the attributes in the SERVPERF are intended for assessing the "general service", i.e., not intended in a particular theme park setting. Therefore, this research employed the attributes in THEMEQUAL [17], which was developed in theme park setting.

In this research, we tried to extend the work by combining SERVPERF with importance-performance analysis (IPA) model [18]. The IPA model is believed to be a simple and effective method to identify attributes that performed well and those which were needed an improvement (see [19]-[22] for the examples of its applications). It is usually used to determine the priority of the service attributes according to the importance and performance. In addition, the inclusion of the IPA model in this research, is because every company is constrained by its limited resources. As a result, it has to be decided how those limited resources are best deployed to achieve the customers' satisfaction. Such an attempt has been performed in assessing service quality of an airport [23]. To exhibit the applicability of the method proposed, a case study was conducted in a theme park located in Jakarta, Indonesia.

2. RESEARCH DESIGN

The objective of this research is to assess and analyze service quality of a theme park. In order to achieve the objective, six dimensions of THEMEQUAL [17] were adopted, i.e., tangibles (TAN), reliability (REL), responsiveness and access (RES), assurance (ASS), empathy (EMP), and courtesy (COU). This scale is intended to measure the satisfaction level of visitors in theme park setting. These six dimensions consist of 26 attributes which are explained in the following.

Tangibles dimension is related to the physical environment of theme park. It includes the facilities, stores, restaurants, and landscape [24]. This dimension has four attributes, i.e., (i) the facilities within theme park have a modern outlook (TAN1), (ii) the staff of theme park have neat appearances (TAN2), (iii) the facilities within theme park are visually appealing (TAN3), (iv) the information media (leaflets, signpost, and map) inside theme park are visually appealing (TAN4).

The second dimension is reliability. From the classical SERVQUAL, it refers to the ability to perform the promised service dependably and accurately [11]. However, safety and security of the facilities are added into the measuring items for accommodating the special characteristic in theme park setting [25]. This dimension contains six attributes, i.e., (i) the staff of theme park will help the visitor to solve the problem when a visitor has a problem (REL1), (ii) all the performance and activities of theme park start on time (REL2), (iii) the facilities in theme park are safe (REL3), (iv) theme park can meet the commitment they have made in their advertisements and brochures (REL4), (v) the facilities within theme park are reliable (REL5), (vi) theme park can accurately perform the service.

Responsiveness and access as the third dimension refers to the willingness of the staff to help customers and provide prompt service. It contains six attributes, i.e., (i) staff are never too busy to respond visitors requests (RES1), (ii) staff can tell visitors exactly when service or performance will be performed (RES2), (iii) staff can give on time service to visitors (RES3), (iv) staff are willing to help visitors (RES4), (v) visitors can obtain information from staff easily (RES5), and (vi) visitors can access staff easily (RES6).

The fourth dimension, i.e., assurance, is defined as the knowledge and courtesy of staff and their ability to convey trust and confidence. It has three attributes, i.e., (i) the behavior of staff gives confidence to the visitors (ASS1), (ii) visitors feel safe during transaction (ASS2), and (iii) staff has sufficient knowledge to answer visitors' questions (ASS3).

Empathy as the fifth dimension is defined as caring, individualized attention the service providers provide to their customers. It has five attributes, i.e., (i) the operating hours of theme park are convenient for all visitors (EMP1), (ii) theme park has staff members who give visitors personal attention (EMP2), (iii) theme park has the visitor best interest at heart (EMP3), (iv) theme park can give visitors individual attention (EMP4), and (v) staff of theme park can understand the specific needs of visitors (EMP5).

The last dimension is courtesy. It refers to the politeness, respect, consideration, friendliness, and attitude of contact personnel, enabling visitors to have a pleasant experience [26], [27]. It contains two attributes, i.e,, (i) visitors have pleasant experience (COU1), and (ii) staff members are consistently polite (COU2).

The service quality is measured by employing the weighted SERVPERF [12] as follows:

$$SQ_j = \frac{\sum_{i=1}^{n} W_{ij} \cdot P_{ij}}{n}, \tag{1}$$

where SQ_j is the service quality of attribute j, W_{ij} is the weighting factor of attribute j to an individual i, and P_{ij} is perception of individual i with respect to the performance on atribute j. The weighting factor is the normalized form of the importance score as follows:

$$W_{ij} = \frac{I_{ij} - \min I_j}{\max I_j - \min I_j}, \tag{2}$$

where I_{ij} is the importance score, min I_j is the minimum score of attribute j and max I_j is the maximum score of the attribute j.

The importance of each attribute along with its corresponding performance are then utilized to establish the IPA diagram [17]. It is a two-dimensional state space where the vertical axis describe the importance of such attribute, while the horizontal axis describes how well the service provider is performing the service. The IPA diagram has four quadrants: (I) concentrate here, (II) keep up with the good work, (III) low priority, and (IV) possible overkill.

The first quadrant is located in the north-west corner. The attributes belong to this quadrant are considered as important but have low performance ratings, which become the priority of the service provider to be improved. The second quadrant identifies that both importance and performance of the attributes were already good and should be preserved well by the service provider. The attributes that are slightly important and have low performance ratings are located in the third quadrant: they perform well yet the customers observe as less important. The last quadrant is believed to be less

important but have good performance score: they are needed to be downgraded because of the unnecessary investment.

3. RESULT

A case study was conducted to assess the service quality of a theme park located in Jakarta, Indonesia. It takes about 40 minutes from Soekarno-Hatta International Airport (approximately 24.2 km). This theme park is considered as the biggest theme park in Indonesia with 9.5 hectare covered. It was opened and inaugurated on August 29, 1985.

The assessment of the service quality has been carried out through an online questionnaire-based survey. The questionnaire consists of three parts. The first part aims to collect demographic data of the respondents, such as age, gender, and occupation. The second is to assess the performance of the object of the research using the weighted SERVPERF according to the THEMEQUAL attributes. The third is to identify the relative importance of each attribute.

The participants of this survey were required to be over 17 years old and have been experienced visiting the object of the research. All item statements were measured on a 5-point Likert-type scale, ranging from 1 (strongly disagree for performance-type—and unimportant for importance-type questions) to 5 (strongly agree for performance-type—and important for importance-type questions). One hundred and ninety-three respondents were participated in this survey. They consist of students, employees, entrepreneurs, civil servants etc., indicates plenty diversity for the purpose of the research. There are more female respondents (64.8%) than male respondents (35.2%). The majority of the age of the respondents in this study were between the ages of 18-29 years old (96.43%), followed by 50-59 years old (1.02%), and below 17 years old (1.02%). Based on the level of education, the respondents were higher education students (68.88%), while 21.43% of them are high school students. The profile of the respondents is shown in Table 1.

The reliability test with Cronbach's alpha [28] was conducted before analyzing the questionnaire further. All of the attributes have the value of Cronbach's alpha more than 0.7; indicated that the questionnaire being utilized is reliable [29].

Table 1. Profile of the respondents

Variable		Percentage
Gender	Male	35.2
	Female	64.8
Age	> 17	1.02
	18-29	96.43
	30-39	0
	40-49	0
	50-59	2.55
	< 60	0
Education	High school student	21.43
	Higher education student	68.88
	Others	9.69
Occupation	Student	88.27
	Civil servant	2.55
	Employee	7.65
	Entrepreneur	0.51
	Others	1.02

Table 2. Service quality assessment results

Dimensions/ Attributes	$\frac{\sum_{i=1}^{n} I_{ij}}{n}$	$\frac{\sum_{i=1}^{n} W_{ij}}{n}$	$\frac{\sum_{i=1}^{n} P_{ij}}{n}$	SQ_j
Tangibles:				
TAN1	4.285	0.762	4.083	3.110
TAN2	4.192	0.731	4.083	2.983
TAN3	4.321	0.774	4.083	3.159
TAN4	4.363	0.788	4.130	3.252
Reliability:				
REL1	4.254	0.751	4.052	3.044
REL2	4.000	0.500	3.990	1.995
REL3	4.389	0.796	4.135	3.292
REL4	4.264	0.755	4.098	3.093
REL5	4.269	0.756	4.073	3.081
REL6	4.228	0.743	4.073	3.025
Responsiveness and access:				
RES1	4.238	0.746	4.078	3.042
RES2	4.301	0.767	4.067	3.119
RES3	4.202	0.734	3.990	2.928
RES4	4.352	0.784	4.140	3.246
RES5	4.244	0.748	4.166	3.115
RES6	4.192	0.731	3.891	2.843
Assurance:				
ASS1	4.358	0.786	4.150	3.261
ASS2	4.389	0.796	4.155	3.309
ASS3	4.306	0.769	4.155	3.194
Empathy:				
EMP1	4.161	0.720	3.979	2.866
EMP2	3.751	0.688	3.632	2.498
EMP3	4.031	0.677	3.819	2.585
EMP4	3.632	0.658	3.570	2.349
EMP5	3.979	0.745	3.865	2.879
Courtesy:				
COU1	4.497	0.832	4.326	3.602
COU2	4.451	0.817	4.114	3.361
Average	4.217	0.744	4.034	3.009

The performance score for each attribute is multiplied with the normalized value of the corresponding importance score. The average value for each attribute is then computed throughout all respondents using Equation (1). The results are shown in Table 2, respect to each attribute and each section: importance and performance.

The attributes with the highest score of importance for each dimension are: TAN4 of tangibles, REL3 of reliability, RES4 of responsiveness and access, ASS2 of assurance, EMP5 of empathy, and COU1 of courtesy. The dimension of courtesy has the highest average score of importance. From the visitors' point of view, the most important thing is being served by staff with courtesy, friendliness, and fun. On the other hand, the attributes with the lowest score of importance for each dimension are: TAN2 of tangibles, REL2 of reliability, RES6 of responsiveness and access, ASS3 of assurance, EMP4 of empathy, and COU2 of courtesy.

In the performance, the attributes with the highest score are: TAN4, REL3, RES5, ASS2 & ASS3, EMP1, and COU1 of tangibles, reliability, responsiveness and access, assurance, empathy, and courtesy, respectively. The attributes with the lowest score for each dimension are: TAN1, TAN2, and TAN3 of tangibles, REL2 of reliable, RES6 of responsiveness and access, ASS1 of assurance, EMP4 of empathy, and COU2 of courtesy.

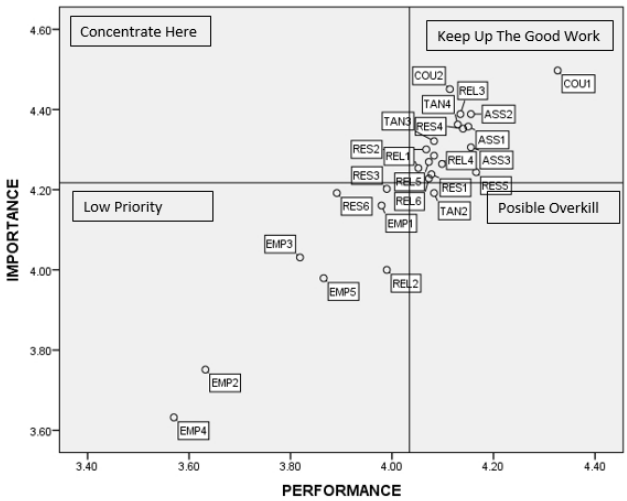

Figure 1. The IPA diagram result

The overall performance of the object of the research is considered as "average", based on the average score of 3.009 from the maximum score of 5. Nevertheless, the object of the research still has to do something to advance its service performance as a part of continuous improvement in order to achieve customer satisfaction. The IPA diagram then can be utilized to establish strategic strategies to achieve the customer satisfaction based on the performance and the importance of the item statements from the customers' point of view.

To establish the IPA diagram, the average score for each attribute were plotted in the two-dimensional state space. The horizontal axis refers to the performance or how well the object of the research is performing its service; while the vertical axis refers to the importance (not in a normalized form) of the atributes. The lines which are divided the diagram into four quadrants are calculated from the average scores of performance and importance. The IPA diagram of the object of the research is depicted in Figure 1.

There is no attribute belong to the first quadrant. The attributes located in the second quadrant, i.e., keep up the good work, is: TAN1, TAN3, TAN4, REL1, REL3, REL4, REL5, REL6, RES1, RES2, RES4, RES5, ASS1, ASS2, ASS3, COU1, and COU2. Visitors believed that those are important and the service provider has performed as their best. All attributes in the assurance and courtesy dimensions belong to this quadrant; it means that visitors perceived the politness, courtesy, and knowledge of the staff well.

Third quadrant, i.e., low priority, have these attributes: REL2, RES3, RES6, EMP1, EMP2, EMP3, EMP4, and EMP5. This quadrant refers to the performance that are not quite satisfactory and they are considered as not important form the visitors' perspective. Fourth quadrant consists of attributes that are considered as less important for the visitors' point of view, but the object of the research has carried it out excessively. Therefore, there is no need for improvement. The attributes in this quadrant is only TAN 2: staff have neat appearances.

Effective service quality serves as an important factor that must be considered in the face of intense competition from other entertainment services [30]. Based on the research that has been done, the results of this study indicate that the theme park has the average performance, both in employee performance and in the facilities provided to visitors; thus, management needs to improve current performance in order to attain customer satisfaction.

4. CONCLUSION AND FUTURE RESEARCH DIRECTION

The research has shown how to assess service quality of a theme park using the combination of weighted SERVPERF and the IPA model, by employing the attributes in THEMEQUAL scale. A case study to exhibit the applicability of the methods has been conducted in one of the largest theme parks in Indonesia. The result indicates that overall, the performance of the object of the research was average. To do improvement about what attributes to be enhanced to gain customer satisfaction, the firm might utilize the IPA model to recognize the attributes perceived important by the customers. Note that not all attributes have to be improved eventually. This can reduce the excessive investment spent by the firm.

The proposed methods are considered easy to implement, relatively simple to be interpreted, as well as inexpensive to be conducted. It has many potential benefits for the service provider since it can gain valuable insight about what attributes that have to be improved according to their performance scores and importance scores based on the visitors' perspective.

This study brings a new basis of knowledge on marketing and service science related to customer satisfaction in the theme park setting. From the practical perspective, in-depth outcome from this study will also be useful for theme parks management, as the outcomes provide guidelines to determine the priority of service attributes from the visitors' point of view.

For further research, it is recommended to use and compare other methods to assess and evaluate service quality of theme parks, especially in Indonesia, which does not have sufficient data and research on customer satisfaction in theme parks setting. For example, the customer zone of tolerance-based service quality (CZSQ) and CZSQ-based IPA (CZIPA) [31] to assess the service quality based on the competitive zone of tolerance by benchmarking against its competitors, as well as to prioritize the service attributes to be improved. Although these novel methods originally were developed in the area of hospitality to handle the inability of zone of tolerance to evaluate the priority of improving the service quality of the attributes and to overcome some limitations in the applicability of IPA, it can be further implemented to assess the service quality of theme park with some adjustments and modifications. However, despite of the superiority of CZSQ and CZIPA, the applications remain limited— see [32], [33] that were applying these methods to the different service areas.

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Modeling Regional Innovative System Performance in China Using A Dynamic Two-Stage SBM Model

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ABSTRACT

Innovative development has always been an important policy tool for accumulating effective intelligent property to the desirability of all policy makers in China, even more so now as the trade war has seriously threatened the Chinese economy. To understand the efficacy of regional innovative policies, we proposed the dynamic two-stage slacks-based measure (SBM) model with carry-over and intermediate variables, highlighting the importance of the status of invention patent, as granted patent and patent in force, to measure the overall innovative performance for the purposed of regional innovative development, which makes significant difference to previous studies on modelling setting. Using data of 30 provincial administration regions in China for the period of 2011-2017, the average regional innovative system performance is deemed as 0.5858 and we postulated that the difference of commercialization performance among three main areas should be pay attention, because the average performance of commercialization stage in the east area is obviously better than that the west and central areas. Based on this finding, we propose several policy suggestions as the provincial and central government who should be put more efforts on innovative competitiveness, as enhancing the quality and quantity of invention patents and the market-oriented to guild the direction for the R&D stage.

CCS Concepts

•Law, social and behavioral sciences → Economics •Operations research → Decision analysis

Keywords

Dynamic network model; Two-stage system; slacks-based measure; Regional innovative system

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1. INTRODUCTION

As of today, knowledge innovation plays a key policy in China's economic structural transformation to accumulate effective intelligent properties of great communization value to strengthen existing economic system to be impressed by growth performance over two decades running. The effective knowledge innovation activity is a major source of competitive advantage in the highly competitive business environment, and is also could be viewed as one important criterion to rate the extent of the national power. That is, invention patent and its commercial application on the new product and/or service development may have to change inherent human life and consumer experience and contribute value-added on gross domestic product.

China benefits from outstanding manufacturing industry, namely world factory, to be the second world economic market, representing that its business activities are more closely tied to the outside world. There are 120 corporations listed in Fortune Global 500 in 2018. Moreover, from production to innovation, is the national strategy of innovation-driven planning, provincial administration hierarchy must follow the political direction to purse industrial structure upgrade with more competitiveness due to the featured pyramid framework of political operation in China. Evaluation of the performance of regional innovative system (here, RIS) in China has attracted extensive notation.

Data envelopment analysis (DEA) is one of the famous methodologies applied in performance evaluation [1] with the linear programming specification of multiple input and output variables in the single period. Tone [2] proposed a crucial parameter, namely slacks, to show the difference between the actual value and the efficient value, which provides a direction to decision-maker a guild for improvement. However, one of the challenge of it is to ignore the internal structure on performance evaluation. An evaluation framework with network structure, e.g. two-stage activities, is introduced to rich and valuable managerial information to manager how to improve their efficiency in various industrial applications [3-5]. Tone and Tsustui [6] expended their concept of slack-based measure to the modelling on network DEA framework.

According to the impressing characteristics of knowledge capital on innovation activity, a performance evaluation of innovative system based on traditional DEA or network DEA is not suitable

framework. Tone and Tsutsui [7], for example, incorporated the setting of time frame into the NDEA by their SBM approach not only to generalize its evaluation ability from specific time period with internal structure to the entire evaluation period in the unified mathematic programming, but also assign some particular features on carry-over variables such as non- discretionary, discretionary, desirable and undesirable.

To explore the effect of innovation activity aggressively driven by China government, we used a dynamic two-stage DEA with SBM approach to estimate the performance of regional innovative system in China from 2011 to 2017, in terms of performance in R&D and commercialization stages. The intertemporal effect from applying the carry-over activities to link two consecutive periods in the R&D and commercialization stages are fed into the proposed evaluation framework that could make it possible to not only measure the overall and stage performance and observe their dynamic change, and but also identify the improvement on each stage performance to plan their future policy by the projection of selected variables.

The main findings of this paper can be summarized as follows. First, the average R&D performance of provincial administration is greater than the average commercialization performance, representing that focusing on the commercial effect of the patent should be enhancement their quality and the market-oriented to direct their new product development.

Second, the eastern region shows the best commercialization performance followed by the western region, and the central region demonstrate the worst performance. The government should focus on the performance of the regional innovative systems in central and the west area with relatively lower score. Having a systematic policy planning and innovative mechanism to promote collaborative development among different provinces and areas.

The remainder of this paper was structured as follows. Section 2 introduced the evaluation framework and data collection. The methodology was presented in Section 3. In Section 4, we presented the empirical results for the regional innovative system performance on provincial administration player and classified into three main areas in China. Finally, in section 5 we concluded our research with discussion of policy implication.

2. LITERATURE REIEW

The DEA-based methodology of performance evaluation in innovative system was of interest in researches as well as in practical application. For managerial purposes, the main advantage of DEA model was benchmarking application based on multiple input and output variables, which did not satisfy specifically functional form, effectively provided comparison information from ranking the DMUs and identifying the inefficient sources of crucial variables [8]. Conventional DEA model, a single-stage performance structure to be treated as black box, would not have adequate information to managers to the problem solving due to mainly ignoring the internal or intertemporal linkage relationship of each DMUs [7, 9]. As such, the two-stage performance model has gradually come to focus and has been cited in a vast number of studies [9, 11-14].

Zhang et al.'s study [9] is among the leading research using the two-stage DEA model based on a production approach to measure innovative performance in the Chinese high-tech industry. Li et al. [16] evaluated the innovative performance of the regional high-tech industry in China using dynamic DEA model. Xiong et al. [12] proposed a two-stage DEA model to assess the R&D performance of research institute in China. There were two main performance measures, R&D performance and commercialization performance or socio-economic performance, to estimate the overall performance of each high-tech industry. In addition, Lu et al. [13] employed two-stage DEA model to compute the performance of R&D and socio-economic stages of Taiwanese technology development programs and then examined their determinants.

As any decision-making about expenditure on innovative activity, however, will change the limited resources allocation among internal organizations of DMU and its operating in the future. Kao [15] pointed out that the overall performance of DMU over several periods must be measured in DEA-based model with dynamic component, taking into account the difference between annually expenditure and cost capitalization on the characteristic of variable definition from the accounting perspective. Li et al. [16] evaluated the innovation performance of the regional high-tech industry in China using dynamic DEA model.

3. MODEL BUILDING AND DATA COLLECTION

3.1 Conception Framework

The two-stage network DEA model proposed in Zhang et al. [9] and applied to measure the high-tech industry's innovative performance in China. They consider patent, such as patent applications and patents in force, as intermediate links between the R&D process and the commercialization process. We try to propose an advance framework of the work of Zhang et al. [9] used to evaluate the Chinese regional innovation system in this paper. We firstly introduce the dynamic effect into the evaluation framework they proposed by employing patent applications at the specific period to be a carry-over activity in stage 1 and patents in force at the period t as another carry-over activity in stage 2, given that patent applications and patents in force are consistently carried forward from now to subsequent period in the R&D stage and commercialization stage, respectively. Moreover, we add scientific paper published in SCI and SSCI database as desirable output of the R&D stage to better reflect the regional R&D performance due to incorporate the effort from the academy and research institute. Revenue from technology transfer is also added as another one of ultimate output in the evaluation framework to understand the economic benefit of the commercialization stage. Therefore, the modified evaluation framework of regional innovative system is developed based on the dynamic two-stage network SBM proposed by Tone and Tsustui [7], as shown in Fig. 1.

As illustrated in Fig. 1, the logic evaluation framework we proposed is applied to estimate the Chinese regional innovative system. In general, the production approach (the value-added approach) is commonly used in DEA-based modelling of innovation performance [10-14]. We model the operational structure as being composed of two stages with serial connection and intertemporal relationship, considering the different objectives of the stages in the entire value creation chain of innovative activity.

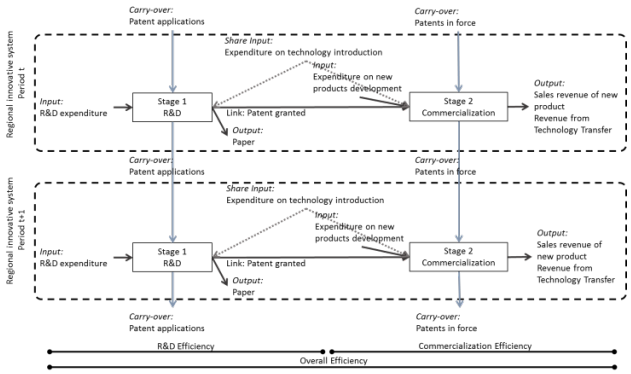

Figure 1. Dynamic two-stage network structure for regional innovative system

In the R&D stage, we consider R&D expenditure (input) and patent applications (carry-over) as two inputted variables. One intermediate variable, patent granted, is used to link between the R&D stage and the commercialization stage, and we employ one desirable output, paper, to be a desirable outcome. In the commercialization stage, we execute performance evaluation om the economic outcome of new product and patents in force, expenditure on new product development (input), patents granted (intermediate) from the R&D stage, patents in force (carry-over) from the previous year are inputted in to the model, while sales revenue from new product and revenue from technology transfer are the output variables. We illustrate the definition of selected variables in Table 1.

Table 1. Variables definition

Indicator	Definition	Unit
R&D expenditure (Input)	The R&D expenditure in the reporting year	billion RMB
Technology introduction expenditure (Shared Input)	The expenditure on technology introduction in the reporting year	billion RMB
Patent applications (Carry-over)	The quantity of accepted patent applications in the reporting year	1000 piece
Patent granted (Output/Input)	The quantity of granted patent applications in the reporting year to the subsequent year	1000 piece
Paper (Output)	The quantity of published SCI and SSCI paper in the reporting	1000 piece
New product development (Input)	The expenditure on new product development in the reporting year	billion RMB
Patents in force (Carry-over)	The quantity of patents in force in the reporting year to the subsequent year	1000 piece
Sales revenue (Output)	The sales revenue from new product in the reporting year	billion RMB
Technology transfer income (Output)	The revenue from technology transfer in the reporting year	million RMB

3.2 Data Collection

There are 31 provincial regions in China to be DMUs of an initial sample and the selected variables of modelling evaluation framework is mentioned in the previous section. As noted that the requirement to run DEA-based performance evaluation cannot have the non-negative and missing data of selected variables. After data inspection, we have 30 provincial administration region in Chia as final sample in this paper, Tibet is not included, covering the seven years from 2011 to 2017. The data of all selected variables were obtained from *China Statistics Yearbook* and *China Statistical Yearbook on Science and Technology* (2012-2018). One of the main purpose of this paper is to provide a rational evaluation framework with considering intertemporal effect to evaluate the Chinese regional innovative systems over 2012-2017 in the unfiled methodological framework. Avoiding the effect of time value of monetary on the evaluation results, it should be noted that all monetary variables used in this paper were transformed to be real values in 2011 RMB, which have been deflated with the customer price index (CPI index 2011 = 100). The customer price index is extracted from National Bureau of Statistics of China. Descriptive statistics of all variables are provided in Table 2.

Table 2. Descriptive statistics

Year	RDE	ITE	Paper	PatentG	PatentF	PatentA	NewProduct	Sales	TTI
2011	2,895,286	1,858,938	41,889	3,527	10,602	13,447	2,878,867	41,017,522	3,783
2012	3,345,175	1,754,014	42,504	4,570	14,501	17,417	3,289,909	44,215,173	2,795
2013	3,750,295	1,698,643	43,016	4,610	18,158	23,103	3,696,542	50,561,740	2,638
2014	4,039,614	1,567,077	44,092	5,258	22,105	26,320	4,001,170	55,376,107	3,136
2015	4,336,920	1,364,767	46,308	8,545	29,044	31,905	4,071,869	58,858,565	4,267
2016	4,704,441	1,336,958	48,065	9,826	36,761	39,774	4,599,437	66,485,556	6,238
2017	5,200,442	1,313,349	49,483	10,673	45,177	41,111	5,197,912	72,410,513	8,423
Overall	4,038,882	1,556,249	45,051	6,716	25,193	27,582	3,962,244	55,560,739	4,469

According to Tone et al. [17], homogeneity, minimum number of DMUs, and isotonicity were important assumptions on the validity test of DEA-based evaluation model. We therefore used these criteria to verify the discriminatory ability of the proposed dynamic two-stage SBM model. First, we finally selected 30 provincial regions in China to be DMUs. The underlying concept for supporting the homogeneity criterion was that, these regions were the in second-tier administrative bodies under the central government and all have equally political statutes. Even though, it was rationally expected that regional imbalance does exist in China due to geographical difference, which prompted us to modelling the evaluation framework with dynamic and intermediate components for rating the Chinese regional innovative development and providing several suggestions to guide policy direction in the future planning.

Second, having acceptable discriminatory ability is an important issue to the DEA-based evaluation model, the number of DMUs should be at least three times the number of input and output variables [18-19]. Similarly, Golany and Roll [18] proposed that the minimum required ratio related to the number of DMUs and model variables was two times. As we had 30 DMUs per year and 7 research years from 2011 to 2017, obtaining totally 210 province-year DMUs, were more than three times of nine variables we

employed, providing acceptable construct validity to the proposed model for analysis propose.

Third, the spearman's correlation analysis for the selected variables in the proposed dynamic two-stage SBM model were calculated, which was not tabulated. The coefficients were almost significantly positive, indicating that the variables we employed were suitable for the proposed dynamic two-stage network SBM model to evaluate the provincial innovative performance for regional innovative development in China. In summary, the model variables we chosen satisfied the assumption of isotonicity proposed by Golany and Roll [18], and then the proposed model hence holds enough validity and would be in reliable for empirical application.

4. RESEARCH METHODOLOGY

These two-stage dynamic network structure with serial connection in this empirical study was a modification to general network or Dynamic DEA. Consider that there are n provinces/regions $(j=1,2,3,...,n)$ treated as DMUs, and that each DMU is involved in two stages as the R&D stage (k) and the commercialization stage (h) during T terms ($t=1,2,3,...,T$). There are L_{hk} serial connection link between the R&D stage (k) and the commercialization stage (h) in period t are donated by $(k,h)_l^t$ $(l=1,...,L_{hk})$. In the R&D stage, if a regional innovation system consumes m_k^t inputs at time t represented as x_{ijk}^t $(i=1,...,m_k^t;\ j=1,...,n;\ t=1,...,T)$ to has the numbers of intermediate outputs as donated $z_{i(h,k)l}^t$ $(j=1,...,n;\ l=1,...,L_{hk};\ t=1,...,T)$ and desirable outputs as named y_{rjk}^t $(r=1,...,r_k^t;\ j=1,...,n;\ t=1,...,T)$. There are L_k carry-over activities between two consecutive periods in the R&D stage (k) denoted as $c_{jkl}^{(t,t+1)}$ $(j=1,...,n;\ l=1,...,L_k;\ t=1,...,T)$. In addition, in the commercialization stage, if a regional innovation system consumes u_h^t and $z_{i(h,k)l}^t$ from the intermediate output of the R&D stage to create r_h^t desirable output at time t , respectively. y_{rjh}^t $(r=1,...,r_h^t;\ j=1,...,n;\ t=1,...,T)$ is the desire output produced from the commercialization stage. There are also L_h carry-over activities between two consecutive periods in the commercialization stage (h) denoted as $c_{jhl}^{(t,t+1)}$ $(j=1,...,n;\ l=1,...,L_h;\ t=1,...,T)$.

The evaluation methodology of the regional sustainable development performance is applied by the DNSBM approach and the overall performance of observed DMU_o $(o=1,...,n)$ is evaluated by the Eq. (1) as follows:

$$\theta_0^* = \min \frac{\sum_{t=1}^{T} W^t \left[w^k \left[1 - \frac{1}{m_k^t} \left(\sum_{i=1}^{m_k^t} \frac{s_{iok}^{t-}}{x_{iok}^t} \right) \right] + w^h \left[1 - \frac{1}{u_h^t} \left(\sum_{i=1}^{u_h^t} \frac{s_{ioh}^{t-}}{x_{ioh}^t} \right) \right] \right]}{\sum_{t=1}^{T} W^t \left[w^k \left[1 + \frac{1}{linkout_k^t + ngood_k^t} \left(\frac{s_{o(kh)_l out}^t}{z_{o(kh)_l out}^t} + \frac{s_{ok_l good}^{(t,t+1)}}{c_{ok_l good}^{(t,t+1)}} \right) \right] + w^h \left[1 + \frac{1}{r_h^t + ngood_h^t} \left(\sum_{t=1}^{r_{oh}^t} \frac{s_{roh}^{t+}}{y_{roh}^t} + \frac{s_{oh_l good}^{(t,t+1)}}{c_{oh_l good}^{(t,t+1)}} \right) \right] \right]} \quad (1)$$

5. EMPIRICAL RESULTS

5.1 Efficiency Analysis of The Regional Suatainable Development

In order to estimate the regional sustainable development performance of each provinces and/or regions in China in the period 2012-2017, it is noted that the choice of preferred weights for time period and stage is an important factor in Eq. (1). According to the suggestion from Tone and Tsutusi [20] the last period T can be assigned as the largest contribution to the evaluation framework. Therefore, we agree that the importance of period-efficiency in the regional sustainable development performance increases year by year from 2011 to 2017. The sum-of-the year's-digits method is applied to calculate the preferred weights of each period. As such, the preferred weights assigned to the year during 2011 to 2017 are assumed to be 2011=0.036, 2012=0.071, 2013=0.107, 2014=0.143, 2015=0.179, 2016=0.214, 2017=0.250, respectively.

In addition, it would be reasonable to the overall performance of two-stage DEA framework with serial connection as the weighted sum of the performance behavior of the individual stages [3]. Thus, we in this paper assumes that both the R&D stage and the commercialization stage have the same contribution to the regional innovative systems, and the preferred weight to each stage is the same as 0.5.

Table 3. Efficiency analysis and ranking by provinces and/or regions

DMU	R&D efficiency	Commercialization efficiency	Regional innovative system performance	Rank
Beijing	1.0000	1.0000	1.0000	1
Tianjin	0.9103	0.9715	0.9456	6
Hebei	0.2605	0.3986	0.1426	28
Shanxi	0.4213	0.3804	0.2068	27
Inner Mongolia	0.2232	0.4250	0.0101	30
Liaoning	0.4878	0.4441	0.4610	19
Jilin	1.0000	0.9920	0.9949	5
Heilongjiang	0.9747	0.5862	0.4013	20
Shanghai	0.5214	0.5084	0.4894	18
Jiangsu	1.0000	0.9999	0.9999	4
Zhejiang	0.5234	0.8416	0.7145	13
Anhui	0.9432	0.7748	0.5642	16
Fujian	0.2826	0.3305	0.2196	26
Jiangxi	0.2809	0.3900	0.0503	29
Shandong	0.7430	0.9764	0.8519	10
Henan	0.6764	0.9804	0.8257	11
Hubei	0.9846	0.7180	0.6748	14
Hunan	0.3849	0.6241	0.2597	24
Guangdong	0.8155	0.9467	0.8779	8
Guangxi	0.9962	0.9628	0.9150	7
Hainan	1.0000	1.0000	1.0000	1
Chongqing	0.8774	0.8511	0.6259	15
Sichuan	0.6345	0.4809	0.3808	21
Guizhou	0.7971	0.4733	0.2512	25
Yunnan	0.8385	0.4883	0.3027	23
Shaanxi	0.9585	0.5166	0.4917	17
Gansu	0.8705	0.7745	0.7206	12
Qinghai	1.0000	1.0000	1.0000	1
Ningxia	0.7946	0.9346	0.8656	9
Xinjiang	0.9804	0.7579	0.3306	22
Mean	0.7394	0.7176	0.5858	

Table 3 shows the evaluation results of the proposed dynamic two-stage network DEA model in Eq. (1). It can be seen that only Beijing, Hainan, and Qinghai are estimated as well-performance in the regional innovative systems performance during 2011-2017. In addition, the mean performance score of R&D stage, Commercialization, and the regional innovative systems are 0.7384, 0.7176, and 0.5858. We can conclude that the R&D performance is slightly better than the commercialization performance, indicating that the commercial benefit of the R&D capability still has a room to further improvement and enhancing the quality and quantity of Patents in force.

5.2 Efficiency Analysis on Regional Discrepancy

Based on the geographical location and economic development, all the 30 provinces and/or regions we selected as the research sample can be categorized into three areas: the east, the central and the west. Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan are belonged to the east area. Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan are classified into the central area. Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang are categorized into the west area.

The regional innovative systems and its stages performance for these classifications are summarized in Table 4. The results show that the average regional innovative system performances in the east area is 0.7002, which is the highest one, while that in central and west areas are 0.4972 and 0.5358, respectively. The ranking for the commercialization performance of the three groups are similar order to that in the overall performance.

Table 4. Regional innovative system performance of the three areas in China

R&D efficiency			
Region	Mean	Efficiency	Inefficiency
Eastern Region	0.6859	3 (27%)	8 (73%)
Central Region	0.7083	1 (13%)	7 (88%)
Western Region	0.8155	1 (9%)	10 (91%)
Commercialization efficiency			
Region	Mean	Efficiency	Inefficiency
Eastern Region	0.7652	2 (18%)	9 (82%)
Central Region	0.6807	0 (0%)	8 (100%)
Western Region	0.6968	1 (9%)	10 (91%)
Regional innovation system performance			
Region	Mean	Efficiency	Inefficiency
Eastern Region	0.7002	2 (18%)	9 (82%)
Central Region	0.4972	0 (0%)	8 (100%)
Western Region	0.5358	1 (9%)	10 (91%)

6. CONCLUSION

This paper proposed a dynamic two-stage SBM model for evaluating innovative performance for the purpose of innovative system development of provincial administration regions in China. The two–stage evaluation model was consisted with R&D and commercialization processes with serial and intertemporal linkage would be important concepts to our model specification, in order to capture more valuable information in the model consideration. Annual patent granted, patents in force, and patent applications, were treated to be intermediate and carry-over variables, which was significant difference to previous studies. These variables brought us a new insight to the innovative performance evaluation by DEA-based modeling, as they reflected dynamic and internal structure that were crucial to regional innovative development from a practical perspective.

The proposed model was designed to highlight the contribution of the status of invention patent to overall innovative performance, which patent granted was regarded as desirable intermediate output in the R&D process, and then was continuously held to the next commercialization process. In addition, annual patent applications will be granted for examination over one year, which was used to the carry-over variable in the R&D stage, while patents in force was efficacy on new product development and assigned a carry-over variable in the commercialization process. The main conclusions were as follow.

First, the average R&D performance of provincial administration is greater than the average commercialization performance, representing that focusing on the commercial effect of the patent should be enhancement their quality and the market-oriented to direct their new product development.

Second, the eastern region shows the best commercialization performance followed by the western region, and the central region demonstrate the worst performance. The government should focus on the performance of the regional innovative systems in central and the west area with relatively lower score. Having a systematic policy planning and innovative mechanism to promote collaborative development among different provinces and areas.

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Assessing Indonesian Military Camouflage using Camouflage Similarity Index (CSI) Algorithm

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ABSTRACT
Military camouflages is one of the research areas in human factors & ergonomics and purchasing a new military camouflage design has been a critical issue in the Indonesian military. The purpose of this study was to assess the existing Indonesian military camouflage effectiveness using Camouflage Similarity Index (CSI) algorithm. CSI algorithm shows a value between 0 to 1 and the lowest value 0 is achieved if the selected camouflage perfectly blends with the selected background. A total of 8 Indonesian military camouflage was evaluated under 5 different locations (20x50 pixels) from one selected woodland background. Each location had different L^*, a^*, and b^* values. ANOVA test showed that there was a significant effect of camouflage on CSI. Post-hoc Tukey test was utilized to derive the difference between each camouflage. This study represents a first attempt to assess the effectiveness of Indonesian military camouflages and the results of this study could be very beneficial for military organizations, academicians, and camouflage manufacturers particularly related to purchasing decisions.

CCS Concepts
• Computing methodologies→ Computer graphics→ Image manipulation • Applied computing→ Computers in other domains→ Military.

Keywords
Military camouflage; Camouflage Similarity Index; Color algorithm; Indonesian military.

1. INTRODUCTION
Military camouflage provides a defense for the first-line soldiers during a mission. The term "camouflage" was first coined from nature where animals used to hide from predators by changing their body color, pattern, or even both [1] and military research organizations adapted this concept to a military uniform. For human factors engineers, military camouflage adorning a uniform is an indispensable determinant of soldier's ability to effectively perform job-related task while avoiding detection [2]. There are two fundamental attributes that need to be minimize by utilizing computer-aided engineering: pattern and color.

Color can be defined in terms of hue, chromaticity, and lightness [3]. It can be measured in several color spaces exist and each was developed for a certain task [4]. Color recently has been a trending topic in computer-aided engineering.

A computer-aided engineering approach using an image similarity algorithm is therefore helpful in overcoming the limitations of assessing camouflage when using human observers [5]. Previously, we developed Camouflage Similarity Index (CSI) algorithm to access the color effectiveness of selected military camouflage [4]. It ranges between 0 to 1 and the best value of 0 is achieved if the selected camouflage perfectly blends with the selected background [4]. Our image algorithm was found outperformed commonly used image quality algorithms such as UIQI [6], MSE, PSNR, and even SSIM [4].

The purpose of this study was to assess the Indonesian military camouflage effectiveness using Camouflage Similarity Index (CSI) algorithm. Indonesia is known as the most powerful military in South East Asian and ranked no.16 among the world's strongest military [7]. This study represents a very first attempt to assess the Indonesian military camouflage effectiveness and the results could be very useful for Indonesian military organizations, academicians, and textile manufacturers particularly related to purchasing decisions of the new camouflage. In addition, the approach can be adapted to evaluate other existing military camouflages in other countries [8-10].

2. METHODOLOGY
2.1 Military Camouflage Collection
There are several different existing military camouflages in Indonesia which consist of army, marine, navy, and air force. 8 different existing Indonesian military camouflages were randomly selected from army, marine, navy, and air force in the current study. Different from the previous study which generated new military camouflage based on the selected background [11], the military camouflages were obtained using the Google search engine by typing "Indonesian military camouflage" or "Seragam tentara Indonesia". Following our previous approach in our previous studies [4, 8-10], the image later was cut to 20x50 pixels using Adobe Photoshop CS6 for CSI calculation. Matlab 2018 was used to transpose the L*, a*, and b* of each color into the overall L*, a*, and b* values of each military camouflage by

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using our previous algorithm [3,8]. Table 1 shows the overall L*, a*, and b* values of each camouflage.

Table 1. Overall L*, a*, and b* values of each selected design.

Camouflage	L*	a*	b*
Design 1	66.8721	0.8102	-0.2539
Design 2	68.9938	-4.5850	9.8698
Design 3	72.4587	0.3212	21.3947
Design 4	51.9453	0.9843	19.3306
Design 5	58.3585	-7.0417	3.4167
Design 6	70.1211	2.5133	-1.3242
Design 7	80.7225	0.4440	-2.2911
Design 8	64.4163	-1.7220	8.5885

2.2 Background Collection

Background collection is a fundamental consideration for military camouflage assessment. The Different background would lead to different L*, a*, and b* values which subsequently lead to different CSI value. At this moment, one military camouflage is impossible to be utilized in different terrains and different climatic conditions since each terrain have different characteristics of L*, a*, and b* values [8-10].

Figure 1. Selected swamp background [4, 8-10].

Table 2. Overall L*, a*, and b* values of each selected location [4, 8-10].

Location	L*	a*	b*
Location 1	76.1949	-4.1246	10.6737
Location 2	59.3054	-7.8107	14.5174
Location 3	67.8591	-7.9443	15.7666
Location 4	51.3341	-6.3474	9.3048
Location 5	78.3972	-7.2132	16.9961

2.3 Camouflage Similarity Index (CSI) Algorithm

CSI was measured by utilizing MATLAB 2018. The detail of CSI calculation had been published in Lin et al [4]. Figure 2 shows the CSI calculation flow which basically similar to our previous studies [4, 8-10]

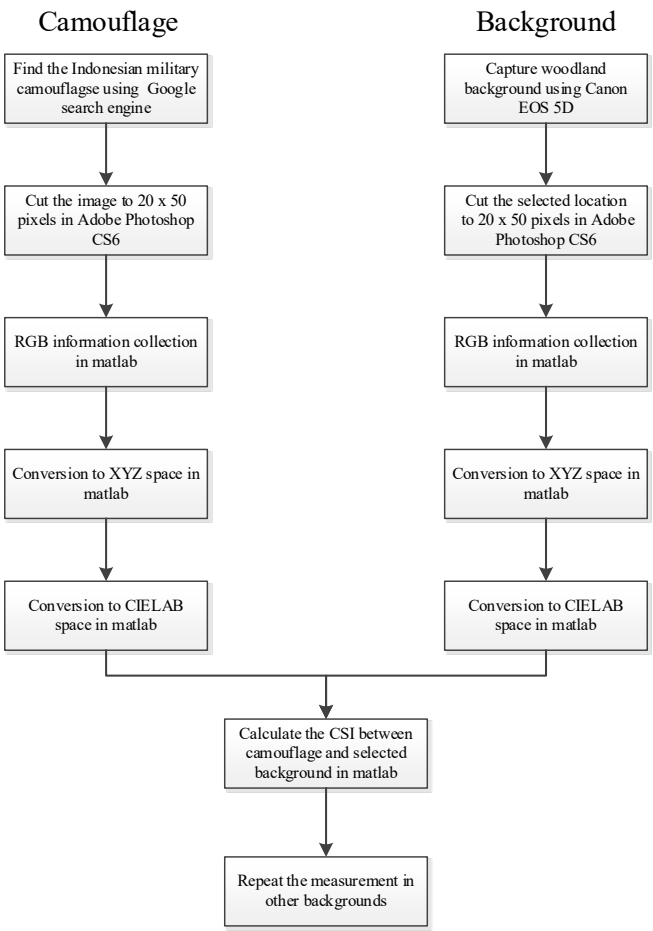

Figure 2. The flow diagram of CSI calculation [4, 8-10].

2.4 Statistical Analysis

For all statistical analyses, Minitab 18 was utilized to measure the significant difference between each existing Indonesian military camouflage. In addition, ANOVA test and Post-hoc Tukey test were utilized to measure the significant difference of CSI value between each camouflage [12,13]. The results were considered statistically significant when $p \leq 0.05$ [14-18].

3. RESULTS AND DISCUSSION

Indonesia is widely known as the strongest military power in South East Asia and ranked 16 in the world with a power index of 0.2804 [7]. However, assessing existing military camouflage has been a critical issue in Indonesia. The purpose of the current study was to assess the existing Indonesian military camouflage using Camouflage Similarity Index (CSI) algorithm.

Table 3 represents the result of the CSI value of each existing Indonesian military camouflages under 5 different locations. Based on this table camouflage design "2" was found to have the lowest CSI value with the average value of 0.83316 and camouflage design "6" was found to have the highest CSI value with the average value of 0.97862. Interestingly, even camouflage design "6" had green, black, and grey color, this design was found to have the highest CSI value. Table 3 also represents an interesting characteristic of several camouflage designs. For instance, camouflage design "2" was found to have the lowest CSI in the location 1,2, and 3. However, in locations 4 and 5, camouflage design "5" and "3" were found to have the lowest CSI values respectively. Regarding the highest CSI value, camouflage design "4" was found to have the highest CSI in the location 1, camouflage design "6" was found to have the highest CSI values in the location "2" and "5", and camouflage design "7" was found to have the highest CSI value in the location "3" and "4".

Table 3. CSI results of the selected camouflages under 5 different locations.

Design	Location					Average
	1	2	3	4	5	
1	0.8843	0.9849	0.9705	0.9372	0.9678	0.94894
2	0.8116	0.8820	0.7813	0.8597	0.8312	0.83316
3	0.8279	0.9233	0.8693	0.9673	0.8019	0.87794
4	0.9296	0.9224	0.9153	0.9249	0.9234	0.92312
5	0.8762	0.9000	0.8905	0.7847	0.9445	0.87918
6	0.9280	0.9961	0.9921	0.9947	0.9822	0.97862
7	0.8298	0.9946	0.9975	0.9949	0.9492	0.95320
8	0.8665	0.9171	0.8727	0.8705	0.8942	0.88420

Table 4 and Table 5 show the ANOVA test result and posthoc Tukey result respectively. Interestingly, there was a significant difference in CSI values among selected existing camouflage designs indicating that there was a significant difference in the level of concealment in the selected swamp background (Figure 3).

Table 4. ANOVA test result.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.084	7	0.012	5.431	0.001
Within Groups	0.071	32	0.002		
Total	0.155	39			

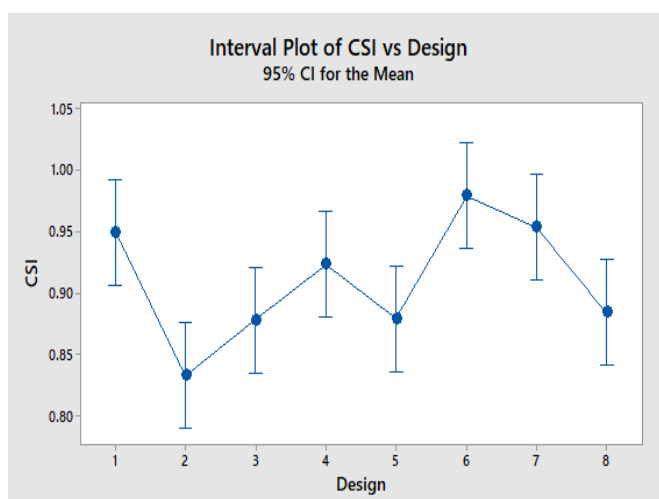

Figure 3. Interval plot of CSI and design.

Table 4. Post-hoc Tukey test results.

	Subset for alpha = 0.05		
Design	**1**	**2**	**3**
2	0.83316		
3	0.87794	0.87794	
5	0.87918	0.87918	
8	0.88420	0.88420	0.88420
4	0.92312	0.92312	0.92312
1		0.94894	0.94894
7		0.95320	0.95320
6			0.97862
Sig.	**0.084**	**0.219**	**0.058**

4. CONCLUSIONS

Military camouflages is one of the research areas in human factors & ergonomics and purchasing a new military camouflage design has been a critical issue in Indonesian military. The purpose of this study was to assess the existing Indonesian military camouflage effectiveness using Camouflage Similarity Index (CSI) algorithm. CSI algorithm shows a value between 0 to 1 and the best value 0 is achieved if the selected camouflage perfectly blends with the selected background. A total of 8 Indonesian military camouflage were evaluated under 5 different locations (20x50 pixels) from one selected woodland background. Each location had different L^*, a^*, and b^* values. ANOVA test showed that there was a significant effect of camouflage on CSI. Post-hoc Tukey test was utilized to derive the difference between each camouflage. This study represents a first attempt to assess the effectiveness of Indonesian military camouflages and the results of this study could be very beneficial for military organizations, academicians [19-27], and camouflage manufacturer particularly related to purchasing decision.

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Session III

Modern Information and Educational Technology

Design of Zentangle Courses for Enhancing the Creativity of Elementary School Students

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ABSTRACT
Present study designed the Zentangle courses with eight teaching units involved the skills of points, lines, faces, geometrics, graphics practices and Zentangle drawing practices involved the clock creative, frame creative, three-dimensional creativity and little designer drawing at least 100 minutes once a week during eight weeks. The Chinese Version Torrance Tests of Creative Thinking applied to assess the effects of Zentangle teaching after eight weeks. Twelve elementary school students participated in this study. The paired samples t-test were compared to effects of intervention the Zentangle teaching courses for fluency, originality, abstractness of titles, elaboration and resistance to premature closure. After eight weeks of Zentangle teaching, there are significant improvement of originality, abstractness of titles and resistance to premature closure for lower grade elementary school students. Conclusion of this study as following: (1) Zentangle courses can effectively enhance the creative thinking of children in elementary school; (2) Zentangle courses affect the performance of lower grade students' motivation; (3) Zentangle courses can reduce the stress and calm the minds of lower grade students.

CCS Concepts
•Human-centered computing→ Visualization→ Visualization design and evaluation methods

Keywords
Zentangle teaching; creativity; Torrance tests of creative thinking; Elementary school students

1. INTRODUCTION
Creativity is fundamental for the preschool curriculum and can be defined as a procedure to create original things. Preschool teachers should provide children with materials to trigger their imagination, should provide opportunities to imagine and to explain their ideas, should appreciate children's individuality, and should encourage their different viewpoints.

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The creators of Zentangle are Rick Roberts and Maria Thomas. He is the Zen and she is the Tangle. The Zentangle Method is an easy-to-learn, relaxing, and fun way to create beautiful images by drawing structured patterns. These patterns called by tangles and created tangles with combinations of dots, lines, simple curves, S-curves and orbs [1]. Chen et al. [2] examined the teaching contents of Zentangle and to investigate the impact of psychosis patients on self-esteem and anxiety interaction support by using Zentangle 8 week's courses. The results showed that the experimental group in self-esteem part and social interaction anxiety scores were significantly differences between before and after using Zentangle intervention. Ho [3] explores the influence of the combination of Zentangle pattern teaching and cartoon storyline on the attention of fifth and sixth-grade students in elementary school. The elementary children attention test was used to examine the effects of Zentangle pattern teaching and cartoon storyline teaching on attention.

Lee [4] also examined that through teaching Zentangle in the visual arts curriculum for elementary school students and researchers have adopted tools in the forms of practicing Zentangle by students. It can not only eliminate frustrations associated with long-term training in traditional art curricula, which hinders creativity, but also provide instant positive feedback to help elementary-school students reduce physical and mental stress when they face the psychological and emotional instability in their prepubescent stage

Hesterman and McAuliffe [5] indicated that people of different ages, skills, and interests enjoy Zentangle as a visual arts practice. It is adopted as a hobby with the intention of creating an abstract art form comprised of drawn images and using repetitive and structured patterns. Zentangle has an associative language and a method that is easy to learn. Participants of Zentangle report feelings of wellbeing when engaged in the meditative drawing activities. In the field of education, research on the potential of Zentangle to support student learning is limited; in early childhood education, the benefits are unreported in the academic literature. This research project aims to fill this gap. The project examined the educational benefits of Zentangle for young children. The project was conducted over a ten-month period in two kindergarten classrooms (with children aged 3-5 years) at a Western Australian independent community school inspired by the Reggio Emilia educational philosophy. Two case study findings showed that Zentangle supported the development of children's fine motor skills and enriched their language experience through the accommodation of cultural and linguistic diversity. Zentangle also provided opportunities for children to demonstrate the Early Years Learning Framework for Australia outcomes.

Dr. E. Paul Torrance, "Father of Creativity," is best known for developing the Torrance Tests of Creative Thinking (TTCT). The TTCT was developed by Torrance in 1966 [6]. There are two forms

(A and B) of the TTCT-Verbal and two forms (A and B) of the TTCT-Figural [7]. Torrance Tests of Creative Thinking are the most widely used tests of their kind since testing only requires the examinee to reflect upon their life experiences. These tests invite examinees to draw and give a title to their drawings (pictures) or to write questions, reasons, consequences and different uses for objects (words). Forms A and B, the Figural and Verbal TTCT can be used for pre- and post-testing. It has become highly recommended in the educational field and is even used in the corporate world. It is the most widely used test of creativity [8] and is the most referenced of all creativity tests [9]. The TTCT-Figural Manual of 1990 states that the interrater reliability among the scorers for Scholastic Testing Service, Inc., was greater than .90. Treffinger [10] concluded that, given the complexity of creative thinking, the TTCT can be seen as having reasonable reliability for group and research applications. For validity of TTCT, three of the TTCT subscales (fluency, flexibility, and originality) correlated significantly (at the .01 level) with both quantity and quality of creative achievements, and the significant correlations ranged from r = .39 to .48. Fan and Liao [11] showed that the revised TTCT is highly relevant to the previous one; besides, the criteria are related to validity as well according to the statistics.

Dere [12] reported that encourage children to participate in creative games, should care about children's new products, and value them. Moreover, children creativity should be appreciated, and children should be given confidence. In this study, it is aimed to investigate the creativity of children in the preschool. Figural Creativity Form A and B of Torrance Tests of Creative Thinking were used as pre- and post-tests. The results showed that preschool curriculum increased children's creativity in a positive way.

Pang et al. [13] investigated the effects of three-generational families on Chinese children's creativity. Participants' creativity was measured by the Torrance Test of Creative Thinking-Figural (TTCT-Figural). These findings have several important educational implications. First, parents and grandparents should pay attention to the possible defects of three-generation co-residence since we found it was associated with lower creativity in children.

Gamification is one of the most significant modern trends in educational technology. The present study aims to identify the effectiveness of gamification of web-based learning on academic achievement and creative thinking among primary school students. A learning environment was designed based on gamification of web-based learning. A quasi-experimental approach was utilized to identify the effect of the independent variable, gamification, on the dependent variables, academic achievement and creative thinking among participants. An academic achievement test and the Torrance test of creative thinking were applied to the participants. Results revealed that there was a statistically significant difference between the means of scores of the experimental and control groups in the post-test academic achievement test and the Torrance test of creative thinking in favor of the experimental group. This suggests a high level of academic achievement and creative thinking after using gamification. The study recommends training in-service teachers in the use of gamification for web-based teaching of English

The purpose of this study was to improve the creative thinking for high school students by Zentangle teaching. Intervention of the eight units Zentangle courses involved the points, lines, faces, geometrics, graphics and Zentangle drawing practices at least 100 minutes once a week during eight weeks. The Chinese Version Torrance Tests of Creative Thinking applied to assess the effects of Zentangle teaching after eight weeks.

2. METHODS

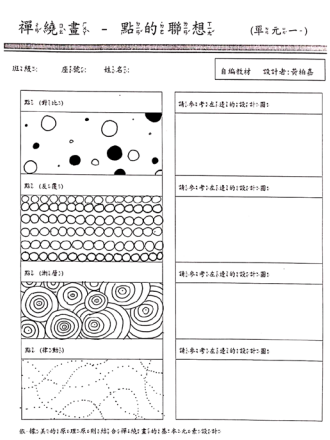
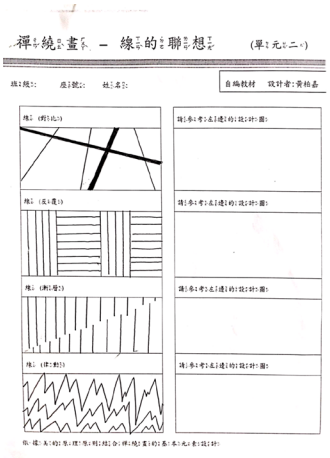
2.1 Participants

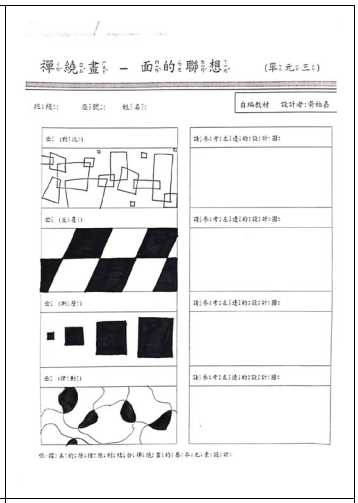
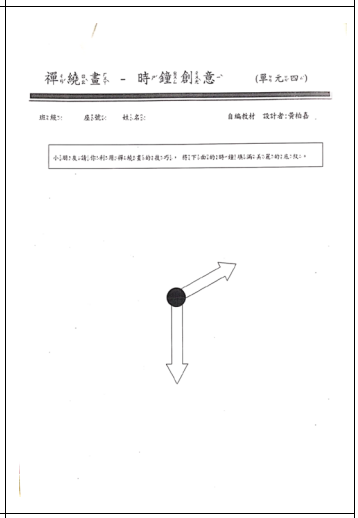
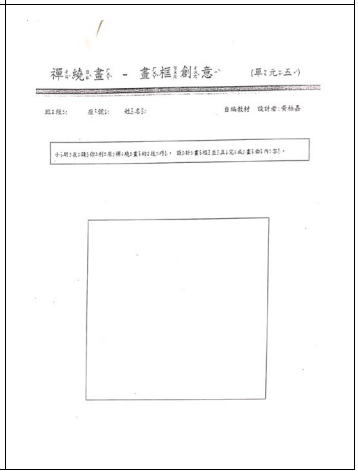
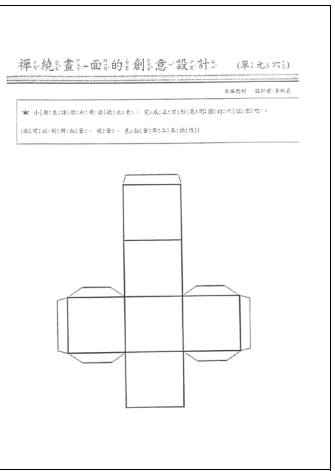
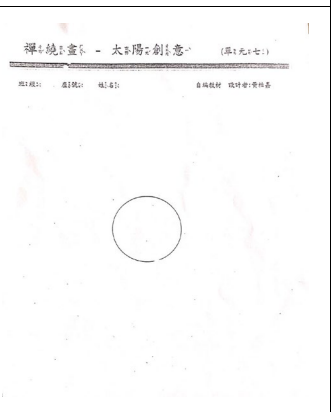
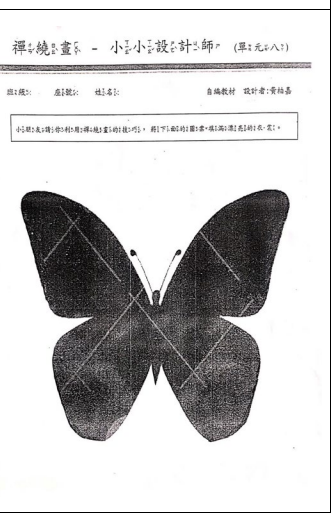
Twelve participants who are first and second grade elementary school students jointed with this study. The participants conducted the program of enhancing the creative thinking by Zentangle teaching. Based on ethical considerations, participants and their parents were fully informed about the course of enhancing the creative thinking prior to the Zentangle teaching.

2.2 Courses of Enhancing the Creative Thinking

Intervention of the eight units of Zentangle courses (Table 1) involved the points, lines, faces, clock creative, frame creative, three-dimensional creativity and little designer drawing at least 100 minutes (preparing time 10 minutes, drawing time 75 minutes, sharing time 10 minutes) once a week during eight weeks.

Table 1. Courses of enhancing the creative thinking

Units	Description	Courses
1	Point connection practices, point segmentation, point concatenation	
2	Line connection practices, line segmentation, free lines	

3	Face connection practices, face segmentation, face stereo	
4	Clock creative：drawing the clock face	
5	Frame creative：drawing the picture in frame	
6	Three-dimensional creativity：drawing the six faces	
7	Sun creativity	
8	Little designer	

2.3 Chinese Version Torrance Tests of Creative Thinking

This study applied the Chinese Version Torrance Tests of Creative Thinking TTCT-Figural based on 1992 version (E. Paul Torrance and Orlow E. Ball with H. Tammy Safter, Psychological Publishing Co., Ltd) to assess the effects of Zentangle teaching after eight weeks. It uses three picture-based practices to assess five mental characteristics: fluency, resistance to premature closure, elaboration, abstractness of titles, originality. According to the 1092 participants from the elementary school, junior high schools and high schools in northern, central, southern and eastern regions of Taiwan, the Chinese Torrance Tests of Creative Thinking was established to establish the norm. The inter-rater reliability of this

test is between 0.911 and 0.991 and the test-retest reliability is between 0.401 and 0.724 after measured six weeks. The coefficient of parallel-forms is between 0.598 and 0.951. This test has good reliability.

2.4 Data Analysis

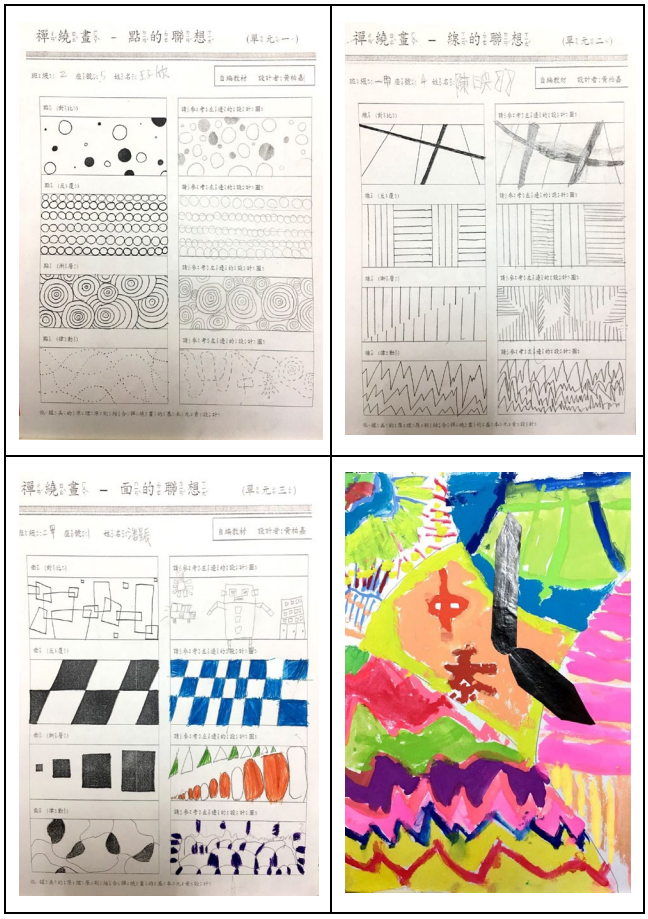
All data were coded and summarized using IBM SPSS Statistics (Version 21.0, IBM, and New York, USA). Furthermore, The paired samples t-test were compared the effects of intervention the Zentangle teaching courses for fluency, originality, abstractness of titles, elaboration and resistance to premature closure. The level of significance used for all analyses was $p < 0.05$.

3. RESULTS

3.1 Painting Achievements of Creative Thinking Courses

Some painting achievements of creative thinking courses showed in Table 2. The children drew well for point connection practices, line connection practices and face connection practices. Other pictures drew boldly and creatively with colors.

Table 2. Some painting achievements of creative thinking courses



3.2 Effects of Zentangle Teaching Courses on Creative

Results of the paired-sample t test were shown in Table 3. All variables were significant difference after intervention Zentangle teaching. The fluency means that the total number of interpretable, meaningful, and relevant ideas generated in response to the stimulus. The Fluency significantly increases after intervention Zentangle teaching courses. Further, the statistical rarity of the responses (Originality scores) significantly increased 47 points after Zentangle teaching. In addition, abstractness of titles, resistance to premature closure, and elaboration also increases 20 points.

Table 3. Table captions should be placed above the table

Variables	Before	After	Paired-difference	t	p value
Fluency	71.42	91.33	19.91	6.42	0.001
Originality	78.58	125.75	47.17	9.45	0.001
Abstractness of titles	38.33	58.5	20.16	3.14	0.01
Elaboration	79.83	99.92	20.09	5.42	0.001
Resistance to premature closure	68.50	96.08	27.58	5.45	0.001

The reason is that in the former researchers, the middle school children were unable to write in the drawing process, and it took them a long time to familiarize themselves with the subject's mood and judge the graphic structure. However, after training, students have higher logical concepts and can quickly think about how to draw patterns to draw, so the time for thinking is relatively reduced, which directly affects the subsequent smooth performance.

The pre- and post-tests have been significantly improved, because after participating in the eight-week teaching practice of Zen painting, the participating researchers gradually realized the nature of things and learned the characteristics of the objects one by one by adding them to the picture. Describe the work clearly so that viewers can better understand what is being painted. Make the original scoring content get more scoring points from activity one and activity two

The title power has increased from 38.33 points to 58.50 points. The front-to-back test has been significantly improved. The headline power is a comprehensive expression covering cognitive ability and affective degree. Artistic conception, participating researchers can improve the ability to express the relationship between patterns and propositions in the process of abstract and concrete thinking.

The precision was improved from 79.83 points to 99.92 points. The pre- and post-tests were significantly improved. It was found that the combined power and finesse of the participating researchers gradually improved in the post-test. The participating researchers were able to use basic graphics and add Whitewashing, line thickness expression, diversity of arrangement methods, and dot size ratio, it is not difficult to find many surprising picture compositions in the observation of the post-test.

Opening power was increased from 68.50 to 96.08. The pre- and post-tests have been significantly improved. The openness score for activity two will be improved. If the participant's precision power activity two scores are higher, the openness will be relatively improved. The study observed that in the post-test activities of the participating researchers, the content of the established framework was broken, indicating that after studying the Zen painting course, the participating researchers also explored the use of a rich background to strengthen the storytelling ability of the picture. Overall, it is quite good Performance.

3.3 TTCT-Figural Test

A case of TTCT-Figural test showed in Figure 1. Pikachu (formerly tested A) is the Case A who put a dark purple oval shape in the middle of the picture pattern, and added eyes, allowed noses, smiling mouths, a pair of sharp ears, four A foot, a lightning-shaped tail, a long row of grass is designed below the composition background, and three similar-sized clouds and a radial sun on the upper left are drawn on the top. The background on the screen is too blank, and the content is too simple for the viewer to detect it. Meaning, this is a pity.

The eggplant purple horse (post-tested type B) is the design of the purple pill-like pattern in the picture. The author used a rich imagination to draw a symbolic horse. A cowboy on the horse was designed like a Mercedes on the grassland, the picture is full of fun. Flowers, houses, drizzle, sun, clouds, etc. are added to the background. The picture shows a vast space. There are front and rear scenery arranged in the picture, with flowers before and after. The arrangement creates a sense of well-being, as if people can also feel the vitality of the land, and a happy mood walks in the picture. This work is a rare masterpiece for children in the lower grades

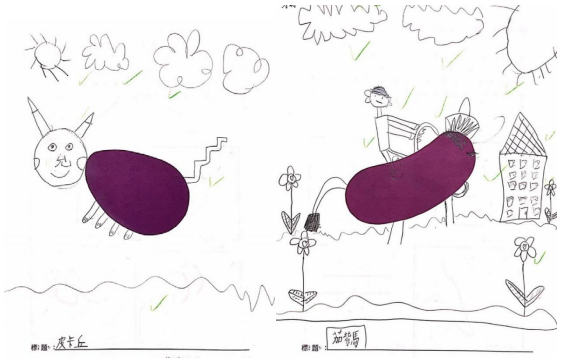


Figure 1. A case of TTCT-Figural test (Left: pre-tested versus right: post-test)

4. DISCUSSION

Lin [14] reported that the implementation of creative teaching and teaching for creativity in Taiwan. The following principles are important for creative teaching and teaching for creativity: (1) the concept clarification between creative teaching, instructional innovation, and teaching for creativity; (2) assertion of the nurturability of creativity and the learner-centered approach; (3) teaching complying with the essence of creativity; (4) incorporation of domain-related knowledge and skills, creativity-related knowledge and skills, habits of mind, meta-cognition, and ethical concern. Finally, the process of “design thinking” is used as the exemplar of teaching for creativity. Hou [15] examined the relation and the effect between image edification and creativity. For the design beginners, the graphic inspiration training was carried out, and the Williams Creative Thinking Activity Scale was used to evaluation difference in creativity before and after the experiment. The results showed that the creativity, fluency, openness and precision of the experimental group were better than the control group after five weeks of experiment; after 10 weeks of experiment, the creativity, openness, flexibility, originality and precision of the experimental group Sex is also superior to the control group. Therefore, the way graphics are inspired helps designers to improve their creativity.

Zentangle is known to many artists and craftivists as a way to create structured designs through drawing various patterns. Basically, it’s a specific way to draw images, most often in black pen on white paper. Zentangle has become an international phenomenon that now has applications in stress reduction, education, therapy and even motivational training [16]. Two case study findings showed that Zentangle supported the development of children’s fine motor skills and enriched their language experience through the accommodation of cultural and linguistic diversity. Zentangle also provided opportunities for children to demonstrate the early years learning framework for Australia [5].

5. CONCLUSION

Conclusion of this study as following: (1) Zentangle courses can effectively enhance the creative thinking of children in elementary school; (2) Zentangle courses affect the performance of lower grade students’ motivation; (3) Zentangle courses can reduce the stress and calm the minds of lower grade students.

6. ACKNOWLEDGMENTS

Researchers are very grateful for all of participants in this study.

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Promotion of the Graphic Control Program and Building Block Robot Education for Disadvantaged Students in Orphanages

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ABSTRACT
The Ministry of Education in Taiwan attaches great importance to robotic and program education. However, when it is popularized to disadvantaged children, robot education will face many challenges involving teachers, equipment, venues, activity funds, and teaching experience. In this study, 27 children from Orphanage A in Yunlin County were taken as the target objects. The research results of developing graphic control programs are introduced into Jimu robot education to promote science popularization activities in the orphanage, in order to provide opportunities for disadvantaged children and adolescents in the orphanage to experience basic program design, learn to operate robots, and contact with alternative scientific stimulation. It can reduce the gap in the information education of students, promote equality in learning opportunities, and improve the quality of information science in orphanages.

CCS Concepts
Social and professional topics→ Professional topics→ Computing education→ K-12 education

Keywords
graphic control program; Scratch; Jimu robot; disadvantaged students

1. INTRODUCTION
The changes brought by information technology and rapid global competition have changed the social structure and daily life, and become an important index of national competitiveness. To enhance national competitiveness and the real power of science and technology, governments of all countries attach great importance to the cultivation of national ability to use information technology and innovative thinking [1]. Taiwan's 12-year national basic education program, as created in 2014, includes "literacy", and "technology" as new literacy requirements, which is as important as reading and arithmetic in the subsequent curriculum reform [2].

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Robot education is a rapidly developing topic in recent years, as it can improve children's interest in learning science [3]. However, in the robot education of disadvantaged groups, there are many challenges that involve teachers, equipment, venues, and activity funds.

2. MOTIVATION AND PURPOSE
Due to the changes of science and technology and the demands of the times, robot education in primary and secondary schools has become a policy that governments of various countries are ready to launch [4-6]; however, the learning resources of disadvantaged students in orphanages are limited. Robot-related equipment is a relatively expensive teaching aid for orphanages, and orphanages are short of the manpower, technology, and equipment required for the application of robotics in education [3].

The purpose of this study is to introduce robot education resources and energy into Jimu robot education in orphanages, which provides opportunities for disadvantaged children to experience basic programming, and learn to assemble and operate robots, in order to shorten the scientific learning gap of disadvantaged children and use the interactive games of robotics to improve the growth of children and adolescents with low self-confidence.

3. LITERATURE REVIEW
3.1 Graphic Control Program
In recent years, graphic control programs have developed rapidly and been widely used in many fields of education [7]. The integration of Scratch and educational robots opens up a new development space for maker education [8]. The maker spirit has aroused more involved thinking and resonance of educators. Maker education can cultivate learners' innovative knowledge, ability, vision, and will to explore [9]. The actual case of the integration of Scratch programming technology and creative intelligent robotics can help to cultivate innovative talents. In the Scratch classroom, teachers combine the maker education theory to make the classroom a maker space full of innovative ideas and concepts, which encourages children to learn to create and have innovative ideas, enables the on-site participants to turn their ideas into reality, and be willing to share, thus, promoting the comprehensive quality of participants [10]. This study hopes to make children in orphanages with limited scientific and technological resources realize that Scratch can seamlessly connect with robots through on-site teaching cases, giving play to the respective advantages of Scratch and educational robots, and expanding their application scope and innovative functions by combining them.

To meet the requirements of education and social development in the era of science and technology, we should give full play of the role of maker education in cultivating innovative thinking, expand

maker education resources, integrate the design and production of intelligent robots and the application of Scratch creative design technology into maker education, organically combine Scratch and educational robots, give full play to the spirit of innovation for children and adolescents, complete the creative works of dynamic robots, and expand the development space of maker education.

3.2 Robots

Robot technology enables children to develop the habit of participating in social interaction and consultation in the process of learning and playing [11]. Robot technology can be a way for children to learn practical mathematical concepts, scientific inquiry methods, and problem-solving [12]. Robotics in the field of education would enhance or extend teachers' expression ability, knowledge processing ability, and communication ability [13]. Robotic education will stimulate the development of disadvantaged children's learning interests and motivation for intelligent technology in orphanages, improve their information technology ability, and enhance their competitiveness in the era of science and technology.

3.3 Disadvantaged Groups

From the perspective of social justice and citizenship, disadvantaged groups are the citizens who need special care in society; therefore, the education of disadvantaged children is one of Taiwan's current priorities to improve the education of disadvantaged groups. It is an important social policy of the current government to improve the quality of education, survival skills, and social adaptation of disadvantaged children [14].

The subjects of this study are orphans, and primary and secondary school students from violent families. The purpose of this study is to reduce the psychological barriers and improve the self-confidence of these disadvantaged children through the accompanying interactive teaching graphic control programs and robots, in order to cultivate these disadvantaged children to adapt to the future technological world.

4. ROBOT EDUCATION

4.1 Objects

There are 24 primary school students and 3 junior high school students in Orphanage A in Yunlin County, Taiwan. All of them are disadvantaged groups (including orphans in primary and secondary schools, children who have lost their parents, children from violent families, and children of drug addicts and criminals).

4.2 Execution Process

The activity structure is shown in Figure 1:

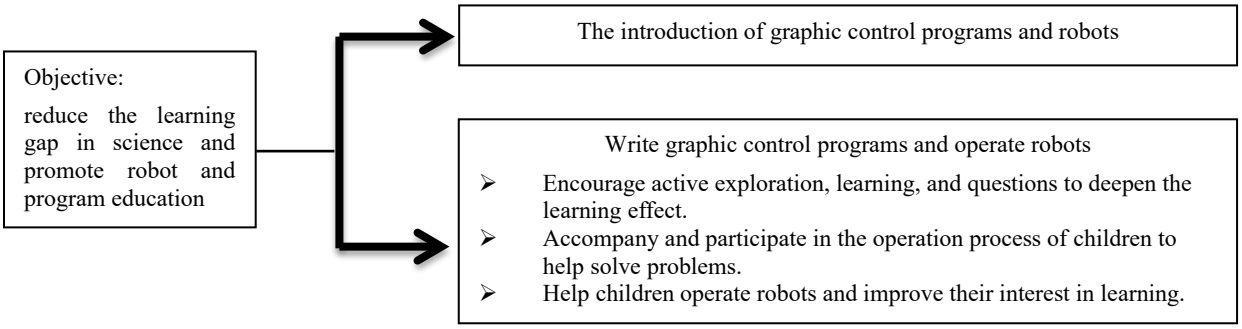

Figure 1. Planning framework of popular science activities of the "graphic control program and robot education"

The infrared application function of this study includes the infrared remote-control digital function and infrared remote-control vehicle function.

The popular science activities of "graphic control program and robot education" in Orphanage A mainly include the following topics:

(1) The introduction of graphic control programs and robots

This study introduced the application and development trend of new information technology, such as the robotic and mobile app, in order that the 27 children in the orphanage can understand the scientific and technological information. This study took the graphic control program and Jimu robotics as the teaching aids.

(2) Writing graphic control programs and operating robots

The children in the orphanage wrote the graphic control program and operated the Jimu robot, which improved their logical thinking and established their understanding.

4.3 Tools

(1) Jimu robot: Bluetooth Ninja Turtle robot - Michelangelo
(2) Graphic control program
(3) Jimu mobile APP

4.4 Activities

Time:180 min

(1) Preparatory stage

This study promoted robot activities in the orphanage to enhance the self-confidence of disadvantaged groups through teaching interaction, and designed award-winning questions to increase the understanding and participation of these children.

Before the activity, it was confirmed that the children in the orphanage had never been exposed to the graphic control program or robotics. Therefore, we adopted award-winning questions to improve their concentration and stimulate their thinking, and donated school supplies and materials to the disadvantaged group.

(2) Activity stage

At the beginning of the activity, we introduced the tools, software, ultrasonic principles and applications, infrared principles and applications in a PowerPoint presentation, and interacted with the children through questions and answers. In this process, we found

that they were enthusiastic about the award-winning questions, and almost all participants were willing to try to answer.

Then, we taught these children basic programming through computer projection, let them try to write programs on stage through the award-winning questions and answers, and make different changes to guide thinking, and then, connect the written programs to the robot through Bluetooth, in order that these children could understand how to write the graphic control program and operate the robot.

Learning to write programs and operate robots can help children improve their logical thinking ability, stimulate their creativity, and build their ability to solve problems when they make mistakes.

(3) Reflective stage

The children in the orphanage were interested in robot activities. Because of the interaction and the courage to ask questions, they learned more applications and changes, and have a strong interest in learning.

The popular science activity flow of the "graphic control program and robot education" is shown in Figure 2.

Activity photos: Figure 3 shows that, in front of the Jimu robot, we taught the graphic control program and robot concept, and many children raised their hands to answer questions; Figure 4 shows that children focused on participating in writing the graphic control program and operating the robot, and they were happy in learning.

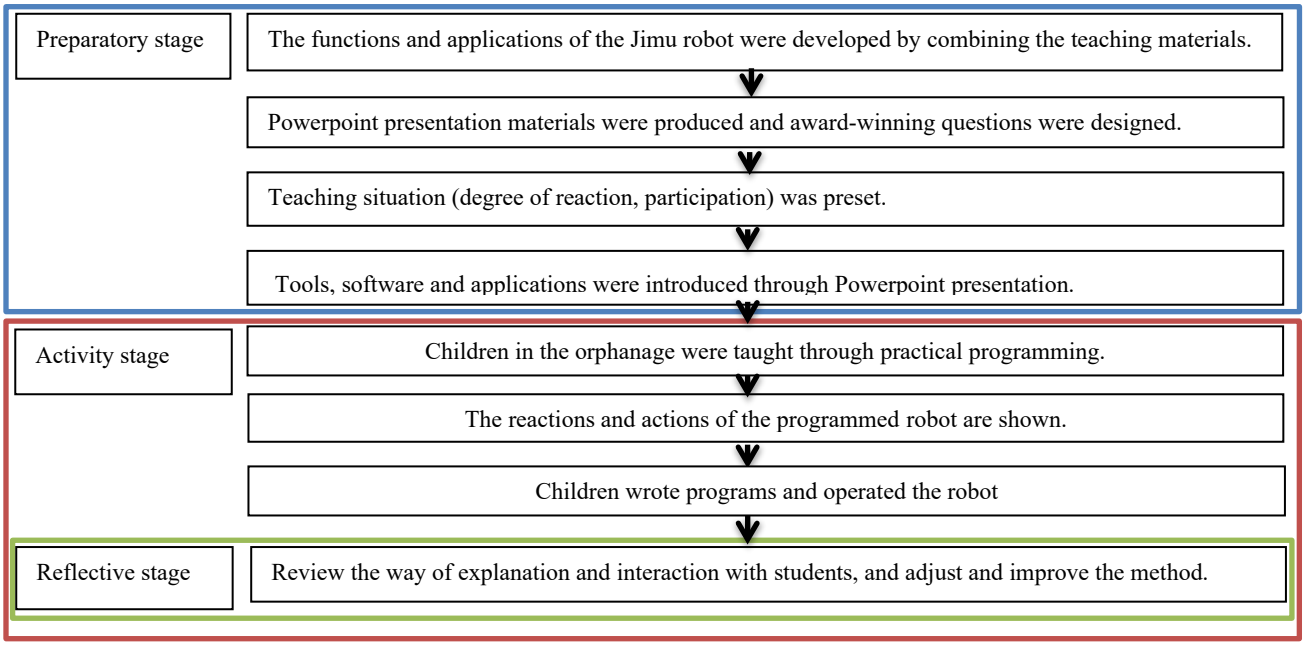

Figure 2. The popular science activity flow of the "graphic control program and robot education"

Figure 3. In front of the Jimu robot, we taught the graphic control program and robot concept, and many children raised their hands to answer questions.

Figure 4. Children focused on participating in writing the graphic control program and operating the robot, and they were happy in learning

5. CONCRETE RESULTS

To shorten the gap between science and technology learning for disadvantaged groups, this study mainly held the graphic control program and robot education activity in Orphanage A in Yunlin County, Taiwan.

(1) Graphic control program and robot teaching, and its implementation

The participants wrote graphic control programs, operated the robots, and learned to integrate information technology.

(2) Robot education teachers training.

We carried out the teaching activity for college students' self - ability and trained the teachers in robot education.

(3) Learning effectiveness improvement

The activity focused on allowing students to write programs, operate the robot in person, and try different changes, which improved their logical thinking ability, stimulated cooperation, and built their problem-solving ability, as students and teachers communicated and shared the process experience, and combined play and learning.

6. CONCLUSION

This study combined Scratch with the interaction platform of building block robots, which allowed the children of the orphanage to experience the processes of "imagination, creation, play, and reflection", cultivated their innovative consciousness, and opened a new avenue for the maker education of disadvantaged groups. We transferred the thinking knowledge of Scratch programming into the activities of the orphanage, and cultivated the scientific literacy, innovation spirit, practical ability, and the lifelong learning ability of the children.

The purpose of robot education in this study is to let children in orphanages learn by operating robots to improve their ability of integrating theory and practice, in order to strengthen the scientific and technological literacy, innovation spirit, and comprehensive practical ability of disadvantaged children, achieve the goal of reducing the gap in the application of science and technology learning, promote the education of robots, improve learning achievements, cultivate scientific interest, and build up the spirit of scientific research.

Through ultrasound, infrared, and other key elements of life, combined with graphic control programs and robots, we stimulated their interest and curiosity, actively extended many questions, and successfully aroused their learning motivation.

It was observed that the award-winning questions are the best way for children to think actively, answer bravely, and challenge their current abilities.

We hope to bring education to disadvantaged groups who lack care because of dysfunctional families and improve children's self-confidence.

This robot promotion activity is expected to serve disadvantaged students in education. In this process, college students became teachers, thus, they experienced different role tasks, incorporated teaching thinking, and improved the ability of two-way thinking from the perspective of students and teachers. The children and adolescents were exposed to different objects, people, times, and places, and they accumulated experience. This robot promotion activity helps cultivate seed teachers through teaching exercises, as they could identify teaching deficiencies and make improvements. The limitation of this study is that the orphanage wanted all the children to participate, thus, the participants include children aged 7 to 14.

7. SUGGESTIONS

It is suggested that more different components of robots be provided to the students of the orphanage to verify the learning effect of different tools on disadvantaged students.

8. ACKNOWLEDGEMENT

The authors appreciate the comments of the review committee.

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Cluster Analysis of Personal Data towards Student's Graduation in Information Technology Program

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ABSTRACT
This research aims to analyst and cluster the student's personal data towards student's graduation in the Information Technology program, Faculty of Industrial Technology and Management, King Mongkut's University of Technology North Bangkok, Prachin-Buri Campus. The sample of this experiment consists of 544 instances and 13 attributes such as sex, province, father's occupation, mother's occupation, and student's graduation status, *etc*. These samples are clustered in order to analyst the relationship between personal factors and student's graduation by partition clustering techniques. The Manhattan distance is used as a measure of the proximity or the similarity between objects. The basic idea contains five processes: (1) selecting data; (2) preprocessing data; (3) clustering data; (4) determining the optimal number of clustering; and (5) analyzing and interpreting the model. As a result, the presented method has successfully identified five clusters of students with similar characteristics in terms of personal data and student's graduation. This study will help the academic staff of IT department to get the knowledge and use it as the guidelines for public relations in recruiting new students for the next academic year.

CCS Concepts
• Computing methodologies → Machine learning → Learning paradigms → Unsupervised learning → Cluster analysis

Keywords
Clustering; k-means; data mining; student's graduation

1. INTRODUCTION
Recently, information technology has led to develop and plan education policies in order to improve education standards in both Thailand and other countries. Most universities collected data and used it to make decision-making and improve their curriculum in various ways. Data mining is one of the popular techniques to extract patterns or correlations from the large database or raw data. This technique is used in the education domain to analyze student data[9], analyze learning behavior [12] or predict student data [6] etc. Clustering analysis or clustering is a popular used in Educational Data Mining (EDM) domain for grouping the data object into groups based on data similarity using the descriptive analysis with statistical data [8]. For example, some universities used clustering techniques for categorizing students in different groups to understand and improve the performance of the student [9]. In the work by Jayabal *et al*. [4], they analyzed the student performance based on the scores of three main subjects (such as Mathematics, Science and Social Science) and their medium of study. The results shown a strong positive plausible causal relationship between performance and the medium of study.

The Department of Information Technology, King Mongkut's University of Technology North Bangkok, Prachin-Buri Campus is an organism that has stored information about student data both personal and academic into the registration system. The data is stored in a large database and reported with a special purpose, then how to use these student data to drive instruction and student admission. Moreover, the department needs to know that what are the characteristics of a successful student in terms of personal data. Thus, the data mining technique is appropriate to analyze and comprehend qualitative and quantitative student data.

The aim of this study is to implement the data mining technique to identify the characteristics of student based on the analysis of personal data towards student graduation in Information Technology program using clustering methods. The extract knowledge can help the teachers identify valuable student data to promote the students' admission to and completion of university education.

This paper is structured as follows: Section 2 presents the related works and Section 3 shows the methodology. Section 4 explains the results and discussion. Finally, Section 5 contains the research summary.

2. LITERATURE REVIEW
2.1 Clustering Techniques
Clustering Techniques are referred to as unsupervised learning. It groups the data objects into the different clusters based on similarity or distance measures such as Euclidean or Manhattan distances. Clustering techniques can be divided into hierarchical and non-hierarchical techniques. K-means algorithm is a non-hierarchical clustering and well known as partitioning method. It sprits the number of objects into "*K*" clusters where every object belongs to the cluster with the nearest mean [9]. In the k-means algorithm, user must set the value of *k* before training and user decided that how many clusters they should create. The k-means algorithm uses "centroids", which corresponds to the mean of

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points assigned to the cluster. Then, the algorithm assigns every data points to the nearest centroid where each object belongs to only one group [10]. The steps are: [9]

1. Initialize the cluster's centroid objects randomly equal to the value of '*K*' (*K* is the number of clusters).
2. Assign each object to the closest cluster centroid.
3. Update the cluster means, the position of *K* centroid is recalculated.
4. Repeat steps 2th and 3th until convergence or until the end of a fixed number of iterations.

2.2 Clustering in the Education Domain

The aim of clustering students is to create groups of students according to their customized features, personal characteristics, etc. The novel clustering algorithm named PLS-PM is proposed to display a strong positive plausible causal relationship between performance and the medium of study. Clusters of students are identified based on the degree of influence [4]. In a national university in Taiwan, k-means, seal-organizing maps (SOM) and two-step clustering (i.e. BIRCH) are used to separate students into different clusters. Then, they used the decision tree algorithm to extract useful rules from each clusters[11]. Another research is to find meaningful indicators or metrics in the learning context to study the inter-relationships between Educational Data Mining and the metrics using the concepts of Learning Analytics. The k-means algorithm is used to find the important factors of a learning context. They found that Parents' Involvement in Students' education and Students' Interaction with the LMS are important factors of Learning Analytics [1]. In addition, Kuswandi and Surahman [5] proposed the k-means learning model of student perceptions on the project-based learning model applications. The data conducted from an online questionnaire and they used Euclidean distance as the distance measure of the k-means algorithm. The results of clustering are four clusters in which cluster 1 showed respondents agree that the project-based learning model is able to provide satisfaction when the project is complete. Some of the researches related to clustering in the education domain are [2; 3; 7; 13]

3. METHODOLOGY

The framework method applied from many data mining techniques such as pre-processing technique, clustering technique and elbow technique, which illustrated in Figure 1.

3.1 Research Data

The data used for the study was compiled from the registration information system in the Department of Information Technology, Faculty of Industrial Technology and Management (IT-FITM) of King Mongkut's University of Technology North Bangkok (KMUTNB), Prachin-Buri campus in Thailand, among the first-second year students. The dataset after eliminating outlier and noise contains 544 instances and has 13 personal attributes. The original personal attributes in the registration system are shown in Table 1.

From Table 1 in No. 13, "Yes" is mean as the student can graduate with bachelor degree in the Information Technology field within 4 years, while "No" is mean as the student cannot finish their degrees in four years.

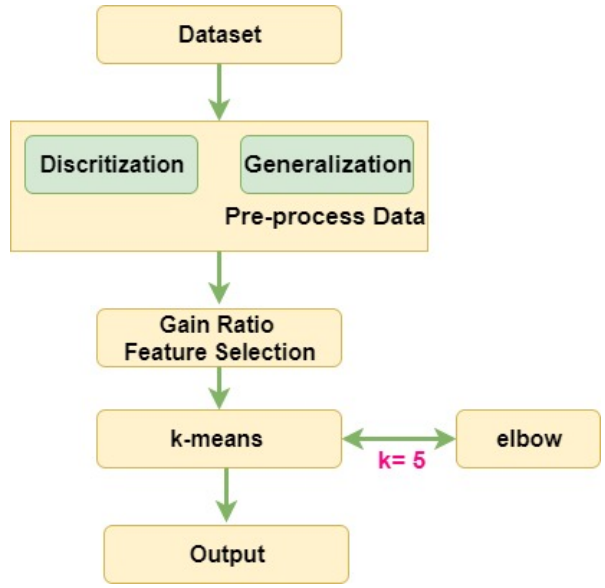

Figure 1. Framework method

Table 1. List of the original attributes

No.	Attributes Name
1	Gender
2	Province
3	Type of high school
4	GPA of high school
5	Mother's education
6	Father's education
7	Mother's income
8	Father's income
9	Type of admission
10	No. of sibling
11	Mother's Occupation
12	Father's Occupation
13	Success (Yes, No)

Table 2. List of the final dataset

No.	Attributes Name
1	Gender
2	Region
3	Type of high school
4	GPA of high school
5	Mother's education
6	Father's education
7	Mother's income
8	Type of admission
9	Mother's Occupation
10	Success (Yes, No)

After that, two pre-processing techniques are performed in order to improve data quality. Firstly, the discretization technique is used to divide the range of continuous attribute into intervals. The equal width discretization method is processed with a "GPA of high school attribute". The attribute was discretized into three categories (low, medium, and high). Secondly, the province attribute is edited using the Generalization technique in order to perform meaningful

analysis and knowledge. The attributed are perform into four groups as the region: central, north, northeastern and south.

After that, a Gain Ratio is used as the method for data reduction. It is a ranking method modified from the information gain. The low-ranking attributes are filtered to form new reduced data subset. After Gain Ratio processed, the three attributes are removed including Father's income, No. of a sibling, and Father's Occupation. Therefore, the final dataset has 10 attributes as shown in Table 2.

3.2 Clustering Data

In this study, the personal data will be clustered in order to find the student characteristics that predicted future academic success. Therefore, the k-means algorithm is selected because it is the most famous data mining method in grouping data. Moreover, k-means is easy to implement. In part of the distance metric, Manhattan distance is used to calculate the distance between centroid and object because it will try to reduce all errors equally since the gradient has constant magnitude. The Manhattans distance is defined by equation (1).

$$d(n,m) = \sum_{i=1}^{n} |x_i - y_i| \qquad (1)$$

Where $d(n,m)$ is a Manhattan distance; n is the number of variables, x_i and y_i are the variables of vectors x and y, respectively.

However, the k-means algorithm has an input parameter, which is the number of clusters (k). The value of k is of great importance and the user must set before training. In this paper, the elbow method is used to find the optimal value of k. This method runs k-means algorithm for a range of values for k (2-10) and then for each value of k calculate an average score (sum of square error: SSE) for all clusters. Then, we plot a line chart of the SSE for each value of k. If the line chart looks like an arm, then the location of elbow on the arm is generally considered as an indicator of the appropriate number of clusters or the optimal value of k.

The result combined the system test of the k-means algorithm with the elbow method according to Figure 2.

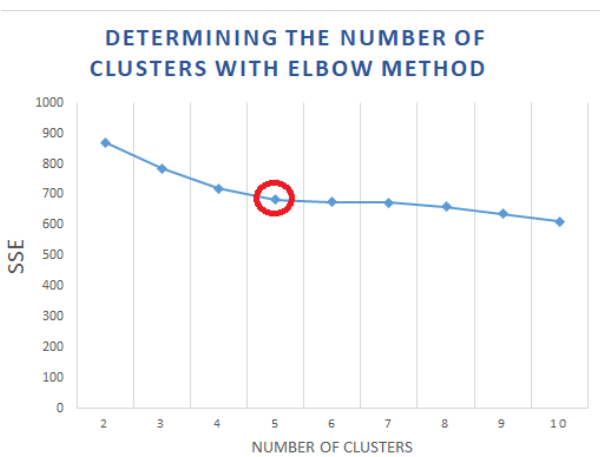

Figure 2. Determining the number of cluster with elbow method

From Figure 2, the results showed that the "elbow" is indicated by the red circle. The number of cluster chosen should therefore be 5.

4. RESULTS AND DISCUSSION

From above, the results of the elbow method have given the appropriate number of clusters (k = 5). Therefore, the k-means algorithm is performed over the personal student dataset with the number of 5 clusters. The number of instances of the cluster can be seen in Table 3 and the centroid results of the k-means algorithm have been summarized in Table 4.

Table 3. Clustering results

Clustered	The number of instances	Percentage
0	102	18.75
1	117	21.51
2	95	17.46
3	58	10.66
4	172	31.62

From Table 3, the results of clustering above it can be seen that there are 102 instances that enter cluster 0, while 117 instances enter cluster 1. The cluster 4 is the maximum cluster size. On the other hand, cluster 3 is the minimum cluster size.

Table 4. Centroid Results

Attribute Name	cluster 0	cluster 1	cluster 2	cluster 3	cluster 4
Gender	2	2	1	2	1
Region	central	central	central	central	central
Type of high school	1	1	1	1	1
GPA of high school	Middle	Middle	Middle	High	Middle
Father's education	3	1	3	1	5
Mother's education	1.5	1	2	2	5
Mother's income	5	4	18	6	11
Type of admission	2	2	2	1	1
Mother's Occupation	3	6	13	6	2
Success	No	Yes	Yes	Yes	Yes

According to Table 4, consider cluster 0 that identifies the characteristics of the status of student's graduation, which is No. It means that the student cannot finish their degrees in four years. Meanwhile, the remaining clusters the status of student's graduation is Yes. However, in order to clearly analyze the characteristics of students, the success feature and cluster number after applying the k-mean algorithm is drawn in terms of scatter plot as shown in Figure 3. The scatter plot is drawn in this study because sometimes the data pointed in a scatter plot from distinct group. These groups were called clusters.

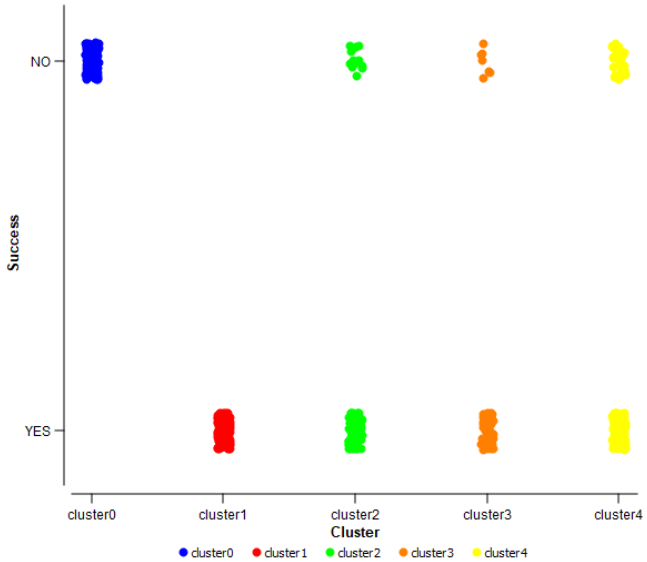

Figure 3. Scatter plot for the student's success and cluster number

Table 5. The main characteristics of two clusters

Clustered	Characteristics of each cluster
0	Cluster 0 represents students who have the opportunity to **not graduate** in four years. This cluster has the following characteristics: - Most students are female. - They live in the central region and entrance qualification is Senior High School that grade point values (GPA) range from 2.01 to 3.00. - The factors of father's education and mother's education were the same. They had a junior-high-school degree or a vocational certificate. - Their mothers earned income from around 8,001 to 10,000 Thai Baht a year. - They apply through the regular admission process. - Their mother's occupations were private company employees (not self-employed).
1	Cluster 0 represents students who have the opportunity to **graduate** in four years. This cluster has the following characteristics: - Most students are female. - They live in the central region and entrance qualification is Senior High School that grade point values (GPA) range from 2.01 to 3.00. - The factors of father's education and mother's education were the same. They had a primary-school degree. - Their mothers earned income from around 6,001 to 8,000 Thai Baht a year. - They apply through the regular admission process. - Their mother's occupations ware farmer.

From Figure 3, the result confirms that cluster 0 represents students who have the opportunity to not graduate in four years. On the other hand, cluster 1 represents students who have the opportunity to graduate in four years. Meanwhile, the remaining clusters get a mix of both values (Yes and No). Therefore, the main characteristics of student's graduation from personal data on this dataset are only described from cluster 0 and cluster 1. The student characteristics of both clusters are shown in Table 5.

From Table 5, five attributes have certain characteristics that have the same values. These attributes consist of gender, region, type of high school, GPA of high school and type of admission while three attributes are different including the father's education, mother's education, and mother's occupation. Therefore, the results can be concluded that these three personal factors influence student' graduation in the Information Technology program of Department of Information Technology, Faculty of Industrial Technology and Management, King Mongkut's University of Technology North Bangkok, Prachin-Buri Campus, Thailand.

5. CONCLUSION

In this paper, data mining clustering techniques were conducted over a student's personal data towards student's graduation in the Information Technology program in order to obtain interesting information (knowledge) in a more efficient and faster way. The academic staff can use this knowledge to perform as the guidelines for public relations in recruiting new students for the next academic year. This paper used the k-means algorithm and the elbow method as a methodology of clustering analysis for data mining. There are five clusters obtained from the k-means algorithm and the results showed some characteristic features of students. However, this paper only focuses on cluster 0 and cluster 1. The characteristics of students who have the opportunity to graduate in four years as briefly explained as follows: father's education and mother's education were a primary-school degree; mothers earned income around 6,001 to 8,000 Thai Baht a year and; mother's occupation was the farmer. In future research, we carry out experiments with various features such as academic features and time-based social features.

6. ACKNOWLEDGMENTS

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Design of the Graphic-Controlled Robot for the Education of Teenagers

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ABSTRACT
Taiwan has implemented the National Twelve-year Basic Education since 2019, and the curriculum focuses on "core literacy", in which independent action, communication and interaction, and social participation echo the educational spirit of Science, Technology, Engineering, Art, and Mathematics. Moreover, situated learning is an important topic discussed in the National Twelve-year Basic Education curriculum, which can guide students to experience, practice, deepen their thinking, and improve their vision. It is the key to link learning and application. By building knowledge and training skills in this way, learners' learning motivation and learning effectiveness can be improved. In this study, teenagers are taken as the research object, and the integrated STEAM teaching of robot and program education is constructed by combining the education method of micro: Maqueen robot with a graphic control program, in order to promote the integration and innovative application of robot software and hardware, and provide teenagers with opportunities to contact with robots. The implementation results include the teaching design of program-controlled micro: Maqueen, such as the writing of the graphic control program and its ultrasonic application in micro: Maqueen. The ultrasonic application in micro: Maqueen includes the ultrasonic automatic obstacle avoidance function, ultrasonic distance measurement function, and ultrasonic following function, which aim to cultivate students' logical thinking, problem-solving ability, and other high-level thinking ability, and stimulate students' sustainable development in the field of information technology

CCS Concepts
• Social and professional topics→ Professional topics→ Computing education→ K-12 education

Keywords
program education; robot; STEAM; situated learning

1. INTRODUCTION
Technology has changed our living habits and AI (Artificial Intelligence) technology education will be closely related to our daily life [1]. Taiwan actively promotes AI education, which is extended to students and people of different ages, and arouses the interest of young people in AI. Therefore, robot education with intelligent identification ability plays an important role in creating intelligent life.

The ICT (Information and Communication Technology) education team of UNESCO (United Nations Educational, Scientific and Cultural Organization) has actively developed a new plan for the transformation of AI, global talents, and educational institutions [2]. In the narrow sense, robot education focuses on robot-related knowledge and production skills, including professional theoretical knowledge, robot courses and teaching, and robot competitions. In a broad sense, it refers to all teaching and learning activities related to robot knowledge or technology [3-4]. It is a new way to popularize robot education to let robots approach students, and can cultivate students' learning and scientific spirit, in order that robot and program design are rooted in youth education.

2. MOTIVATION
The application of robot and program design has gradually entered our daily life; for example, Pepper, a service-oriented robot, has been used to provide interactive services, such as business consultations and guide experience at the service counters of banks, shopping malls, restaurants, and department stores in various regions [5]. In recent years, AlphaGo has defeated many go masters and shocked the world [6], which further stimulated the discussion on the application of AI technology in various industries.

To meet the coming of the robot era, this study develops and applies the graphic- controlled robot to the teaching of teenagers. Through the trend of robots entering school curriculums, this course can cultivate students' integration, creativity, and problem-solving ability.

3. PURPOSE
In this study, an on-the-spot educational course with a graphic-control-program robot was designed to cultivate teenagers' abilities in computing and logical thinking. This study has two purposes. First, the graphic control program was developed for teaching purposes. Microsoft MakeCode and micro: Maqueen were used as tools to develop graphic control programs, including the ultrasound automatic obstacle avoidance function, the ultrasonic distance measurement function, and the ultrasonic following function program code combined with micro: Maqueen robot's ultrasonic, sound, light, and other applications, in order that the students could learn to write programs, understand the principle of robot mechanism, and improve their creativity and logical thinking ability. Second, on-site teaching operation was carried out to improve students' interest in learning robots. The course of robotics is an interdisciplinary and highly comprehensive course of

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emerging science and technology, and practical operation is an important method in programming teaching. By means of making software and hardware products, students can apply theories to solve practical problems, and then, gain cross-field knowledge and understanding of technology. Although such curriculum design is challenging, it can improve students' learning interests and skills.

4. LITERATURE REVIEW

4.1 Robots

Taiwan has been strengthening the development of its "intelligent robot" industry and technology since 2005, when it was listed as the development goal in the Executive Yuan Strategy Review Board Meeting. The robotics industry is poised to become the next technology star, and could become Taiwan's third Trillion Dollar Industry after semiconductors and FPD, making it the world's leading manufacturer of intelligent robots. Therefore, robot education is imperative [7].

Robot education is a course of innovative and integrated technology, which requires both theoretical basis and practical innovation. It starts with understanding robot knowledge to cultivate students' interest and guide them to learn robot-related application knowledge and technology. Various information technologies and general technology contents have been integrated into various interesting robot making projects through the production of robots [8]. The advantage of robot teaching is that students not only need to use their knowledge in science and mathematics, they also have to select appropriate materials and parts for practical operation, which makes them combine knowledge and practical operation [9]. Robot education can help students lay a solid foundation of science, technology, engineering, and mathematics, cultivate their innovative spirit and practical ability, and promote the growth of innovative and entrepreneurial talents.

4.2 Program Education

Barack Obama, President of the United States, promoted the "Hour of Code" activity in the computer science education week, which hoped to change the way of thinking through programming, and encourage more people to invest in information creativity and design, in order to enhance national competitiveness. In the UK, programming is a compulsory course for primary and secondary schools, and 2014 was designated as the "Year of Code" [10]. In 2019, Taiwan included programming education in the new curriculum [11], in order that students can learn computational thinking through writing programs [12].

The combination of programming education and robots can effectively improve the learning effect of learners, which has attracted more and more attention from both practical and academic circles [13]. This is one of the important development directions of future education. Past research has also confirmed that the program design course is helpful to cultivate students' high-level thinking abilities, such as computational thinking and problem-solving abilities, and it can stimulate students' sustainable development in this field and make it a reference for future employment choice [14]. Program education can cultivate students' logical thinking, systematic thinking, and other operational thinking, and the design and implementation of information technology for controlling robots can improve students' ability to apply computing thinking in different fields, solve problems, and think creatively.

4.3 STEAM

Science, Technology, Engineering, Art, and Mathematics (STEAM) have received a lot of attention in recent years [9]. The collaborative teaching of the cross-disciplinary STEAM curriculum can cultivate primary school students' ability to "explore and practice", which is a global education trend [15]. The National Research Council of the United States [16] has determined the goals of STEAM in K-12 education: learning the connotation and practice of STEAM, developing a positive attitude toward STEAM, and preparing for lifelong learning [10].

The curriculum outline of the National Twelve-year Basic Education implemented in 2019 takes "core literacy" as the main axis of the curriculum, and endows the new curriculum with the kinetic energy of practice. The independent action, communication and interaction, and social participation in "core literacy" correspond with the STEAM education spirit, which emphasizes the subjectivity of learners, pays attention to the cultivation of knowledge and skills, focuses on the combination of learning and life situations, and promotes the overall development of students through the integration of knowledge and practice [17]. The innovation of the STEAM curriculum focuses on the concept of "learning-by-doing", and develops relevant interesting learning activities based on problems in reality. Through these robot activities, the spirit of STEAM was implemented into the education of teenagers. This study guided teenagers to start from DIY and assemble various parts into the ideal robot according to their own artistic creativity.

4.4 Situated Learning

Field situated learning, which can guide students' practical experience and morality, deepen their thinking, and improve their vision is a new and important topic in the National Twelve-year Basic Education curriculum. It is also the key to link learning and life, in order that students can truly obtain situational and contextual literacy through field experience, observation, and feeling, which is conducive to the implementation of the vision of the National Twelve-year Basic Education [18]. According to the theory of situated learning, knowledge exists in learning situations, and learners actively participate in interaction and explore things in the situations. In this way, knowledge or training skills can be constructed, and learners' learning motivation and learning effectiveness can be improved [19]. This study provides opportunities for adolescents to participate in interactive discussions, field experience, observation, and exploration in robot education, and hopes to construct a programming language to master the action knowledge or training skills for robot education.

5. RESEARCH METHODS AND IMPLEMENTATION STEPS

In this study, the teaching content of "micro: Maqueen" was developed, and the application of ultrasound in micro: Maqueen was emphatically developed, including the functions of ultrasonic obstacle avoidance, ultrasonic distance measurement, and ultrasonic following.

The following description promotes the content of "graphic control program and robot education promotion activities".

(1) Teaching content of "micro: Maqueen" and application of ultrasonic wave in micro: Maqueen were developed:

- Operation mode: computer, smart phone
- Usage procedure:

①. Computer: Microsoft MakeCode for micro: bit
②. IOS Mobile: search for micro: bit in App Store
③. Android Mobile: search for micro: bit in Google play store

- Transmission media: Bluetooth, USB transmission line
- Operation steps: (taking mobile phone programming and Bluetooth transmission as an example)

①. Open the App program and Bluetooth, and connect with micro: Maqueen. For example, Figure 1 shows the operation pages of Android and IOS.

Press "PAIR A NEW MICRO: BIT" to match a new micro: bit motherboard, and press "NEXT" to carry out the next step (as shown in Figure 2).

The left picture in Figure 3 is the micro: bit motherboard, and the right picture is the screen of the mobile phone. Confirm that the picture of the mobile phone is the same as that on the micro: bit motherboard, and press "PAIR" to confirm.

Android IOS

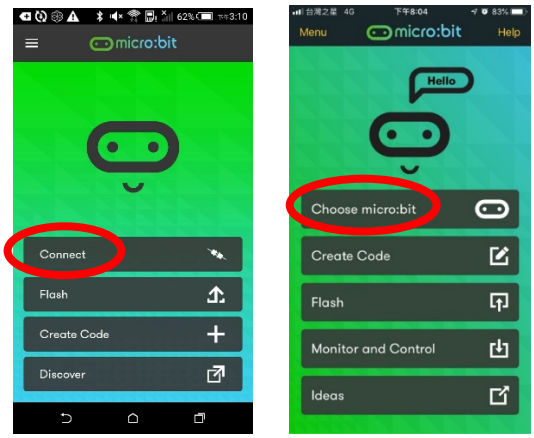

Figure 1. The picture on the left is the APP operation page of the Android version, and the picture on the right is the APP operation page of the IOS version

Press "PAIR A NEW MICRO: BIT" to match a new micro: bit motherboard, and press "NEXT" to carry out the next step (as shown in Figure 2).

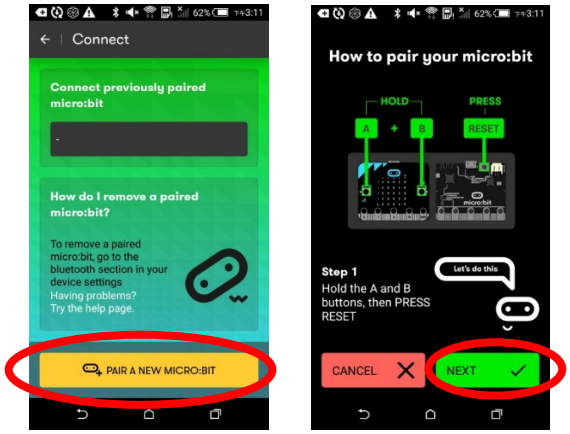

Figure 2. Match a new micro: bit motherboard for "PAIR A NEW MICRO: BIT"

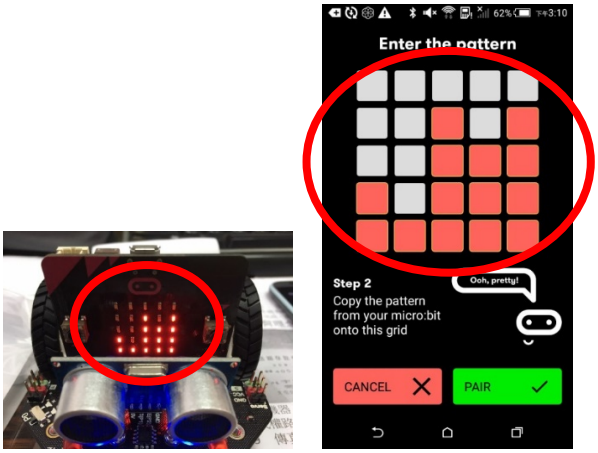

Figure 3. The picture on the left is the micro: bit motherboard, and the picture on the right is the corresponding screen of the mobile phone

When the screen in Figure 5 appears, it means the connection is successful. Press "OK" to finish.

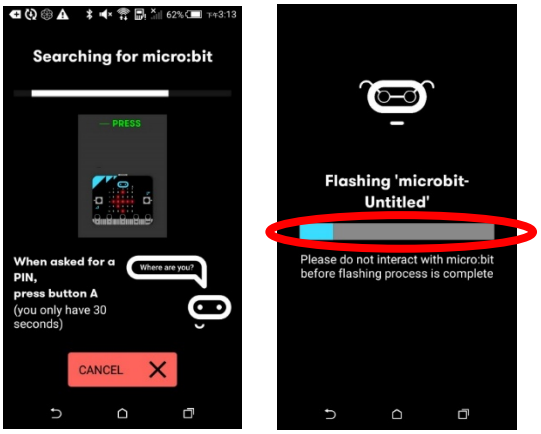

Figure 4. Connecting screen

Figure 5. Press "OK" to finish online connection

②. Start programming

As shown in Figure 6, you can click "Create Code" to start programming. After entering the programming page, click "Extension" to join the micro: Maqueen program.

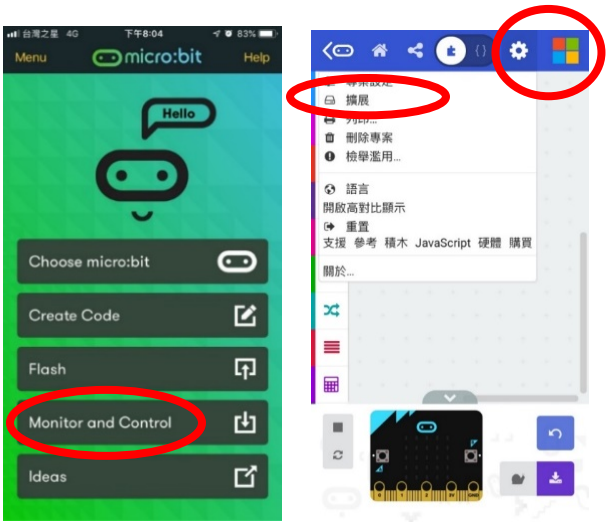

Figure 6. Writing micro: Maqueen program

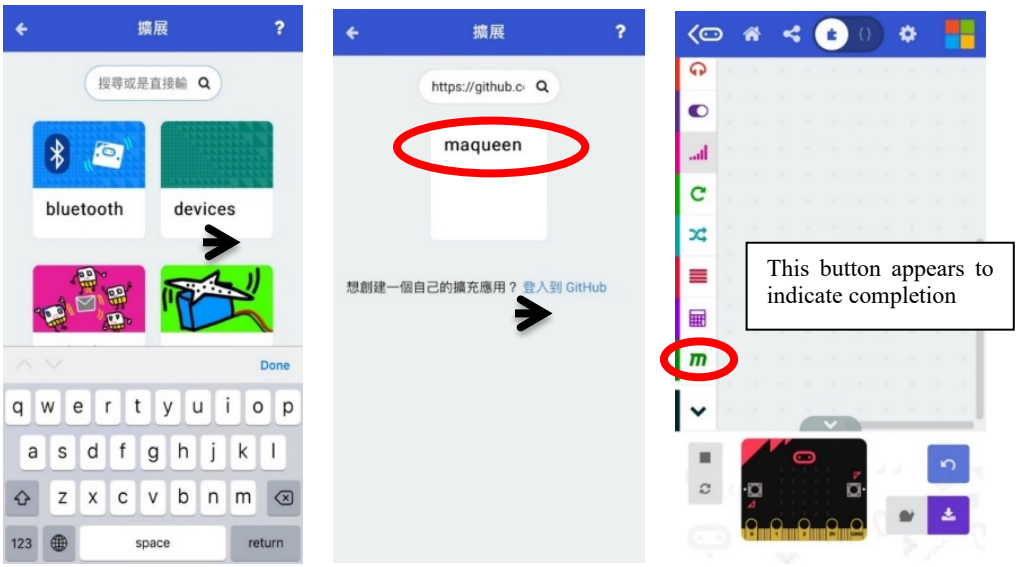

Figure 7. Press "maqueen". When m appears, it means success

Figure 7: Enter micro: Maqueen website: https://github.com/kodorobot/maqueen, and press "maqueen". When m appears, it means success.

③. Naming and saving of successful programs

Figure 8 shows the saving or sharing of the finished Scratch 3.0 program. Press first, then name the project and publish it. To share this project, press the duplicate key to share the website; to save directly press to finish the naming. As shown in Figure 9, press to finish saving.

④. If the user does not want to save the program, but wants to transfer it to the dolly for operation, follow the steps below.

As shown in Figure 10, press the A and B keys on the Micro: bit motherboard at the same time, press "RESET", then press the save key . There will be a connection-waiting screen (as shown in Figure 11).

Figure 8. Share written programs

Figure 9. Press to finish saving

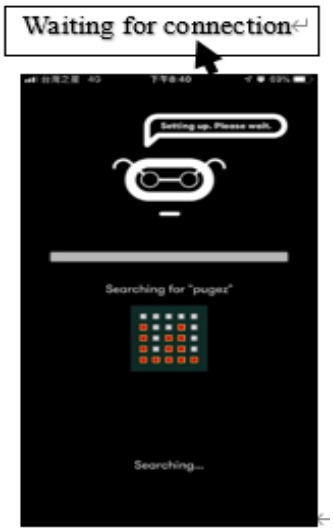

Figure 11. The screen of waiting for connection

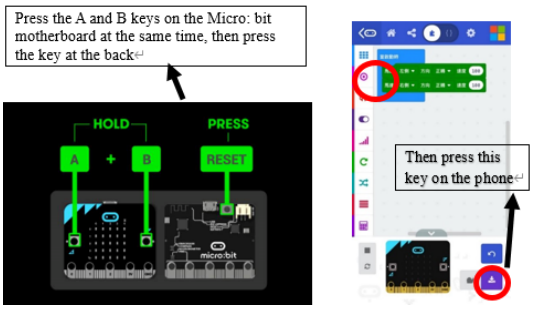

Figure 10 Direct program transmission

⑤. The ultrasonic application function code, as shown in Figure 12 and figure 13.

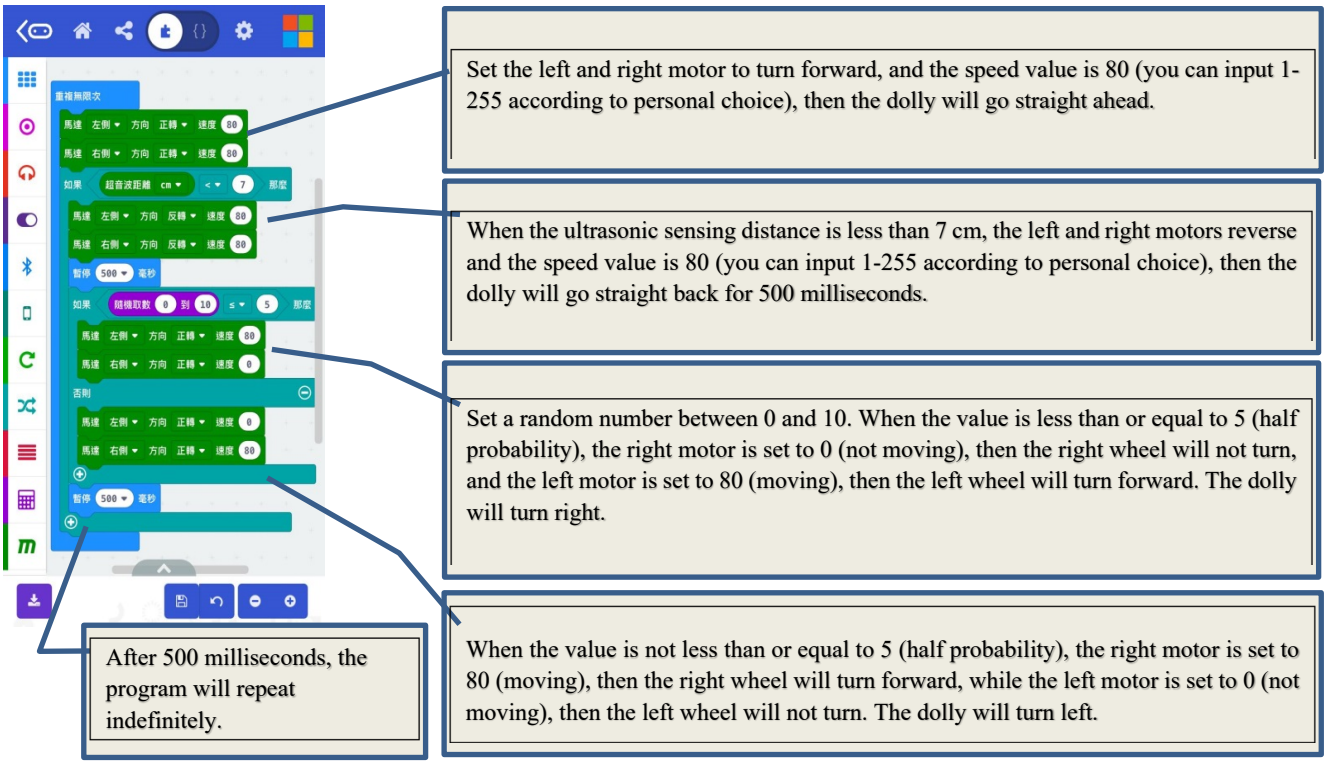

Figure 12. Code and description of ultrasonic automatic obstacle avoidance program

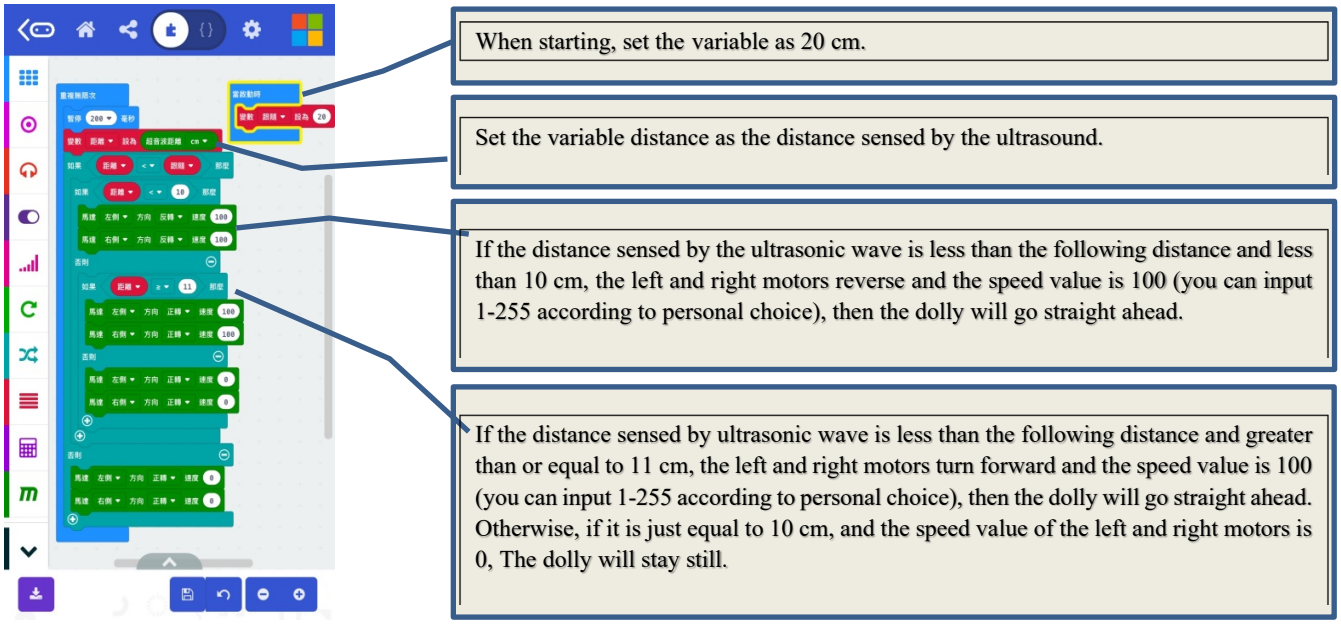

Figure 13. Code and description of ultrasonic following program

(2) The first graphic control program and robot education promotion activity:

①. Teaching objects: 15 junior high school students

②. Tool: micro: Maqueen

③. Specification

- Power supply voltage: 3.5V~5V DC
- Infrared sensor × 2
- Buzzer × 1
- Infrared receiver × 1
- LED light × 2
- RGB ambient light × 4
- SR04, SR04P ultrasonic interface (5V) × 1
- IIC interface (3.3V) × 1
- Gravity module expansion interface (P1, P2) × 2
- N20 metal reduction motor × 2
- Motor reduction ratio: 1:150

- Maximum speed of motor: 133 rpm
- Motor drive mode: PWM motor drive
- Support and cover extension M3 screw hole × 6
- Programming method: Makecode and Mind+ (based on Scratch 3.0)

Product size: 81mm wide × 85mm long × 44mm high(excluding the height of mainboard and ultrasonic sensor)

- Product weight: 75.55g (only the Maqueen robot dolly, excluding the mainboard and battery)
- Tire width: 0.9 cm

5. User program: Microsoft MakeCode

The first activity was extended to junior high school students. It was introduced from the most basic programming and operation of micro: Maqueen, and then, the application of ultrasound in the graphic control program and the robot was demonstrated. Ultrasonic applications can be seen everywhere in human life, such as ultrasonic cleaning glasses, fetal examination, and parking sensors. The combination of ultrasound and robots can add interest and interaction. In the teaching activities, we first asked the students whether they have been exposed to the graphic control program and robots, in order to enhance the interaction with them, and made the explanation adjustment according to the students' answers. Then, we invited the students to leave their seats and get close to the stage to see the micro: Maqueen follow-up mode. We asked students to guess its principle to arouse the students' thinking and curiosity. Five students expressed their opinions, which enhanced interaction. Finally, we introduced the ultrasonic sensor of micro: Maqueen and its application principle, as well as the programming method and logic of the graphic control program, and let the students experience it. In the process, science, technology, engineering, mathematics, and art were integrated, which makes the teaching process have unlimited innovation space and truly embodies "learning by playing", endowing the robot with thinking and soul, and enabling the robot to sense independently. Students obtained valuable experience while “interacting with the robot”.

At the end of the activity, we first reflected on the teaching method, the speed of speech, the situation of interaction with students, and the teaching content, and then, readjusted these factors for the next activity. In addition, during the activity, we observed the students' interest in graphic control programs, robots, and ultrasound, and found that about 1/3 of the students were willing to leave their seats for close learning and interaction with the speakers, as shown in Figure 14 and Figure 15.

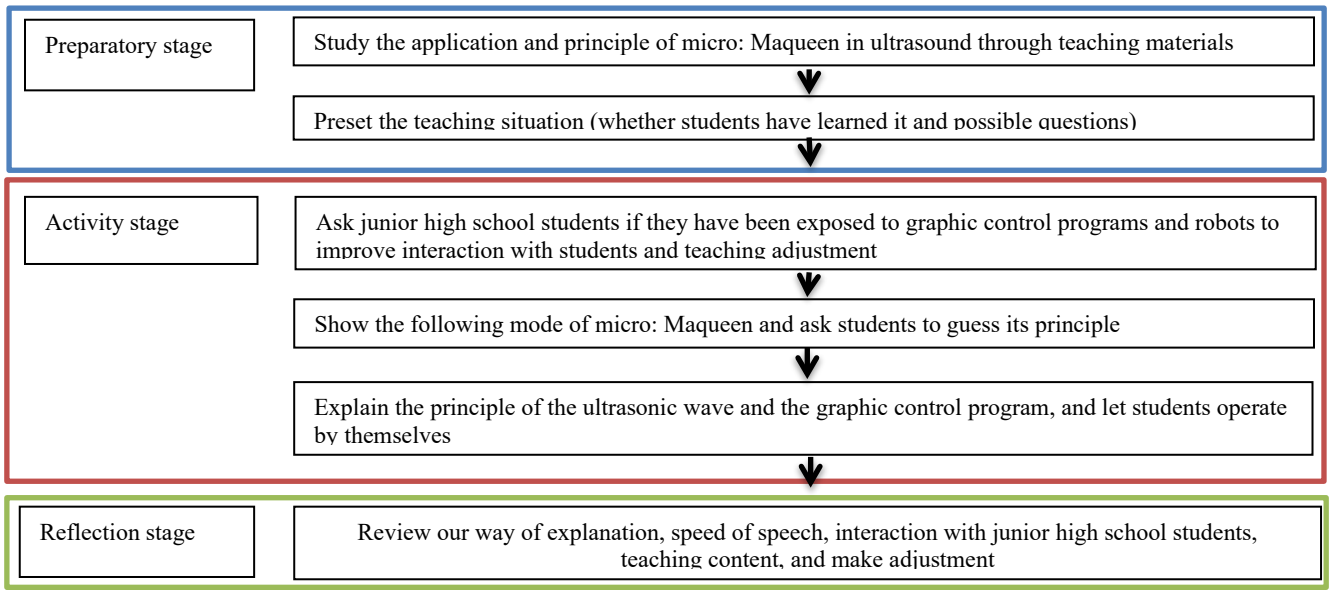

Figure 14. Flow chart of the first promotion activity on the graphic control program and robot education

Figure 15. Participation of junior high school students in the ultrasonic following mode

(3) The second promotion activity of the graphic control program and robot education

①. Teaching objects: senior high school students
②. Tool: micro: Maqueen
③. Usage procedure: Microsoft MakeCode

Through the same teaching method, the differences between junior high school students and senior high school students in the application of robot education were observed and discussed. Figure 16 shows the flow chart of the second promotion activity of the graphic control program and robot education.

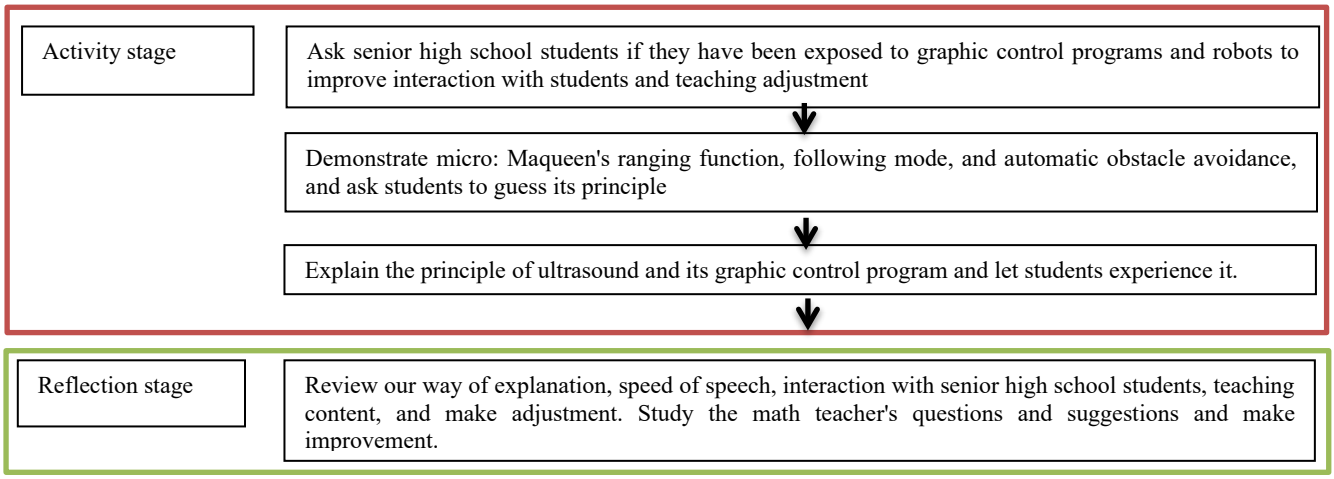

Figure 16. Flow chart of the second promotion activity of the graphic control program and robot education

Compared with the first activity, and taking the application of the ultrasonic wave in the following mode as an example, we added the function of measuring distance, the function of automatically avoiding obstacles, and the way and logic of writing control programs. In addition, we listened to the suggestions from the former math teacher of the class regarding the limitation of the ultrasonic sensor and the farthest distance it can measure. Since this problem was not considered in advance, we reviewed the reflection question, carefully studied the teacher's suggestions, and made the improvement.

Through the comparison of two activities, we found that junior high school students are more interested in the activity, they expressed their opinions more enthusiastically, and they are not afraid of making mistakes. In the second activity, only one senior high school student was willing to study in front of the stage and answer questions, and he stayed after the activity and continued to observe the robot. After class, we discussed this with the senior high school teachers, and found that it may be caused by enrollment pressure. Please see Figure 17 and Figure 18.

Figure 17. It shows the micro: Maqueen ultrasonic following mode

Figure 18. It shows that the micro: Maqueen uses ultrasound to avoid obstacles automatically

6. CONCLUSION

The importance of STEAM inter-disciplinary integration education is increasingly emerging. Students' ability to integrate theory and practice in the face of problems is one of the core concepts of STEAM, the main axis of science and technology, and an indispensable high-level ability in the 21st century. Since robots are representative teaching materials in STEAM education, this study aims to improve students' scientific and technological knowledge and literacy through robot and program education, and the implementation results are, as follows:

(1) We have developed the teaching content of the "graphic control micro: Maqueen" for teenagers in educational institutions, including programming the graphic control program, micro: Maqueen, ultrasonic application, etc.

(2) We developed the teaching method of the ultrasonic wave in micro: Maqueen, including explaining the definition, basic knowledge, principle, and application of ultrasound in life. We introduced the application of micro: Maqueen combined with the ultrasonic wave, and developed the program code of the ultrasonic automatic obstacle avoidance function, ultrasonic distance measurement function, and ultrasonic following function.

(3) We introduced the graphic control program combined with robot education to teenagers in educational institutions, which can cultivate students' high-level thinking abilities, such as operational thinking and problem-solving ability, and promote students' sustainable development in this field.

7. SUGGESTIONS

It is suggested to verify the difference in learning effectiveness of the program code of the robot among teenagers.

8. ACKNOWLEDGEMENT

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Session IV

Operations Research

Work Classification and Workstation Design for Person with Functional Difficulty (PFD)

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ABSTRACT
Employing Persons with Disability (PWD) is a challenge for every employer especially in the Philippines. Some companies have hesitation on hiring PWD because employers are not confident that persons with difficulty could function and deliver what they are expected from them to do in their job. In a similar way, most workplace environment is not yet designed to fit or accommodate this particular group. According to Philippine Statistics Authority (2015), Persons with Disability (PWD) has a branch called Person with Functional Difficulty (PFD); these are individuals that have difficulties in executing activities but are still capable of having a job [7]. For these reasons, it became the research interest of the authors to conduct a study on the work classification and workstation design for persons with functional difficulty (PFD). The authors examined the employment profile of 270 PWDs within NCR region and classified them according to their functional difficulty in terms of the following: (a) difficulty in seeing, even if wearing eyeglasses, (b) difficulty in hearing, even if using a hearing aid, (c) difficulty in walking or climbing steps, (d) difficulty in remembering or concentrating, (e) difficulty in self-caring (bathing or dressing) and (f) difficulty in communicating. Afterwards, specific tasks and work activities that can be performed by each person with functional difficulty were identified in order to match them with the job suitable for PFD. It was done using a career aptitude test and job analysis. Finally, principles of ergonomic were employed in order to design a workstation that would be suitable for the persons with functional difficulty based on the specific job that were identified in the study appropriate for PFD.

CCS Concepts
•General and reference→ Document types→ General conference proceedings

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Keywords
Persons with functional difficulty; work classification; workstation design; ergonomics

1. INTRODUCTION
The World Health Organization (WHO) defines disability as an umbrella term for impairments, activity limitations, and participation restrictions denoting the negative aspects of the interaction between an individual with a health condition and that individual's contextual factors such as environmental and personal factors. Person with disabilities represent a significant proportion of the world population [1], however, persons in this particular group are having a hard time finding a job or employment. In the study conducted in Romania, it states that employment rate of people with disabilities on the work is significantly lower of more than 57 percentage points in the employment rate of the general population sample of the same age [2]. It is also mentioned that to integrate the person with disabilities in the labor market, effective early support to guarantee schooling and professionalization of all the people with disabilities should be properly addressed, irrespective of the place in which they find themselves, by observing their individual development needs. The involvement of employers to design and adapt workplaces so that they should become available for the persons with disabilities is essential [3]. Workplace accommodation is important to person with disability. It gives them the feeling of independence, usefulness, responsibility, and mobility. The European Community ensured disabled workers have the same opportunity with normal employees. In United States, the Americans with Disabilities Act (ADA) implements this law to require employers to make reasonable accommodation in policies, practices, or procedures when such modifications are necessary to allow disabled workers to access goods, services, facilities, privileges, advantages, or accommodations [4].

In the Philippines, a study conducted revealed that the proportion of employed PWDs in the urban area within Metro Manila and Batangas was higher (58.3%) than that in the rural area (41.7%) [5]. Among the type of PWDs who were commonly employed are those who have hearing-impairment (40.6%), followed by those who have mobility-impairment (28.1%) [6].

Disability laws implying the rights and opportunities of PWD in terms of employment exist in the Philippines. One of which is the Republic Act 10524 also known as Employment of Persons with Disability Act (2012), which states that at least one percent (1%) of all regular and non-regular positions in all government agencies shall be reserved for persons with disability. For private corporations with more than one hundred (100) employees, they are

encouraged to reserve at least one percent (1%) of all positions for PWDs [7]. In fact, companies who hire PWDs were given incentives by the government. Yet, in a study by Cortes (2013) revealed that in spite of tax incentives and other privileges given to employers who will hire PWDs, only about 10 to 30 percent of employable PWDs in the country are engaged in regular paid work, 50 percent are in the informal sector and the remaining percentage are not working (PSA, 2005). Based on the study, this is due to poor perception of Filipino employers towards PWDs such as *Negative Stereotype* (low productivity, frequent absenteeism and turnover); *Added Cost and Efforts at Management* (additional safety measures, needs closer training and supervision) and *Social Cost* (negative reactions from customers and co-workers) [8].

However, there are still positive outcomes and benefits that companies could gain in hiring PWDs, such as: incentives from the government; positive image for the company that can help improve their marketability and attract potential clients; expansion of their talent pool; and reduction of job turnover, since studies confirm that PWDs often show greater loyalty to employers [9] [10].

For these reasons, it became the research interest of the authors to conduct a study on work classification and workstation design for persons with functional difficulty in order to give them a greater chance of employment. This study intends to classify the functional difficulty of PWDs who are currently employed in the Philippines, then identify the specific tasks and work activities that would match the job suitable for PFD. And finally, design the workstations that will be appropriate for the PFD using ergonomic principles.

2. METHODOLOGY

A total of 270 PWDs who are currently employed within NCR region were chosen to be the subject of the study. In gathering initial data, interview, direct observation, and survey were done to determine current problems, issues and difficulties that PWDs are facing in their current employment in terms of their work activities, workstation design, facility design and relationship to their co-workers. These data are needed to justify the objectives of the study.

Next, the ICF Checklist of the World Health Organization (2003) was used to identify and classify the functional difficulty of the PWDs. International Classification of Functioning, Disability and Health Checklist (ICF) is a framework for organizing and documenting information on functional disability of a person (WHO,2001). It provides a standard language for the definition and measurement of disability, and it provides classification and codes. Classification of functional difficulty were determined by gathering data on the subjects such as: demographic information, health information, impairment of body functions, impairment of body structures, activity limitations and restrictions, and other environmental factors.

Afterwards, aptitude test using Skill Master software was utilized to determine the capabilities, strengths, knowledge and skill sets of the subjects. This is used in order to identify the specific tasks that are able and not be able to perform by the subjects based on their classification of difficulty.

Then, principles of job analysis and design were applied to match the identified skill sets of the PFD to the type of work or job best suited for them. Specific job description and specification were developed for each type of work based on the classification of difficulty of the person. These includes the following, (a) job description: job summary, job responsibilities, relation of job to other tasks, tools/equipment required in the task, work conditions, location of work, job hazards; (b) job specification: education level, experience, training needs, physical effort, physical skills and communication skills.

And finally, using all information and data gathered from the study, the researchers were able to design the workstation of the PFD based on identified job suited for them using the principles of ergonomics. Ergonomics is the process of designing and arranging workplaces, products and systems so that they will fit the people who use them. Ergonomics aims to improve workspaces and work environments to minimize the risk of injury or harm to the person [11] [12]. And in order to ergonomically design a workstation fit for PFD, following data were gathered: subjects' anthropometric measurements, subjects' visual acuity, subjects' postural scores and analysis, and environmental condition measurements (light, noise, temperature).

3. RESULTS & DISCUSSION

3.1. Functional Difficulty Classification

The authors were able to identify and classify the functional difficulty of the 270 respondents of the study into the following: (a) difficulty in seeing, even if wearing eyeglasses, (b) difficulty in hearing, even if using a hearing aid, (c) difficulty in walking or climbing steps, (d) difficulty in remembering or concentrating, (e) difficulty in self-caring (bathing or dressing) and (f) difficulty in communicating. The summary of the frequency and percentage of PWDs under each classification is shown in the table below.

Table 1. Summary of Functional Difficulty Classification

Functional Difficulty	Frequency	Percentage	Cumulative %
Seeing, even if wearing eyeglasses	163	60.45%	60.45%
Walking or climbing steps	35	12.97%	73.42%
Hearing, even if using a hearing aid	27	10.09%	83.51%
Remembering or concentrating	16	6.07%	89.57%
Self-caring (bathing or dressing)	14	5.26%	94.84%
Communicating using his/her usual language	14	5.16%	100.00%
TOTAL	270	100%	

The summary of data shows that majority of the PWDs currently employed within the NCR region has seeing difficulty with 60.45%, followed walking or climbing steps difficulty (12.97%), hearing difficulty (10.09%), remembering difficulty (6.07%), self-caring difficulty (5.26%) and communicating difficulty (5.16%).

3.2. Result of Work Classification

After which, the authors conducted an aptitude assessment test using Skill Master software in order to identify the possible jobs or occupation that can be performed by persons based on their type of functional disability. The summary of the results is shown in the table below.

Table 2. Summary of Possible Occupation per PFD

Type of Functional Difficulty	Occupation
Seeing, even if wearing eyeglasses	Counter and Rental Clerks
	Telemarketers
	Counter Attendants, Cafeteria, Food Concession and Coffee Shop
	Host and Hostess, Restaurant, Lounge and Coffee shop
	Ushers, Lobby Attendants and Ticket Takers
Hearing, even if using a hearing aid	Cashiers
	Retail Salespersons
	Parts Salespersons
Walking or climbing steps	Cashiers
	Retail Salespersons
	Parts Salespersons
	Booth Cashiers
Remembering or concentrating	Food Servers, Non-restaurant
	Combined Food Preparation and Serving Workers, Including Fast food
	Food Preparation Workers
Self-caring (bathing or dressing)	Counter and Rental Clerks
	Counter Attendants, Cafeteria, Food Concession and Coffee Shop
	Host and Hostess, Restaurant, Lounge and Coffee shop
	Ushers, Lobby Attendants and Ticket Takers
	Parking Lot Attendants
Communicating using his/her usual language	Packers and Packagers, Hand
	Helpers – Carpenters
	Sewers, Hand
	Laundry and Dry-Cleaning Workers

The results of aptitude test revealed all the possible jobs or occupation that can be appropriate for each type of PFD. However, the most suitable job or occupation are the following: (a) seeing difficulty- counter and rental clerk, (b) for hearing difficulty- cashier, (c) walking difficulty- cashier, (d) remembering difficulty- food servers, non-restaurant, (e) self-caring difficulty- counter and rental clerks, (f) communication difficulty- packers and packagers.

Afterwards, principles of job analysis and design were applied to match the identified skill sets of the PFD to the type of work or job best suited for them. Specific job description and specification were developed for each type of work based on the classification of difficulty of the person. Specific tasks for each job that are able and not be able to perform by the subjects based on their classification of difficulty were also identified. Results are shown in the tables below.

Table 3. Summary of ABLE/UNABLE Tasks

FOR SEEING, EVEN WITH EYEGLASSES	
Counter and Rental Clerk	
Specific Duties	Remarks
1. Entertains customers coming inside the store and assist on choosing the best items for the customers.	ABLE
2. Provide accurate, valid and complete information that the customer needs.	UNABLE
3. Accomplish the necessary documents such as customers' information and customers concern.	UNABLE
4. Handle customer complaints and provide suitable solutions and alternatives within the time limits.	ABLE
5. Attend to telephone inquiries and provide information about the products.	ABLE
6. Prepare the orders receives thru phones and ensure availability before pick up schedule.	ABLE
7. Maintain records of transactions.	UNABLE
8. Maintain updated customers' information in the record.	UNABLE
FOR HEARING, EVEN IF USING HEARING AID	
Cashier	
Specific Duties	Remarks
1. Perform cashiering activities using cash registers.	ABLE
2. Ensure accurate price scanning on goods and quantity of items being bought.	ABLE
3. Receive payments in cash or credit and transact it as appropriate.	ABLE
4. Issue official receipts for the purchased goods.	ABLE
5. Perform the guidelines for refunds or change of items.	ABLE
6. Process discounts, coupons and stamps for claiming customers.	ABLE
7. Maintain clean and tidy checkout areas	ABLE
8. Strictly handle merchandise returns and exchanges as per company policies	ABLE
9. Calculate money in cash drawers at the beginning and the ending shifts	ABLE
10. Generate transaction/sales reports and ensure accuracy of data.	ABLE
11. Assist with the inventory of supplies.	ABLE
FOR WALKING OR CLIMBING STEPS	
Cashier	
Specific Duties	Remarks
1. Perform cashiering activities using cash registers.	ABLE
2. Ensure accurate price scanning on goods and quantity of items being bought.	ABLE
3. Receive payments in cash or credit and transact it as appropriate.	ABLE
4. Issue official receipts for the purchased goods.	ABLE
5. Perform the guidelines for refunds or change of items.	ABLE
6. Process discounts, coupons and stamps for claiming customers.	ABLE
7. Maintain clean and tidy checkout areas	ABLE
8. Strictly handle merchandise returns and exchanges as per company policies	ABLE
9. Calculate money in cash drawers at the beginning and the ending shifts	ABLE
10. Generate transaction/sales reports and ensure accuracy of data.	ABLE
11. Assist with the inventory of supplies.	UNABLE

FOR COMMUNICATING USING OWN LANGUAGE	
Packers/Packager	
Specific Duties	Remarks
1. Pick and pack the items as per packing list	ABLE
2. Prepare the necessary information such as weight and measurement, description of prepared items needed for the shipping documentation	ABLE
3. Ensure strict compliance on the company packing guidelines	ABLE
4. Identify and evaluate defective items and seek approval for final disposition of the item	ABLE
5. Efficiently utilize packaging materials, including hand tools, glues, nails and padding	ABLE
6. Assist the supervisor in maintaining a complete and accurate records of warehouse transactions	ABLE
7. Keep the warehouse and work area clean and orderly	ABLE
8. Check the condition of packing equipment quarterly.	ABLE
FOR SELF-CARING	
Counter and Rental Clerk	
Specific Duties	Remarks
1. Entertains customers coming inside the store and assist on choosing the best items for the customers.	UNABLE
2. Provide accurate, valid and complete information that the customer needs.	UNABLE
3. Accomplish the necessary documents such as customers' information and customers concern.	ABLE
4. Handle customer complaints and provide suitable solutions and alternatives within the time limits.	UNABLE
5. Attend to telephone inquiries and provide information about the products.	ABLE
6. Prepare the orders receives thru phones and ensure availability before pick up schedule.	ABLE
7. Maintain records of transactions.	ABLE
8. Maintain updated customers' information in the record.	ABLE
FOR REMEMBERING OR CONCENTRATING	
Food Server, Non Restaurant	
Specific Duties	Remarks
1. Take orders from the customer.	ABLE
2. Prepare the ordered food.	ABLE
3. Receive payment from customer.	ABLE
4. Ensure timely serving of food and beverages.	ABLE
5. Perform closing duties such as cleaning the area, orderliness of the tables and chairs, and regular changing of table cloth and decors etc.	ABLE
6. Provide management with customer's feedback.	UNABLE
7. Replenish stocks	ABLE
8. Monthly conduct inventory of all kitchen wares and utensils	UNABLE
9. Check conditions of the working area	UNABLE

The results revealed that the majority of the work activities and tasks are able to perform by the persons based on their functional difficulty. Hence, it was validated and proven that the job classification really matches the PFD.

3.3. Results of Work Station Design

Using the information from previous analysis, the researchers were able to design a workstation that will ergonomically fit the requirements of the PFD using the principles of ergonomics. Data on the anthropometric measurements, postural scores and visual acuity were obtained in the study in order to design an ergonomic workstation for each type of PFD.

Table 4. Summary of Anthropometric Measurement

Anthropometric Data (cm)	**Seeing, even using with eyeglasses** *(n=270)*					
	Female			**Male**		
	Percentile					
	5th	**50th**	**95th**	**5th**	**50th**	**95th**
STANDING						
Knee Height	41.5	42.7	43.9	43.8	47.9	51.9
Knuckle Height	62.4	66.8	71.2	68.5	75.3	82.1
Elbow Height	88	92.5	96.9	95.1	102.9	110.7
Shoulder Height	131.2	132.7	134.3	146.8	157.1	167.5
Stature	156.4	158.6	160.7	155.1	161.7	168.3
Functional Overhead Reach	186.1	195.2	204.3	176.1	181.9	187.8
SITTING						
Functional Forward Reach	69	73.7	78.3	76.8	79.5	82.1
Buttock Knee Depth	47.8	49.8	51.7	46.7	55.5	64.2
Buttock Popliteal Depth	43.2	47.7	52.2	42.1	45.3	48.6
Popliteal Height	37.3	40.9	44.4	45.2	47	48.8
Thigh Clearance	10	14	18.1	11.3	14.2	17.1
Sitting Elbow Height	17.7	19.6	21.5	18.7	23.1	27.6
Sitting Eye Height	61.7	65.9	70.2	64.5	70.9	77.3
Sitting Height	72.6	82.3	92.1	74.8	82.5	90.3
Hip Breadth	35.2	39	42.8	37.6	38.6	39.7
Elbow-to-Elbow Breadth	34.3	36.9	39.4	31	40.2	49.3
OTHER DIMENSIONS						
Head Circumference	51.3	53.1	54.9	55.5	56.1	56.7
Chest Circumference	77.2	88.5	99.8	71.2	91.9	112.7
Waist Circumference	59.6	78.5	97.4	61.5	79	96.4
Length of Upper Arm	18.5	23.3	28	16.9	24.9	32.9
Length of Lower Arm	18.7	24.9	31	22.1	27	31.9
Step Height	13.2	25.9	38.6	7.3	21.7	36.1

The objective of anthropometric data is to improve the design of an existing workstation so that they will match the requirements and needs of the user by considering the body measurements of the users. Data are shown in the table 4.

In addition, postural analysis was also done in order to measure the risk of users in the current use of workstation using the Rapid Entire Body Assessment (REBA) tool. This tool uses a systematic process to evaluate whole body postural musculoskeletal disorders (MSD) and risks associated with job tasks. It measures the persons' body posture, forceful exertion, type of movement or action, repetition, and coupling based on the tasks performed. The data obtained serve as the basis for the workstation design for PFD. The results are shown in the table below.

Table 5. Summary of Postural Scores

REBA Employee Assessment	**SCORES**	
	Hearing, even if using hearing aid	*Seeing, even with eyeglasses*
A. Neck, Trunk and Leg Analysis	*Cashier*	*Counter and Rental Clerk*
Neck Score	2	2
Trunk Score	3	2
Leg Score	1	1
Posture Score A	4	3
Force/ Load Score	0	0
Score A	**4**	**3**
B. Arm and Wrist Analysis		
Upper Arm Score	2	2
Lower Arm Score	1	1
Wrist Score	1	1
Posture Score B	1	1
Coupling Score	0	0
Score B	**1**	**1**
Activity Score	1	2
Table C Score	**3**	**2**
Activity Score	1	2
REBA Score	**4**	**4**
Scoring	**4**	**4**
Remarks	*Medium Risk. Further Investigate. Change Soon*	*Medium Risk. Further Investigate. Change Soon*

The results revealed that the current workstation design pose moderate risk for developing MSD to the persons with functional difficulty, hence, workstation redesign is needed.

And lastly, visual acuity is also measured especially for persons with seeing difficulty. This is needed in order to determine the appropriate distance of the computer screen to the person and minimum size of the text fonts to be used in order for them to easily perform their tasks. The data are obtained using the formula:

$$Visual\ acuity = \frac{1}{\alpha v}$$

$$\alpha v = 3438 \frac{font\ size\ (height)}{Eye\ distance\ to\ screen}$$

$$font\ size\ (height) = \frac{Eye\ distance\ to\ screen}{Visual\ acuity * 3438}$$

Highest vision grade obtained = 700

Eye distance to screen = 69.0 cm = 2.26378 ft.

Solution:

$$font\ size\ (height) = \frac{2.26378\ ft.}{(\frac{20}{700}) * 3438}$$

$$= 0.02305\ ft.$$

font size (height) = 0.702564 cm

$$font\ size\ (point\ unit) = 0.702564\ cm * \frac{1\ inch}{2.54\ cm} * \frac{72\ pt}{1\ inch}$$

font size (point unit) = 19.9152 pt. ***≈20 pt***

3.3.1. Workstation Design for Person with Seeing Difficulty (Counter and Rental Clerks)

The figure below shows the actual design of the workstation with detailed dimensions based on the anthropometric measurements of persons with seeing difficulty. The designed workstation was for a job position of counter and rental clerk which was the top 1 career that have been identified to be prioritized. The designed workstation would fit for counter and attendant type of careers due to similarity of working posture and usage of table and chair. The researcher recommended to have a font size of 20 based on the computation using the value of vision grade and distance from the screen.

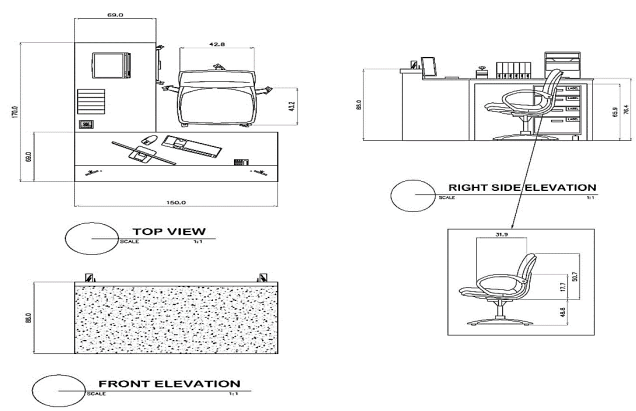

Figure 1. Workstation Design for Counter and Rental Clerks

3.3.2. Workstation Design for Person with Hearing Difficulty (Cashiers)

The figure below shows the actual design of the workstation with detailed dimensions based on the anthropometric measurements of persons with hearing difficulty. The designed workstation was for a job position of cashier which was the top 1 career that have been identified to be prioritized. The designed workstation would fit for cashier and salesperson type of careers due to similarity of duties, standing posture, usage of table and point of sale terminals. The researchers also designed common sign languages and alphabets to be able to help customer interact and communicate with the persons with hearing difficulty.

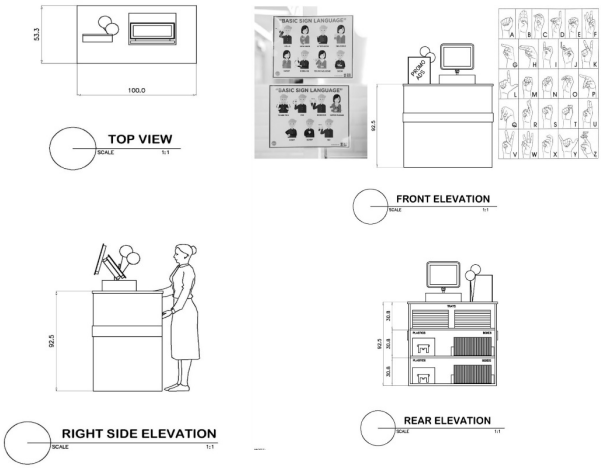

Figure 2. Workstation Design for Cashiers

3.3.3. Workstation Design for Person with Remembering or Concentrating Difficulty (Food-Servers)

The figure below shows the actual design of the workstation with detailed dimensions based on the anthropometric measurements of persons with difficulty in remembering and concentrating. The designed workstation was for a job position of food servers, non-restaurant which was the top 1 career that have been identified to be prioritized. The designed workstation would fit for food servers and food preparation type of careers due to similarity of duties, standing posture and usage of table. Food servers, non-restaurants are servers found usually in hotels, lobby, hospital and residential care facilities wherein the demand of food was low. The activities involve was delivery and serving food within the facility.

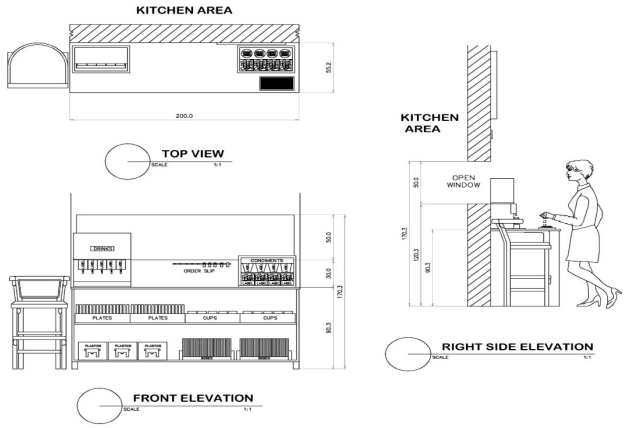

Figure 3. Workstation Design for Food Severs

3.3.4. Workstation Design for Person with Communicating Difficulty (Packaging Counter)

The figure below shows the actual design of the workstation with detailed dimensions based on the anthropometric measurements of persons with communicating difficulty. The designed workstation was for a job position of packer and packager which was the top 1 career that have been identified to be prioritized. This job position was composed of standing activities such as wrapping and packing boxes. Typically, the table was designed in large-size to be able to handle large boxes and multiple packers and packagers can perform. The designed workstation would fit for carpenter helpers and sewers type of careers due to similarity of duties such as building and creating, standing posture and usage of large-size table.

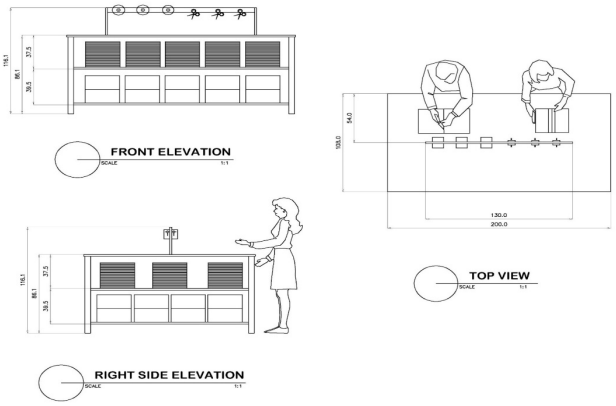

Figure 4. Workstation Design for Packaging Counter

3.3.5. Workstation Design for Walking and Climbing Difficulty (Cashier)

The figure below shows the actual design of the workstation with detailed dimensions based on the anthropometric measurements of persons with walking and climbing stairs difficulty. Also, the wheelchair dimensions were also considered by the researchers. The designed workstation was for a job position of cashier in a sitting position which was the top 1 career that have been identified to be prioritized. The designed workstation would fit for cashiers and salespersons type of careers due to similarity of duties, sitting posture and usage of table with point of sale terminal.

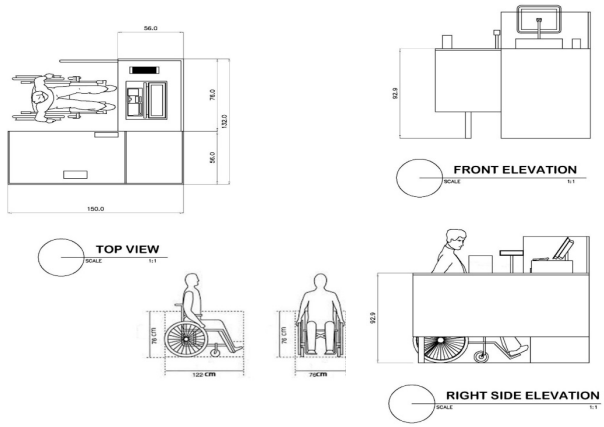

Figure 5. Workstation Design for cashier

3.3.6. Workstation Design for Self-Caring Difficulty (Counter and Rental Clerk)

The figure below shows the actual design of the workstation with detailed dimensions based on the anthropometric measurements of persons with self-caring difficulty. The designed workstation was for a job position of counter and rental clerk in a sitting position which was the top 1 career that have been identified to be prioritized. The table was designed with rounded edges to be able to manage some amputated body parts and deformed body shapes in reaching and working around the workstation. The designed workstation would fit for counter and attendant type of careers due to similarity of duties, working posture and usage of table and chair.

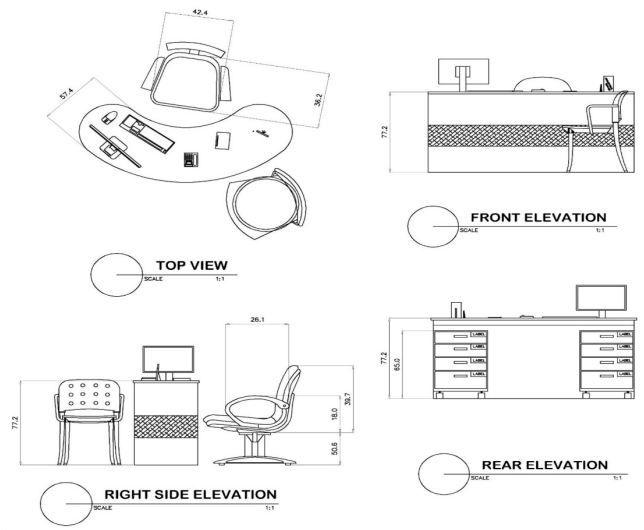

Figure 6. Workstation Design for Counter and Rental Clerk

4. CONCLUSION

The purpose of this research is to conduct a study on the work classification and workstation design for persons with functional difficulty (PFD) in order to give them a greater chance of employment. The researchers examined the employment profile of 270 PWDs within NCR region in the Philippines. Initial data were gathered through interview, observation and survey to determine the current issues, problems and difficulties that the PWDs are experiencing in their current employment. The study revealed that PWDs are facing problems in terms of facility and workstation design since most of the workplace environment of the PWDs are not designed to accommodate and match their needs and requirements. For these reasons, it became the interest of the authors to identify the suitable job or occupation of the PFD and design a workstation appropriate to their needs. The researchers initially identified and classified the functional difficulty of each respondents of the study using the ICF checklist developed by WHO. The identified types of functional difficulty are as follows: (a) difficulty in seeing, even if wearing eyeglasses, (b) difficulty in hearing, even if using a hearing aid, (c) difficulty in walking or climbing steps, (d) difficulty in remembering or concentrating, (e) difficulty in self-caring (bathing or dressing) and (f) difficulty in communicating. Afterwards, specific tasks and work activities that can be performed by each type of PFD were determined, as well as their skills sets through aptitude test using Skill Master software. Then, principles of job analysis and design were applied to match the identified skill sets of the PFD to the type of work or job best suited for them. Specific job description and specification were developed for each type of work based on the classification of difficulty of the person. These includes the following, (a) job description: job summary, job responsibilities, relation of job to other tasks, tools/equipment required in the task, work conditions, location of work, job hazards; (b) job specification: education level, experience, training needs, physical effort, physical skills and communication skills. All possible jobs and occupation for each type of functional difficulty were identified in the study. However, the jobs that were proven to be most suitable are as follows: (a) seeing difficulty- *counter and rental clerk*, (b) for hearing difficulty- *cashier*, (c) walking difficulty- *cashier*, (d) remembering difficulty- *food servers*, *non-restaurant*, (e) self-caring difficulty- *counter and rental clerks*, (f) communication difficulty- *packers and packagers*. Finally, the researchers were able to design a workstation that will ergonomically fit and match the requirements of the PFD using the principles of ergonomics. Data on the anthropometric measurements, postural scores and visual acuity were obtained in the study in order to design an ergonomic workstation for each type of job or occupation of PFD.

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Workplace Design Improvement for Cable Tray Production in an Electrical Equipment Company: A Lean Perspective

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ABSTRACT
Workplace ergonomics deals with designing or arranging work areas, products and systems so that they fit the people who use them and eliminate wastes associated with poor layout and physical environment. Elimination of ergonomic wastes in production lends itself to lean manufacturing applications. The study is not an attempt to assess a production process using the lens of lean manufacturing but aims at identifying relationships between lean elements and physical environmental factors in the context of workplace design that affects worker performance. Specifically, the setting of the study is in an electrical equipment company in which the lean elements of waste volume, workspace dimension, operating time and plant layout are analyzed together with the ergonomic aspect of work environment that include the factors of light intensity, temperature level and noise. The core idea is to find significant relationships between the two sets of factors with the end in view of improving workforce performance in terms of labor productivity, throughput, number of accidents and workers' attendance. The study is capped with the development of a model for analyzing and improving workplace design, facility layout and worker performance.

CCS Concepts
•General and reference→ Document types→ General conference proceedings

Keywords
Workplace design; physical environmental factors; lean elements; facility layout; worker performance

1. INTRODUCTION
Workplace design refers to the process of designing and organizing a workplace to enhance employee performance and work quality. Workplace conditions that address the important issues of health and safety of production and office workers include sound, light, temperature, airflow, and air quality [1]. These affect workers' ability to interpret nonverbal and verbal cues for meaningful face-to-face interaction in material and transaction processing areas [2]. Similarly, the physical workplace design does not only enhance employee competence in equipment operation and material handling but as well as contributing positively to employee motivation, engagement, satisfaction and performance [3].

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The widely accepted lean concept provides an optimum framework for efficient production by optimizing inventory, eliminating downtime, reducing space and distance requirements, minimizing errors, simplifying excessive processes, averting overproduction, and maximizing flow [4]. According to Arezes, et al., "Lean principles focus too on creating appropriate workplaces to improve team spirit, challenges, motivation, flexibility, cross skills, responsibility, autonomy, and so on." [5][6]. A process of designing the workplace lacking in lean elements can create a situation where activities are of a reactive nature that can lead to poor productivity and employee performance [7].

Productive employees are the lifeblood of every company. Punctuality, quality of work, personal work habits and attitudes are major factors of consideration in measuring employee performance [8]. Inevitably, with the growing work demand and task diversity, most employees are made to stay in unchanged and unsupportive workplaces filled with distractions – visual and acoustical [9], and consequent interruptions at work affecting work flow, process efficiencies and worker well-being [7].

The mechanical and electrical industry is one industry with a fast changing technology and an increasing volume demand that render capital-intensive infrastructure, including work sites and production facility, unchanged with little or no modifications that present work hazards and threat to occupational health [10]. Such events led to the increasing awareness of the importance of improving workplace design which behooves this study to look into the incorporation of lean elements when considering environmental factors in coming up with a better workplace subscribing to principles of ergonomics, safety and health. The interest of the study adheres to highly recommended directions to tread new paths and approaches of workplace design (WPD) that promotes employee engagement and well-being and improves work performance for all generations of operators [11].

Generalizations from extant literature commonly focused on health issues, particularly musculoskeletal disorders affecting worker productivity but a dearth of research studies exists on ergonomics that incorporated lean elements, not lean manufacturing per se, on workplace design improvement for increased employee performance, instead of process efficiency only, as the end in view.

The study seeks to find the significance of lean elements to the physical environmental conditions at the workplace that impact

worker performance. Additionally, the study aims to determine the relationships between the lean elements and physical environmental factors employed in workplace design, with the latter impacting worker performance based on grounded theory from previous researches. As such, the study takes on these lean elements as enhancing worker performance measured in the aspects of output for productivity, safety for ergonomics, and attendance for employee behavior.

2. METHODOLOGY

With the aforementioned interest of the study, the overall objective of the undertaking will answer the question if the relationship between lean elements and the physical environmental factors of ergonomic workplace enhances worker performance, that is, to know if the lean elements have a moderating relationship on the effect of environmental factors to worker performance. The following conceptual framework shown in Figure 1 represents the logic adopted by the study.

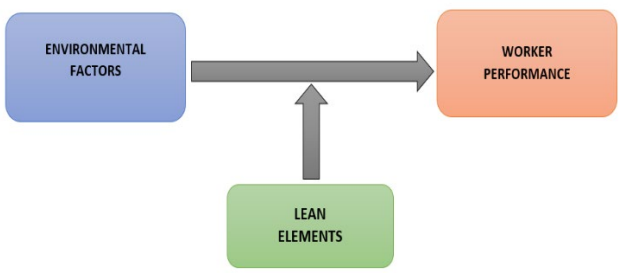

Figure 1. Conceptual Framework

The constructs of environmental factors, lean elements and worker performance are taken in the context of workplace design considerations and improvement. Environmental Factors pertain to the physical conditions in an ergonomics approach; Lean Elements are related to the principles of waste elimination, smooth flow and cycle time; and Worker Performance is the dimension of interest directly impacted by physical environmental factors of workplace design, the relationship of which is the focal point of investigation with respect to the moderating relationship as posited by the following hypotheses:

H_{1o} : There is no significant relationship between Environmental Factors and Lean Elements

H_{1a} : There is a significant relationship between Environmental Factors and Lean Elements

H_{2o} : There is no significant relationship between Environmental Factors anratured Workers Performance

H_{2a} : There is a significant relationship between Environmental Factors and Worker Performance

H_{3o} : There is no significant relationship between Lean Elements and Worker Performance

H_{3a} There is a significant relationship between Lean Elements and Worker Performance

To test the above hypotheses, the following operational framework in Figure 2 below shows variables for said three constructs:

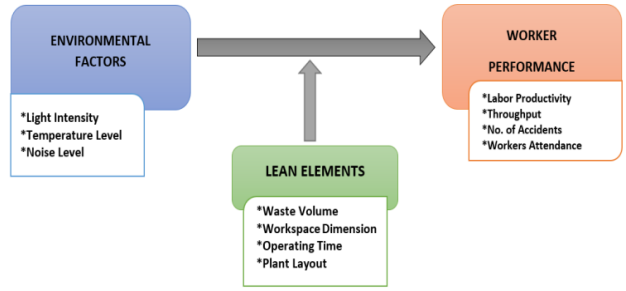

Figure 2. Operational Framework

The study employed these variables as defined by the chosen unit of analysis – a Philippine-based top 10 producer of cable trays for electrical wiring installations and cable distribution. Said company has not implemented lean manufacturing on a formal structure platform but only uses a combination of manual and mechanized processes in meeting high volume market demand. Though the company's lack of other similarly important metrics and measurements set the limitation on the number of measurable factors, a good number of related literature cited the definition of these variables with consistency as regards the premise of the study. Light intensity, temperature and noise level as major environmental factors considered in workplace design in the context of ergonomics; waste volume, workspace dimensions, operating time and plant layout used as representative factors of lean; and worker performance indicators of output for productivity, safety for ergonomics, and attendance for employee behavior.

Figure 3 below is a schematic flow for the conduct of the study, starting with the gathering of information and actual observations of processes and physical conditions at the cable tray production. Then ensued the statistical analysis of data on the variables of interest from company records and actual measurements as well as the survey results from interviews with key personnel and operators to test the posited hypotheses. Finally, the interpretation of the results served as basis for the workplace design anchored on the statistically significant relationships between lean elements and environmental factors.

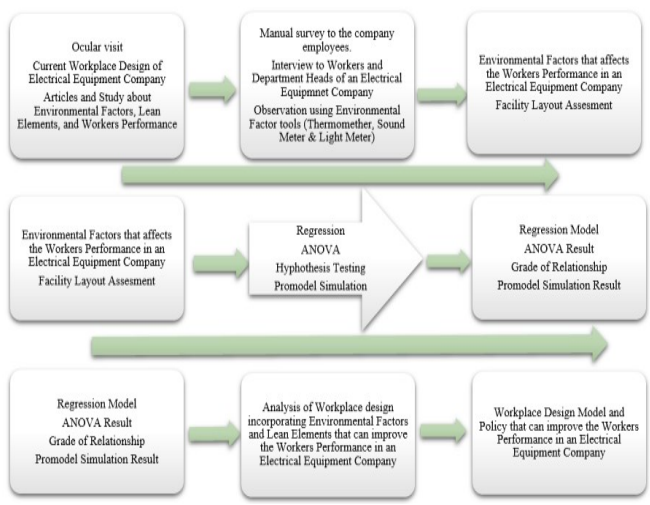

Figure 3. Research Methodology

Actual measurements of light intensity, temperature and noise level at several intervals of work shifts for the study period were used for variables under environmental factors and correspondingly labor productivity, throughput volume, number of accidents and attendance were obtained for regression analysis purposes to determine if a relationship exists. The plant layout, process flow and time study results yielded the current output level, operating cycle times and distance travelled for use of the workspace dimension for the lean elements. The waste management practices and processing activities were included in the analysis to complement in the measurement of lean elements and worker performance.

The study used observations and interviews in grounding the constructs and variables covered by the framework and incorporated them in framing the questions of the survey instrument. Two groups of survey respondents – 21 operators and helpers and 10 supervisory staff, who comprised the entire cable tray production, answered the survey questionnaire on their perspective and assessment of how different environmental factors and current layout features affect worker performance in terms of the chosen aforementioned indicators. The use of regression analysis and one-way ANOVA determined there is a significant difference between the responses of two groups of respondents on the same items of interest. The regression analysis pointed to the significant relationships between lean items and environmental factors and the performance indicators. Coming up with a workplace design made use of the regression results in incorporating lean elements that moderate the effect of environmental factors on worker performance.

Additionally the layout improvement exercise considered the results of studying the current layout, distances travelled and operating times in the cable tray production in generating different layout schemes for evaluation using the ProModel simulation tool package to determine which layout scheme results in better flow that will improve worker performance and reduce waste in terms of the lean factors.

3. RESULTS

The two groups of respondents answered three sets of questions, one each for environmental factors, lean elements and worker performance. Tables 1, 2 and 3 showed the One-Way Analysis of Variance (ANOVA) results and corresponding significant pairwise differences.

Table1. Environmental Factors Survey Summary

A. ENVIRONMENTAL FACTORS	F Comp	P Value	Conclusion
All Lights are functional	2.2	0.149	Not Significantly Different
Sufficient and efficient lighting are provided in my area	0.16	0.695	Not Significantly Different
All exhaust fan and electric fan are in good condition	0.56	0.461	Not Significantly Different
Well ventilated workplace helps me concentrate on my assigned tasks	0.12	0.734	Not Significantly Different
I never experience any noise problem in my work area	6.83	0.014	Significantly Different
Too much noise affect my work performance	3.8	0.061	Not Significantly Different
Windows, doors, screens and other openings are kept open when in use.	7.46	0.011	Significantly Different
I feel comfortable on the setup of my work area	1.84	0.185	Not Significantly Different
Production Area has open aisle spaces enough for workers and lifters to maneuver	4.66	0.039	Significantly Different
I am contented with the company facilities	6.7	0.015	Significantly Different
I am satisfied with the production layout	4.17	0.05	Significantly Different
All Equipment and furniture are in proper places	6.45	0.017	Significantly Different

Above results showed that half of the answers the twelve (12) environmental factors in the survey have significant difference particularly when it comes to the noise problem, windows, doors, screens, spaces, and layout. The obvious difference lies in their respective workstations, with management enjoying the confines of an enclosed field office compared to the worker's workstation with a high noise level and relatively crowded area. Such differences offer insights on the areas of improvement in the cable tray workplace.

As regards lean elements, there were significant differences in the responses on eight (8) out of twenty-two items, particularly, in the areas of tools, resources, maintenance, process, inspection and waste segregation, as shown in Table 2 below:

Table 2. Lean Elements Survey Summary

B. LEAN ELEMENTS	F Comp	P Value	Conclusion
All of the tools and materials I need to do my job are available	0.01	0.944	Not Significantly Different
The tools and resources I need to do my job is located within my workstation	13	0.001	Significantly Different
All of my tools are properly organized and well maintained	2.31	0.139	Not Significantly Different
My workflow was never interrupted by lack of parts/tools	1.91	0.177	Not Significantly Different
My workflow was never interrupted by lack of personnel	0.76	0.389	Not Significantly Different
All machines are well maintained and with machine maintenance checklist	0.44	0.512	Not Significantly Different
All equipment and machine are properly working and condition check daily	0.44	0.512	Not Significantly Different
I never experience a machine failure	0.48	0.494	Not Significantly Different
Whenever a defect product is produced the machine stops automatically	2.2	0.149	Not Significantly Different
Maintain calibration and preventive maintenance procedures and schedules for equipment/instruments used in production.	3.38	0.076	Significantly Different
My job makes good use of my skills and abilities	3	0.094	Significantly Different
There was no over processing in my job assignment	84	0.367	Not Significantly Different
I am willing to rendered an overtime	0.19	0.662	Not Significantly Different
Standard production process are observed.	6.68	0.015	Significantly Different
Every details of production transaction are properly recorded.	0.47	0.499	Not Significantly Different
All finished Cable Wires product are properly identified and inspected prior to storage.	17.76	0	Significantly Different
Periodic inventory cycle count is implemented, reconciled, and documented.	0.55	0.465	Not Significantly Different
Production inventory record, with physical condition and location, are regularly updated.	0	0.952	Not Significantly Different
We have a great turnover rate for inventory	55.3	0	Significantly Different
We always practice 5S(clean and safe working environment)	2.54	0.122	Not Significantly Different
This organization provides proper waste segregation	16.25	0	Significantly Different
All garbage/trash are properly disposed	6.2	0.019	Significantly Different

The apparent lack of standardization in processing and in waste management practices explained these differences. Reviewing the processes for standardization and assessing the waste management policy and practices will address such differences and help identify opportunities of improvement for the cable tray production to include this finding.

Lastly, on worker performance-related items, there were six significant differences out of seventeen items in the areas of process lead time and safety training, based on the following tabulated summary.

Table 3. Workers Performance Survey Summary

C. WORKER PERFORMANCE	F Comp	P Value	Conclusion
All production personnel have job descriptions/tasks list and properly informed of their assignments.	0.98	0.329	Not Significantly Different
My current workload is properly balanced	1.51	0.229	Not Significantly Different
The amount of work I am expected to do is reasonable	0.96	0.336	Not Significantly Different
Every Job Orders I received are finished within established lead time	4.27	0.048	Significantly Different
I can stay healthy in the present level of my work intensity	0.1	0.759	Not Significantly Different
This company provides good training and development to enhance workers performance.	2.74	0.109	Not Significantly Different
This company develop a Safety Training program for every employee	9.58	0.004	Significantly Different
This company provides immediate health care assistance in case of accident/ injury occur	0.22	0.645	Not Significantly Different
First Aid Kit are Available and accessible	3.74	0.063	Not Significantly Different
I always wear my Personal Protective Equipment (PPE)	7.53	0.01	Significantly Different
I feel comfortable wearing my Personal Protective Equipment (PPE)	33.37	0	Significantly Different
I never experienced any health and safety problems in my job	6.97	0.013	Significantly Different
I never suffered from work-related injury or illness at my work (employer)	1.66	0.208	Not Significantly Different
I was never requested a leave of absence because of work-related injury or illness	0	0.968	Not Significantly Different
All Firefighting equipment are in proper place	17.4	0	Significantly Different
I have enough knowledge to use the fire extinguisher	4.14	0.051	Not Significantly Different
Fire Emergency Exit Doors are not Obstructed	0.2	0.66	Not Significantly Different

Behind these differences was the lack of standardization, safety training and safety implementation, like wearing of PPE. The safety dimension will be of important consideration in improving the workplace design to impact on worker performance.

Investigating the relationship of the effect variable of worker performance in terms of overall productivity and the environmental factors and lean elements, necessitated the Pearson correlation technique with the results shown in Table 4 below:

Table 4. Correlation Summary

	Productivity	Temperature	Sound	Light	Metal Scrap	Waste Water	Operating Time	Accident
Temperature	-0.65							
	0.00							
Sound	-0.62	0.902						
	0.00	0						
Light	-0.32	0.861	0.839					
	0.00	0	0					
Metal Scrap	0.93	-0.73	-0.676	-0.458				
	0.00	0	0	0.011				
Waste Water	0.94	-0.533	-0.533	-0.22	0.878			
	0.00	0.002	0.002	0.242	0			
Operating Time	0.90	-0.035	0.047	-0.012	0.046	0.027		
	0.04	0.856	0.806	0.948	0.809	0.888		
Accident	0.02	-0.05	-0.012	0.004	-0.008	0.003	0.148	
	0.94	0.795	0.949	0.982	0.996	0.987	0.436	
Absent	0.03	0.038	0.008	-0.001	0.098	0.01	-0.125	-0.163
	0.89	0.844	0.965	0.994	0.607	0.957	0.512	0.163

The correlation coefficient takes on values between -1.00 and +1.00 indicating the direction the relationship, with strength indicated by the magnitude away from zero. The p-values found in the lower half of each cell will indicate the significance with $\alpha = 0.05$.

For environmental factors, those that have a coefficients above 0.50 are Temperature and Productivity (-0.65), Sound and Productivity (-0.62) but are negatively correlated such that Productivity tends to decrease with high temperatures and noise levels. The p-values of both are zero, confirming the significant relationship between them. The Pearson r coefficient of -0.32 for Light and Productivity is relatively low for a not perfectly negative correlation, meaning as long as there was lighting, the workers continue the operation. Its p-value of 0.08 greater than 0.05 concludes that there is no significant relationship.

On the other hand, for lean elements, the Pearson correlation coefficient for the relationship between Metal Scrap (Solid Waste) and Productivity (0.93) and Waste Water (Liquid Waste), Productivity (0.94) and Productivity and Operating Time with r = 0.90 are positive and highly correlated, that is, as the wastes and operating time tend to increase, productivity will increase. In addition, Productivity and Accident with r = 0.02; and Productivity and Absent with r = 0.03 are all not correlated and without significance due to high p-values of 0.64 and 0.94 respectively. This means that even there was an absentee or accident, employees and heads continue to go about their work in cable tray production.

After the determination which lean elements and environmental factors are significant and highly correlated to the effect variable of productivity as a measure of worker performance, the study conducted a regression analysis of said factors and elements as the independent variables to determine which among them have an impact on productivity as the dependent variable.

Results from the use of Minitab for the impact assessment of the significant environmental factors of temperature, sound and light are as follows:

Table 5. Environmental Factors Regression Model

Regression Analysis: Productivity versus Temperature, Sound, Light

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	73.017	24.339	19.26	0.000
Temperature	1	17.580	17.580	13.91	0.001
Sound	1	5.609	5.609	4.44	0.045
Light	1	27.838	27.838	22.03	0.000
Error	26	32.850	1.263		
Total	29	105.867			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.12403	68.97%	65.39%	60.04%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	66.99	6.82	9.82	0.000	
Temperature	-1.432	0.384	-3.73	0.001	6.68
Sound	-0.1739	0.0825	-2.11	0.045	5.83
Light	0.0524	0.0112	4.69	0.000	4.22

Regression Equation

Productivity = 66.99 - 1.432 Temperature - 0.1739 Sound + 0.0524 Light

The p values of all three (3) environmental factors are less than $\alpha = 0.05$ and thus light, sound and light have a significant relationship with productivity. This translates to supporting that environmental working conditions are an important aspect of worker's performance. Environmental factors studied such as temperature, humidity, ventilation, illumination and noise can have a significant impact on productivity, quality of output and accidents. The improvement phase of the study will consider these environmental factors as the ergonomic aspect of the workplace design. The regression model indicates the coefficients confirming the correlations earlier established with temperature and sound having significant impact and light with a relatively lower impact to productivity.

The study then assessed the impact of the lean elements of Solid Waste, Liquid Waste and Operating Time found to be significant and highly correlated to productivity in the same manner as the environmental factors with the results shown in Table 6.

Table 6. Lean Elements Regression Model

Regression Analysis: Productivity versus Metal Scrap, Waste Water, Operating Time

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	99.028	33.0094	125.50	0.000
Metal Scrap	1	5.557	5.5566	21.13	0.000
Waste Water	1	6.447	6.4472	24.51	0.000
Operating Time	1	0.291	0.2907	1.11	0.303
Error	26	6.838	0.2630		
Lack-of-Fit	25	6.838	0.2735	*	*
Pure Error	1	0.000	0.0000		
Total	29	105.867			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.512854	93.54%	92.80%	91.60%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-28.8	32.0	-0.90	0.375	
Metal Scrap	0.637	0.139	4.60	0.000	4.37
Waste Water	0.3983	0.0805	4.95	0.000	4.37
Operating Time	0.129	0.122	1.05	0.303	1.00

Regression Equation

Productivity = -28.8 + 0.637 Metal Scrap + 0.3983 Waste Water + 0.129 Operating Time

The above results pointed to the significant impact of the two (2) lean waste elements with all p-values less than $\alpha = 0.05$ excluding operating time, but nonetheless the regression model yielded all

positive coefficients indicting their positive impact on the effect variable in terms of productivity, quality of output and accidents. These lean elements would then be the target of improvement areas in the next discussion.

4. DISCUSSION

Based on the correlation and regression results, the study shifted its focus on the identification of improvement areas related to the significant environmental factors and lean elements, which when improved will have an impact on performance. Generally, wastes are the target of both Ergonomics and Lean applications; hence, this undertaking tackled the major cable tray production areas presenting worker well-being and performance issues.

Firstly, the attained output of cable tray production stood at an average level of 59 units against the target production requirement of 85 units (cable tray) per day. Secondly, the observed existing process flow of cable tray production yielded an operating cycle time 261 minutes per unit and a corresponding travel distance of 70 meters with the present production layout. These served as a reference baseline for any improvement. Next, the study did an assessment of the production areas affected by the environmental factors of light, temperature and sound.

Beginning with environmental factor of light, the study used as basis the ILO Tabulation of Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors. Findings showed the production area did not meet the standard of at least 500 lumens. In this regard, the area using the existing T-8 type of lamp with 36-watt power rating used in the production, needed an additional 55 pcs of 36W daylight fluorescent tube or its equivalent to meet the ILO standard summarized in Table 7.

Next, the standard temperature in the production area, should be no more than 28 degrees Celsius, based on the Ergonomic Ventilation System. The computation shown in Table 8 calculated the appropriate number of exhaust and electric fan to meet said standard resulting in an additional requirement of one (1) rectangular Gable Louver ventilation unit, which is already the ventilator type in use in production.

Table 7. Production Area Lumen Calculation

PRODUCTION AREA	
Length (FT)	62.59
Width (Feet)	74.7
SQFT	4675.47
Height	22.96
Desired Footcandles:	200
Lamp Qty. & Type	4F36T8
Lamp Type	TLD36W/84ONG
Watts	36
Fixtures	1
Lamp	4
Length	48
Colour Temperature	4000
Color	Cool White
Diameter	1
CRI	82
Footcandles	200
Rated Lamp Lumens	3100
Total Rated Lamp	12400
Constant DMLL	0.5
Delivered Maintained Lamp	6200
No. of Fixtures	151
Area Per Fixture	31
Space Requirement per Fixture	6

Table 8. Calculation of Required Number of Ventilation Units

PRODUCTION AREA	
Length (FT)	62.59
Width (Feet)	74.7
TOTAL SQFT	4675.47
Ventilation Machine	Rectangular Gable Louvers
Model	FLV24X30
Description	Aluminum
Colors	Silver
Size	24"x48"
Net Free Area	324
Minimum Net Free Ventilation Area Constant (Feet Square)	300
Total Net Free Area Required	15.58491
Amount of Intake and Exhaust (Low and High)	7.792455
Convert Inches to Square	1122.114
Number of Units of Intake and Exhaust Venting Required	3

For noise, OSHA's permissible exposure limit (PEL) is 90 dBA for all workers for an 8-hour day. The OSHA standard uses a 5 dBA exchange rate. This means that when the noise level increases by 5 dBA, the amount of time a person can be exposed to a certain noise level to receive the same dose is cut in half. In the present case of Cable Tray Production, it is not possible to redesign the process immediately or to replace the old equipment not to mention that the source of noise cannot be isolated from other work areas being the heart of operations. The only remedy acceptable was to provide better protective devices such as earplug or earmuffs of industrial grade for every production worker.

Next considerations are the lean elements of waste and operating time. With the current production design, the metal scrap and wastewater are inherent in the current setup. This, however, is still a big potential for improvement. Following sections detail the current waste management, OSH and plant layout practices and accordingly, recommended remedies for immediate attention. The last discussion included an evaluation of plant layout alternatives considering these practices and remedies.

4.1 Solid Waste Management

The company collects all the metal scrap and send them to a material recovery facility through junk shop operators. The metal scrap weight generated daily reach 30-50 kilos with impact on the miscellaneous non-operating income as a source of cash to support operations. The 5S program implementation can significantly enhance flow, visual management, and error reduction in the identification, handling and disposal of solid wastes. 5S Practices also helps the company to systematically arrange their items in the most efficient access and help to have an efficient workflow, faster and tool setup and improved working conditions. Moreover, it helps them to handle problems of safety hazards and unreasonable environmental problems, which any manufacturing operations should be keen to address. Thus, this program is consistent with workplace design incorporating lean elements with the environmental factors to address by this paper, complemented with the EHS approach.

4.2 Waste Water Management

The Cable Tray Company has a wastewater treatment facility suitable for its current operations and volume level of activity. The study focused on the practices that generate the current volume of wastewater.

The metal finishing pollution prevention technique can be used to enhance electrical properties to form and shape components and to enhance the bonding of adhesives or organic coatings. This is suitable to for chemical bathing of cable trays. The technique includes the following:

(1) Parts cleaning to reduce the amount of contaminants
(2) Substitution with non-hazardous or aqueous cleaners
(3) Reduction of drag out losses by extending the drip time, installing drainage boards between tanks, reducing work piece withdrawal rates, installing air knives or water misters, lowering the concentration of plating bath constituents and increasing the plating solution temperature, promoting drain with racks, using of non-ionic wetting agents and angled barrels.
(4) Maintenance of chemical baths for longer use by monitoring bath chemistry with PH and conductivity controls and by filtering chemical baths for re-use
(5) Use of de-ionized water instead of tap water for process baths and rinsing operations to reduce sludge generated.
(6) Reduction of rinse water to extend bath life and helps reduce the amount of waste generated.
(7) Installation of automatic flow controls, such as flow restrictors or conductivity sensors.

The adoption of these measures adds up to what is known as cleaner production technology that also requires tweaking the layout in order to accommodate the technique, storage and handling of materials and supplies and the movement of workers.

To complement the move to address the significant environmental factors and the reduction of wastes via cleaner production methods and the 5S approach, the OSH dimension is equally important for consideration and incorporation in layout schemes for improvement of workplace design.

4.3 Occupational Safety and Health

Compliance with local building codes and subscription to the NFPA (National Fire Protection Association) recommendations on class types of fire extinguishers, spacing and density, access and travel distance for emergency use improved will help workplace design process make a safer place to work in. In addition, per applicable OSHA standards for fire protection workplace design must incorporate the prescribed fire protection systems and other fire-related requirements such as but not limited to the means of egress, fire-fighting equipment and availability of personnel protective equipment (PPE). The storage of such equipment and the provision of aisles and access doors will influence the type of layout considered in this study.

Worker safety is one of the most basic issues in workplace design. Workers cannot be effectively motivated if they feel they are in physical danger. In view of this, the study will be able to address the company's tolerating of non-wearing of PPE due to unacceptable levels of heat and noise. The earlier assessment of the environmental factors already covered these issues, together with mobility constraints in production.

The study established the significant environmental factors and lean elements affecting worker performance in terms of productivity and gained insights from the consequent assessment of the company's production process and its concomitant activities vis-à-vis the environmental factors grounded on ergonomics and the lean elements as a moderating relationship.

The workplace design process, to be complete, must draw an improved layout with the objective of gaining improvements over the reference baseline performance due to the current layout and production setup. The study lends itself to the generation of layout alternatives to select the best layout scheme that befits the research locale and unit of analysis incorporating the significant environmental factors and lean elements affecting worker performance.

4.4 Plant Layout

Layout improvement schemes anchored on the significant environmental factors and lean elements are generated with the consideration of the issues identified in the assessment and their corresponding remedial measures complemented with OSH compliance, 5S program, cleaner production methods and ergonomic approach to meet the standards of required physical conditions of the workplace.

The criteria is based on improved throughput, minimized distance travelled, process efficiency and key production metrics shown in Table 9. Literature on facility layout improvement provided several types of layout, S-shape, L-shape and U-shape among others, which are applicable for the production of cable trays.

In order to get the relevant metrics and measurements for the improved layout schemes, the company did the remedial measures addressing the physical factor-related issues about light, temperature and noise level. It implemented the 5S program elements and OSH compliance requirements on the main areas where easily applicable without need for capital budget and long lead times for execution. The rest of the corrective and improvement measures outside the line responsibility were inputted in each of different types of layout for evaluation using the ProModel simulation package tool, with the results shown below.

Table 9. ProModel Simulation Summary of Results

PROMODEL SIMULATION SUMMARY				
	EXISTING	S SHAPE	L SHAPE	U SHAPE
Total Exists	58 units	84 units	81 units	93 units
Total Current Qty In System	59 units	66 units	36 units	48 units
Average Time In System	260.43 minutes	198 minutes	153.39 minutes	166.44 minutes
Average Time In Move Logic	24.81 minutes	22.13 minutes	5.43 minutes	7.79 minutes
Average Waiting	15.88 minutes	22.02 minutes	0.27 minutes	0.70 minutes
Average Time In Operation	165.74 minutes	153.84 minutes	147.70 minutes	157.78 minutes
Average Blocked Time	0 minute	0 minute	0 minute	0.16 minute
% In Move Logic	12.02%	11.18%	3.54%	4.68%
% Waiting	7.69%	11.12%	0.17%	0.42%
% In Operation	80.29%	77.70%	96.29%	94.80%
%Blocked	0%	0%	0%	0%
Product/ Process Efficiency	58%	84%	81%	93%
Total Distance Travelled by Workers (in one cycle)	71 meters	80 meters	47 meters	43 meters

Results showed that U-shape Layout is the most efficient among all the layouts at 93% with the most number of cable trays produced. In addition, the average time in system of existing process layout improved from 260.43 minutes to 166.44 minutes. To be comparable across the different layouts including the existing set up, the simulation exercise maintained the same number of workers. Thus, it suggests that the best alternative, the U-shaped

layout, can further improve by reviewing the manning requirement and personnel skills inventory of the cable tray production for optimum benefits to the company.

Consequently, with the identification of the improved layout scheme and incorporation of the environmental factors and lean elements, the study conducted an analysis of the impact of the conceived improvements on worker performance with reference to the following summary in Table 14.

Table 10. Workers Performance Analysis

		WORKERS PERFORMANCE							
		Labor Productivity (Unit Produced)		Throughput /Day		No. of Accidents/ Injury		No. of Absent Worker	
		Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
DAY 1	R1	22.00	25	69%	80%	0.00	0	0.00	0
	R2	18.00	22			0.00	0	0.00	0
	R3	19.00	21			0.00	0	0.00	0
DAY 2	R1	21.00	24	71%	80%	1.00	0	1.00	1
	R2	19.00	22			1.00	0	1.00	1
	R3	20.00	22			1.00	0	1.00	1
DAY 3	R1	22.00	28	68%	82%	0.00	0	0.00	0
	R2	19.00	24			0.00	0	0.00	0
	R3	17.00	22			0.00	0	0.00	0
DAY 4	R1	22.00	25	71%	84%	1.00	0	0.00	0
	R2	19.00	24			1.00	0	0.00	0
	R3	20.00	22			1.00	0	0.00	0
DAY 5	R1	22.00	23	68%	80%	0.00	0	2.00	0
	R2	19.00	23			0.00	0	2.00	0
	R3	17.00	22			0.00	0	2.00	0
DAY 6	R1	23.00	25	72%	82%	0.00	0	0.00	0
	R2	19.00	20			0.00	0	0.00	0
	R3	19.00	24			0.00	0	0.00	0
DAY 7	R1	22.00	27	72%	87%	0.00	0	1.00	0
	R2	20.00	23			0.00	0	1.00	0
	R3	19.00	24			0.00	0	1.00	0
DAY 8	R1	23.00	24	67%	82%	1.00	0	0.00	0
	R2	18.00	23			1.00	0	0.00	0
	R3	16.00	22			1.00	0	0.00	0
DAY 9	R1	22.00	27	67%	88%	0.00	0	0.00	0
	R2	18.00	23			0.00	0	0.00	0
	R3	17.00	25			0.00	0	0.00	0
DAY 10	R1	21.00	23	71%	82%	0.00	0	1.00	0
	R2	20.00	24			0.00	0	1.00	0
	R3	19.00	23			0.00	0	1.00	0

The above results confirmed the throughput improvement that will enable the company to meet the increased volume demand of 85 units per day from the baseline daily figure of only 59 units on the average. This also emphasized that improvement in the environmental factor-related concerns of the cable tray production and the incorporation of lean elements have a positive impact on worker performance.

The study also included a summary of observations after the implementation of quick solutions and remedial measures on the environmental factor-related issues of light, temperature and noise and as well as the waste and operating time-related issues addressed by incorporating the significant Lean Elements in the facility layout improvement simulation. This further confirmed the results of the simulation and the before and after assessment of worker performance, as summarized in Table 11.

Table 11. Summary of the Data from Cable Tray Production (with environmental factors and lean elements improvement)

		ENVIRONMENTAL FACTORS			LEAN ELEMENTS			WORKER PERFORMANCE			
		Light Intensity	Temp. Level	Noise Level	Waste Volume		Operating Time (mins)	Labor Productivity (Unit Produced)	Throughput /Day	No. of Accidents/ Injury	No. of Absent Worker
					SOLID WASTE(Kg)	LIQUID WASTE (L)					
DAY 1	R1	502 lux	26.3C°	95 dBA	14	16.00	265.97	25	80%	0	0
	R2	550ux	31.2C°	109 dBA	12.25	14.00	265.97	22		0	0
	R3	525 lux	28.3C°	104dBA	11.00	14.00	265.97	21		0	0
DAY 2	R1	504 lux	26.9C°	96 dBA	14	16.00	260	24	80%	0	1
	R2	549 lux	32C°	110 dBA	12.00	14.00	260	22		0	1
	R3	524 lux	28C°	107 dBA	12.00	14.00	260	22		0	1
DAY 3	R1	505 lux	27.1C°	96 dBA	16	17.00	258.16	28	82%	0	0
	R2	555 lux	30.7C°	109 dBA	12.50	14.00	258.16	24		0	0
	R3	520 lux	27.9C°	104 dBA	10.00	14.00	258.16	22		0	0
DAY 4	R1	500 lux	27.2C°	95 dBA	14	16.00	260.5	25	84%	0	0
	R2	560 lux	31C°	111 dBA	12.50	15.00	260.5	24		0	0
	R3	520 lux	28.4C°	105 dBA	11.00	14.00	260.5	22		0	0
DAY 5	R1	503 lux	26.85C°	97 dBA	14	16.00	259.12	23	80%	0	0
	R2	557 lux	31.5C°	112 dBA	12.50	15.00	259.12	23		0	0
	R3	524 lux	28.4C°	103 dBA	11.00	14.00	259.12	22		0	0
DAY 6	R1	500 lux	26.1C°	98 dBA	14.25	16.00	256.85	25	82%	0	0
	R2	547 lux	30.57C°	114 dBA	12.50	13.00	256.85	20		0	0
	R3	529 lux	28C°	104 dBA	11.00	16.00	256.85	24		0	0
DAY 7	R1	505 lux	26.4C°	97 dBA	13.5	17.00	259.73	27	87%	0	0
	R2	548 lux	30.11C°	112 dBA	12.50	13.00	259.73	23		0	0
	R3	530 lux	27.2C°	106 dBA	12.25	16.00	259.73	24		0	0
DAY 8	R1	503 lux	25.97C°	96 dBA	12.5	17.00	259.55	24	82%	0	0
	R2	552 lux	31C°	115 dBA	12.40	16.00	259.55	23		0	0
	R3	524 lux	28.3C°	103 dBA	12.00	13.00	259.55	22		0	0
DAY 9	R1	505 lux	27C°	97 dBA	14	17.00	257.4	27	88%	0	0
	R2	550 lux	32C°	114 dBA	11.40	13.00	257.4	23		0	0
	R3	523 lux	28.7C°	105 dBA	12.00	16.00	257.4	25		0	0
DAY 10	R1	504 lux	27C°	97 dBA	12	14.00	258.1	23	82%	0	0
	R2	554 lux	31.3C°	111 dBA	14.00	18.00	258.1	24		0	0
	R3	525 lux	28.5C°	105 dBA	12.00	13.00	258.1	23		0	0
DAY 11	R1	503 lux	26.4C°	98 dBA	14.75	18.00	259.12	26	84%	0	0
	R2	549 lux	30.5C°	111 dBA	12.00	14.00	259.12	21		0	0
	R3	521 lux	28.05C°	105 dBA	11.50	13.00	259.12	24		0	0
DAY 12	R1	502 lux	27.3C°	98 dBA	14.9	17.00	258.04	24	81%	0	0
	R2	547 lux	32.3C°	112 dBA	12.00	14.00	258.04	23		0	0
	R3	526 lux	28.52C°	103 dBA	11.00	13.00	258.04	22		0	0
DAY 13	R1	505lux	26.9C°	96 dBA	15.5	17.00	259.01.	25	82%	0	0
	R2	560 lux	31.5C°	114 dBA	10.00	14.00	259.01.	21		0	0
	R3	524 lux	28.2C°	104 dBA	12.00	13.00	259.01.	24		0	0
DAY 14	R1	504 lux	27.3C°	98 dBA	16	17.00	257.18	27	82%	0	0
	R2	548 lux	31.88C°	110 dBA	10.00	14.00	257.18	22		0	0
	R3	525 lux	28C°	104 dBA	11.00	13.00	257.18	21		0	0
DAY 15	R1	505 lux	27C°	98 dBA	16	17.00	257.05	26	84%	0	0
	R2	551 lux	31C°	111 dBA	11.00	14.00	257.05	22		0	0
	R3	524 lux	27.4C°	102 dBA	11.00	13.00	257.05	23		0	0

5. CONCLUSION

The results obtained from the findings and analyses proved that the study achieved its three (3) objectives. First, the research was able to assess the workplace design and conditions of the cable tray production and identified the environmental factors the worker performance. Second, it determined the significant relationships of Environmental Factors and Lean Elements on Worker Performance. Lastly, a model in developing a workplace design that incorporates both lean elements and environmental factors that can improve worker performance.

The research output serves as a reference approach in improving workplace conditions and layout that address not only ergonomics and OSH requirements but also the foremost concerns of worker productivity, throughput improvement, working conditions, waste elimination, process efficiency and employee engagement and commitment.

Despite the limitation in the availability of data on other operational aspects and human dimensions, the output model comes with statistical support to prescribe another way of doing workplace design. This is to be more multi-faceted in approach, similar to the study's incorporation of lean elements in implementing environmental factor-related improvements to enhance overall worker performance in terms of throughput, and attitude.

The industry setting and company size of the unit of analysis influenced the scope of the study. Needless to say, it would have been better to add more companies under study to come up with a more comprehensive model or approach in workplace design improvement using this study as a takeoff point. It is recommendable to have in the future, the inclusion of other factors and approaches not included in the purview of the research. Employee engagement or commitment-related factors and customer satisfaction or supply chain-related approaches can enhance the results of future studies of similar nature as part of a continuous improvement loop.

The results answered the research question that there is significance in the relationships between worker performance in terms of productivity and environmental factors and if there is a moderating relationship between the incorporated lean elements and the interaction between environmental factors and worker performance.

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Automated Monitoring and Behavior Analysis for Proactive Security Operations

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ABSTRACT
This research presents a method for discovery of malware trapped in Honeypot bait. The focus is the network intrusion on the Unix or Linux operating system. A process flow is introduced to facilitate collecting, analyzing, and classifying cyberattack patterns. Log management and analytics are performed with the Elastic Stack or formerly known as ELK. The data logs (cowire.log) are periodically collected from Honeypot, then they will be filtered, formatted, and inspected through the execution of shell scripts. To detect suspicious commands, a set of rules containing groups of commands is defined. These commands seem to cause the organization's assets vulnerable or harmful. If a command is found matching the command risk group, the system will analyze for its attack pattern by querying VirusTotal database. VirusTotal is a free Sandboxing service for analyzing suspicious files or URLs online. The API will return analysis reports all the antivirus application engines that have previously scanned the suspicious file or URL. The experimental result in this work reported 86% of URLs or files that belong to the command risk groups are considered as threats. The analytic results would contribute to the organization's security policies and proactive security operations development afterwards.

CCS Concepts
• Security and privacy→ Software and application security

Keywords
Proactive security operation; Network threat detection; Log analysis; Honeypot; Elastic stack

1. INTRODUCTION
No matter the size of organizations, they all need network security which generally copes with the tasks of moderating, surveilling, and keeping the organization's security. Even so, cyberattacks can occur at any time which the moderator might not be present or available. Not only time intervals of the attack matters, but there are also new attack patterns which evolve to be more complicated. Therefore, organizations are encouraged to start considering more about proactive cyber security operations. The improvement of security detection through 24/7 real-time monitoring and analyzing data activity is critical to ensure timely detection and respond immediately, thereby reducing the time between compromise and detection. Combined skills of security experts with the utilization of more intelligent in detection, security automation brings more effective and efficient defense against data breaches and security attacks.

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The Elastic Stack, or formerly known as ELK, is an open source product well-known as a powerful platform of centralized logging. Elk stands for Elasticsearch, Logstash, and Kibana. Elasticsearch is a search and analytics engine. Logstash is a server-side data processing pipeline that ingests data from multiple sources simultaneously, transforms it, and then sends it to a "stash" like Elasticsearch. Kibana lets users visualize data with charts and graphs in Elasticsearch. Beats is introduced later as a lightweight shipper to forward and centralize logs and files. In literature, ELK contributes to plenty of research [1, 2, 3, 4, 5, 6], and more, as solutions for log management and analytics.

"Honeypot" [7] is a system that creates a virtual environment for the attackers to get trapped. It is set up to look like a real system with exploitable vulnerabilities. The only difference is that it is actually isolated from the rest of the network and carefully monitored. Honeypot will gather information on attackers' behaviors in the form of logs which can then be analyzed in order to discover the attack patterns.

VirusTotal provides a free service for analyzing suspicious files or URL addresses online. Many antivirus application engines and website scanners are used for analysis. Files considered to be harmful are analyzed in individual antivirus application engines. Each antivirus application engine then creates an analysis report for the suspicious file [8].

This research presents a method for discovery of malware trapped in Honeypot bait emphasizing the network intrusion on the Unix or Linux operating system. A prototype is implemented to monitor cyberattackers early and derail their efforts. The suspicious files or URLs will be examined by querying the VirusTotal database. The analytic results would contribute to the organization's security policies and proactive security operations development.

2. WORKFLOW DESIGN
Figure 1 illustrates the workflow describing the presented method of network threat detection. The environment consists of two virtual machines as emulated agents and required product specifications as described following:

- VM1: – Honeypot Server
  - CENTOS-7 (64 bit)
  - Honeypot (cowrie) 19.10.0
  - Shell Script

- VirusTotal
- Filebeat 7.1.0

- VM2: – Report Server
  - CENTOS-7 (64 bit)
  - Elasticsearch 7.2.0
  - Logstash 7.2.0
  - Kibana 7.2.0
  - Nginx 1.17.0

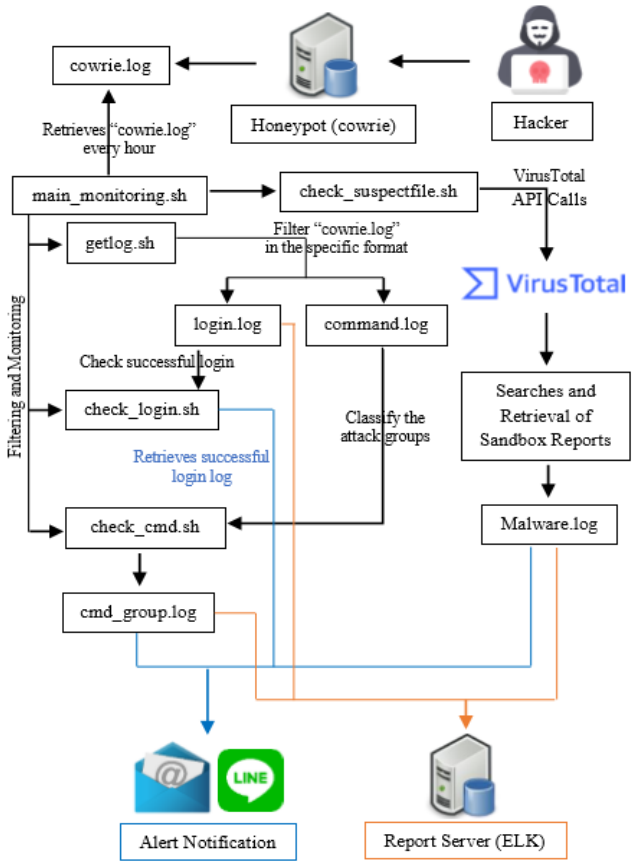

Figure 1. Workflow design

3. METHODOLOGY

The method consists of several major tasks as described in the following subsections. In brevity, the data logs are periodically collected from Honeypot (cowrie). Next, formatting the logs and detecting suspicious commands are performed through shell scripts. If a command matches the command risk group, the system will analyze for its attack pattern by querying VirusTotal database. Given a URL, the API returns the labels from all the antivirus application engines that have previously scanned the URL [9]. Log management and analytics will be handled with the Elastic Stack in this work.

3.1 Data Collection

Starting from altering the Linux machine's default port from SSH Port 22 to 2332 (The port used can be permissively chosen), then Honeypot (cowrie) is installed and its port is configured as 22 replacing the SSH Port. When attackers attempt to access the system or successfully penetrate the system, Honeypot (cowrie) will collect all behaviors including those of attackers in data logs called cowire.log, example as shown in Figure 2.

```
HoneyPotSSHTransport,218,159.203.32.174] 'nproc' trying auth 'password'
HoneyPotSSHTransport,218,159.203.32.174] login attempt [nproc/nproc] failed
HoneyPotSSHTransport,219,95.157.63.185] 'root' trying auth 'password'
HoneyPotSSHTransport,219,95.157.63.185] login attempt [root/password] succeeded
HoneyPotSSHTransport,219,95.157.63.185] CMD: cat /proc/cpuinfo | grep name | wc -l
HoneyPotSSHTransport,219,95.157.63.185] CMD: echo "root:KCP9p8Wzgglt"|chpasswd|bash
HoneyPotSSHTransport,219,95.157.63.185] Command found: bash
HoneyPotSSHTransport,219,95.157.63.185] Command found: chpasswd
HoneyPotSSHTransport,219,95.157.63.185] Command found: echo root:KCP9p8Wzgglt
HoneyPotSSHTransport,219,95.157.63.185] CMD: wget http://flashpointy.xyz/panel/test1.exe
```

Figure 2. Example cowrie.log

3.2 Data Filtering and Monitoring

The monitoring shell script is written to classify the logs and instruct a sequence of the system's operations. The process is initiated with the execution of main script, called main_monitoring.sh, to periodically collect cowrie.log every one hour [10]. The main_monitoring script contains four other scripts: getlog.sh, check_login.sh, check_cmd.sh and check_suspectfile.sh.

```
YHOUR=`TZ="GMT+1" date +'%Y-%m-%dT%H'`
NHOUR=`TZ="GMT+1" date +'%Y-%m-%d_%H'`
${CHOME}/script/getlog.sh ${YHOUR} ${NHOUR}
${CHOME}/script/check_login.sh ${NHOUR}
${CHOME}/script/check_cmd.sh ${NHOUR}
```

Figure 3. Excerpt of main_monitoring script

Firstly, main_monitoring (Figure 3) invokes getlog.sh in order to filter cowrie.log into two groups, namely login log and command log. Examples are illustrated in Figure 4.

login log

```
2019-11-25T13:15:00.514611+0000 141.98.81.150 root admin failed
2019-11-25T13:22:49.625945+0000 27.69.242.187 admin 123456789 failed
2019-11-25T13:28:38.025478+0000 129.158.74.141 kirkemo kirkemo failed
2019-11-25T13:39:23.125713+0000 159.203.32.174 nproc nproc failed
2019-11-25T13:48:42.797545+0000 95.157.63.185 root password succeeded
```

command log

```
2019-11-25T13:48:44.125687 95.157.63.185 CMD: cat /proc/cpuinfo | grep name | wc -l
2019-11-25T13:48:44.709453 95.157.63.185 CMD: uname -m
2019-11-25T13:48:45.146512 95.157.63.185 CMD: wget http://flashpoint.xyz/panel/test1.exe
2019-11-25T13:48:47.054193 95.157.63.185 CMD: crontab -l
```

Figure 4. Example login logs and command logs

The Login logs extracted from cowrie.log are filtered with the keyword: "login attempt" while command logs are filtered from cowrie.log with the keyword: "CMD". Excerpt of getlog script is shown in Figure 5.

```
cat ${PLOGC}/${LOGC}|grep ${YHOUR} > ${PLOGS}/${LOGS}
cat ${PLOGS}/${LOGS} grep "login attempt" > ${PLOGS}/${LOGT}
sed -i 's/\[//g' ${PLOGS}/${LOGT}
sed -i 's/\]//g' ${PLOGS}/${LOGT}
sed -i 's/\,/ /g' ${PLOGS}/${LOGT}
sed -i 's/\// /g' ${PLOGS}/${LOGT}
awk '{print $1,$7,$10,$11,$12}' ${PLOGS}/${LOGT} > ${PLOGS}/${LOGL}
rm ${PLOGS}/${LOGT}
cat ${PLOGS}/${LOGS} |grep "CMD" > ${PLOGS}/${LOGTCMD}
```

Figure 5. Excerpt of getlog script

Subsequently, check_login.sh, excerpt as shown in Figure 6, is called to determine the status whether or not the malware has successfully accessed the system. If the system has been penetrated, it will notify the admin through postfix which is a package on Linux used for sending an email.

```
cat ${PLOGS}/${LOGL} |grep "succeeded" > ${PLOGS}/${TXTA}
ALOG=`cat ${PLOGS}/${TXTA}|wc -l`
if [ ${ALOG} -gt 0 ]
   then
     echo -e "${DMAIL1}$(head -10  ${PLOGS}/${TXTA})${TMAIL1}" |
          mail  -a ${PLOGS}/${TXTA} -s "${SMAIL1}" ${UMAIL}
     curl -X POST -H 'Authorization: Bearer '"$TOKEN"'' -F
          'message='"$LMSG1"''"$(head -10  ${PLOGS}/${TXTA})"''
          https://notify-api.line.me/api/notify
fi
```

Figure 6. Excerpt of check_login script

Once the command logs have been acquired, the script of check_cmd.sh is called automatically. Parts of the script is shown in Figure 7.

```
cat ${PLOGS}/${LOGCMD}|while read cline
do
        echo "${cline}"|awk '{print $4}' > /dev/null
        if [ $? -eq 0 ]
           then
             CMD1=`echo "${cline}"|awk '{print $4}'`
             cat ${CHOME}/script/rule.txt|grep -w ${CMD1}
             if [ $? -eq 0 ]
               then
                 CMAP=`cat ${CHOME}/script/rule.txt|grep -w ${CMD1}|awk -F
                        '|' '{print $2}'`
                 CNUM=`cat ${CHOME}/script/rule.txt|grep -w ${CMD1}|awk -F
                        '|' '{print $1}'`
                 case  ${CNUM}  in
                  1)
                   echo "1 $cline" >> ${PLOGS}/${LOGCASE1} ;;
                  2)
                   echo "2 $cline" >> ${PLOGS}/${LOGCASE2} ;;
                  3)
                   echo "3 $cline" >> ${PLOGS}/${LOGCASE3} ;;
                  4)
                   echo "4 $cline" >> ${PLOGS}/${LOGCASE4} ;;
                  5)
                   echo "5 $cline" >> ${PLOGS}/${LOGCASE5} ;;
                  6)
                   echo "6 $cline" >> ${PLOGS}/${LOGCASE6} ;;
                esac
```

Figure 7. Excerpt of check_cmd script

The script is used to probe and classify the commands into 6 groups: 1) Query Information, 2) Attempt to install, 3) Transfer files, 4) Change Configuration, 5) Take Over the Server, and 6) Error Case.

1) *Query Information* is a group of commands that seek out and read data residing the system.

Table 1. Example commands in group 1

cat	Read data from the file and output the contents
uname	Print system information
ps	List running processes

2) *Attempt to install* is a group of commands that attempt to install tools or files on the system.

Table 2. Example commands in group 2

yum	Primary tool for getting, installing, and managing
gzip	Compress files
gunzip	Compress or expand a file or a list of files

3) *Transfer files* are a group of commands used to transfer or download files onto the system.

Table 3. Example commands in group 3

mv	Allow to move files and directories
wget	Download files from the web
curl	Tool to retrieve information and files from URLs

4) *Change Configuration* is a group of commands that alter or rewrite data in the system.

Table 4. Example commands in group 4

rm	Delete or remove files and directories
touch	Create, change and modify timestamps of a file
mkdir	Create new directories in the file system

5) *Take Over the Server* is a group of commands that attempt to change the system's password or take control of the system.

Table 5. Example commands in group 5

passwd	Change the password for a user
sudo	Used as a prefix of some command that only superusers are allowed to run

6) *Error Case* is a group of commands that are flawed or failed to operate such as mistyped commands.

The commands in each group will be gathered into a file called rule.txt (as shown in Figure 8) which will be used as a reference for other new logs. In case that there exists a command that is not accounted for in rule.txt or has never been detected, the said command will be classified into the 7th group named "New Case". And the administrator will be notified for inspection.

```
1|egrep
1|exit
1|dir
1|find
1|finger
1|whoami
1|history
2|yum
2|apt-get
2|pkg
2|gzip
2|gunzip
2|unzip
2|zip
3|cp
3|mv
```

Figure 8. Excerpt of rule.txt

3.3 Checkup with VirusTotal

In addition to classify the command group, the URLs that are stated in command groups 2, 3, and 4 will be sent for further analysis by calling VirusTotal API via CURL in order to simulate downloading and installing file in a virtual environment in which the process is called *Sandboxing*. Subsequently, VirusTotal will report back if the URL is a threat or not. In case the URL is considered as a threat, the report will state "detected": true as shown in Figure 9. Since VirusTotal sends the suspicious URLs to sandbox through various antivirus engines, each engine may use various definitions of the result. For example, Sophos uses the word "Malicious", whereas Kaspersky uses the word "Malware" to signify the same intent that the URLs or files are harmful.


```
"detail": "https://zeustracker.abuse.ch/monitor.php?host=systemservice.hldns.ru"}
"Sophos": {"detected": true, "result": "malicious site"}
"Google Safebrowsing": {"detected": true, "result": "malicious site"}
"Kaspersky": {"detected": true, "result": "malware site"}
"BitDefender": {"detected": true, "result": "malicious site"}
"Dr.Web": {"detected": true, "result": "malware site"}
```


Figure 9. Example report from VirusTotal

The calling of VirusTotal API through CURL is stated in check_suspectfile script as shown in Figure 10 to hand out the sequence of operations. That is, if the command containing a suspicious URL is detected, it will be sent to VirusTotal automatically. After VirusTotal has reported back and the

inspection result states “detected” = true, the system will collect the result of the said URL into the form of logs of which the format has been configured as in Figure 11. The Malware.log is then used for analysis with the Elastic Stack.

```
curl --request GET  --url 'https://www.virustotal.com/vtapi/v2/url/report?
     apikey='${APIKEY}' &resource='${URL1}| sed 's|\},|\}\n|g'|grep true
  if [ $? -eq 0 ]
    then
     curl --request GET  --url 'https://www.virustotal.com/vtapi/v2/url/report?
           apikey='${APIKEY}'&resource='${URL1}| sed 's|\},|\}\n|g'|grep true|
           awk '{print $0}'|sed  's/\,//g'|sed  's/\://g'|awk -F '"'
           '{print $2"|"$8}' > ${PLOGS}/${LOGVTOTAL}
        cat ${PLOGS}/${LOGVTOTAL}|while read mline
        do
            BODY1="`echo "${cline}"|grep ${FLAG}| awk -F '${FLAG}'
                  '{print $1}'|awk  '{print $1"|"$2}'`"
            echo "${BODY1}|${URL1}|${mline}" >> ${PLOGS}/${TXTM}
        done
   fi
```

Figure 10. Excerpt of check_suspectfile"script

```
Date IPAddress URL Result
2019-11-25T13:48:45.146512 95.157.63.185 http://flashpointy.xyz/panel/test1.exe malware site
2019-11-27T18:37:56.909783 189.19.173.95 http://butenrestold.com/ls5/forum.php phishing site
2019-11-27T18:48:45.146512 95.157.63.185 http://flashpointy.xyz/panel/admin.php malware site
2019-11-25T19:12:12.501420 51.255.197.164 http://goonronto.ru/ls5/forum.php malware site
2019-11-26T19:14:23.431421 107.170.244.110 http://api.ipify.org/ malware site
```

Figure 11. Example Malware.log

3.4 Analysis with Elastic Stack

All monitoring logs will be analyzed and displayed its result by the Elastic Stack. Initially, Filebeat sends logs from the Honeypot Server to the Report Server through the port of Logstash (Port 5044), Logstash’s operations can be partitioned into three main parts as shown in Figure 12: 1) Input: receive information from Filebeat, 2) Filter : sort the data received prior to sending it to the Output, and 3) Output : send data to be stored in Elasticsearch.

Logstash will send the logs to Elasticsearch to be stored through Port 9200. Consequently, Kibana will collect data stored in Elasticsearch for result display to the user.

4. DISCUSSION

4.1 Command Log Analysis

The experiment was carried out to assess the effectiveness of the proposed approach. There were 6888 network traffics collected from Honeypot. Some were attempting accesses but failed to enter the system. The rest of 2163 command logs went through the process flow. Those command logs were examined and classified into the pre-defined groups. The number of suspicious commands classified into seven groups is summarized as shown in Table 6. The results reported that most commands are classified as group 1: Query Information. The second highest is group 4: Change Configuration. Figure 13 visualizes the top thirty suspicious commands, observing that “cat uname”, which is the command used to query system’s information, is the highest number of commands found. Despite having the maximum number of commands detected, commands in group 1 do not inflict much damage to the system, but it allows the attacker to access and collect various data from the system. Regarding the second most detected command group, i.e. group 4, those commands are viable to damage the system as they seek to change or alter the system’s configuration.

```
input {
  tcp {
    port => 5044 }
}
filter {
  if "check_login" in [tags] {
     csv {
         columns => ["Time","IPAddress","Username","Password","Status"]
         separator => " " }
     date {
         match => [ "Time", "UNIX" ]
         target => "time"
          }
     ip2location {
         source => "IPAddress" }
   }
 }
 output {
  if "check_login" in [tags] {
     elasticsearch {
         hosts => ["localhost:9200"]
         sniffing => true
         manage_template => false
         index => "analysis_login" }
     stdout { codec => rubydebug }
   }
 }
```

Figure 12. Excerpt of logstash.yml

Table 6. Number of commands detected in each group

Category	count
1: Query Information	1,414
2: Attempt to install	18
3: Transfer files	16
4: Change Configuration	510
5: Take Over the Server	12
6: Error case	3
7: New case	190

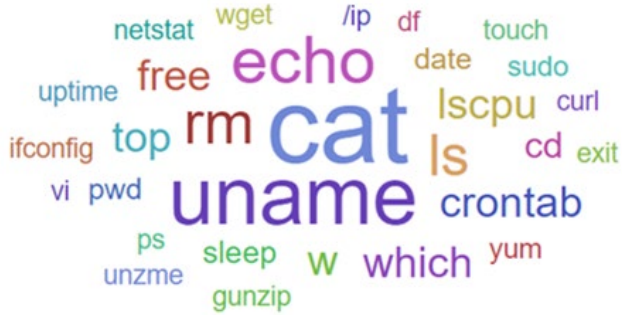

Figure 13. Word Cloud visualization of top thirty commands

4.2 Analysis with VirusTotal

The findings from sandboxing reported the result of examining 544 logs, 76 logs are identified as safe URLs/ files, and 468 logs are determined as harmful. The total of 468 harmful logs are classified as 258 malware logs, 171 malicious logs, and 39 phishing logs as shown in Figure 14. Phishing means counterfeit websites created to obtain certain information. Malware and malicious denote harmful files/ URLs or programs like viruses, worms, trojans, and spywares.

VirusTotal provides the visualization of relationships of querying suspicious URLs. The graph illustrates relations of the querying URL to the domain name to identify whether the domain contains additional harmful URLs and connects to the subdomains to identify if the subdomains have other subsites while additionally relates to the attacker’s location.

Figure 14. Sandboxing report of harmful URLs frequency

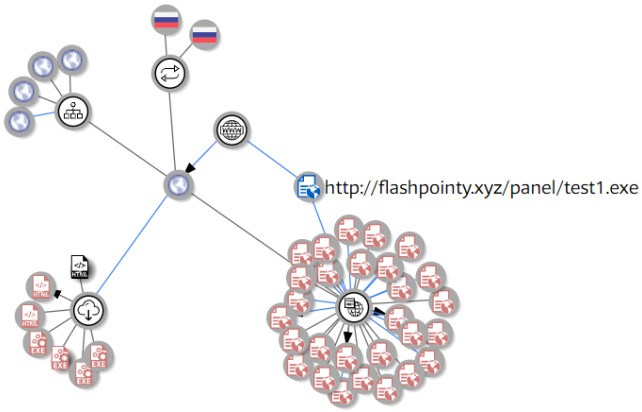

Figure 15. Visualization of harmful URL Relationships

Figure 15 portraits the relationship of the suspicious URL that entails the command in group3, i.e. "wget http://flashpoint.xyz/panel/test1.exe". Table 7 summarizes the relationships of the domain flashpointy.xyz that contains four more subdomains consisting of 1) webdisk.flashpointy.xyz, 2) discover.flashpointy.xyz, 3) mail.flashpointy.xyz, and 4) www.flashpointy.xyz. It is also related to 10 URLs, and 7 downloaded files that are malwares. Moreover, the location of the attacker that has accessed this URL are discovered at 2 IP addresses which are 95.157.63.185 and 178.159.36.185, both of which are traced to Russia.

Table 7. Relationships of Domain: flashpointy.xyz

Name	flashpointy.xyz
Subdomains	4
Urls	10
Downloaded files	7
Resolutions	2

5. CONCLUSION

With security technology evolving, the threats to it are also rapidly evolving along its side. The implementation of process flow presented in this work would be capable of discovering and preventing intrusion before the network and privacy of information are weakened. The methodology facilitates collecting, clustering, and analyzing cyberattacks trapped in Honeypot. The experiment was conducted by gathering 6,888 data logs partitioned into 4,725 logs of system access and 2,163 logs of commands issued by the attackers penetrating the system. It was found that the attackers tried to log into the system using common usernames and passwords or those that are the defaults of variety of OS's. If the attempt is successful, the operated commands will then be classified into the pre-defined groups. The analysis of threats is performed by consulting VirusTotal database. The commands belong to group 2, 3, and 4 are further analyzed since these command groups attempt to utilize URLs or files that seem to harm the system. From the total of 2163 command logs, 544 logs were found categorized into group 2, 3, and 4. The result returned from querying VirusTotal reported that a total of 544 logs, 76 logs were identified as safe URLs or files and 468 logs are identified as threats consisting of 258 malware logs, 171 malicious logs, and 39 phishing logs. The proposed practices would help establish organizational proactive security operations. The statistics or measurement data would also contribute to maintain the organization's security policies.

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Session V

Digital economy and e-commerce

Creation A Strategic Plan for Supporting Digital Transformation

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ABSTRACT
Preparation for the transformation to digital technology that is an important part of an organization needs to adapt to keep up with globalization. The objective of this research is to study the changes in digital technology to make a strategic plan to support the digital system in the case study of a factory in accordance with Thailand 4.0 policy. To reach this goal, this study applies SWOT analysis and PEST analysis for analyzing the factory environment. In addition, the key factor of this research is the Thailand 4.0 policy refers to the government framework. The result is a work plan to adjust the factory to be ready for digital transformation.

CCS Concepts
• Human-centered computing → Accessibility technologies • Human-centered computing → Accessibility systems and tools • Security and privacy → Digital rights management • Applied computing → E-learning Applied computing → E-commerce infrastructure • Applied computing → Marketing • Applied computing → Business process management systems

Keywords
Strategic plan; Thailand 4.0 policy; SWOT analysis; PEST analysis; digital transformation

1. INTRODUCTION
Nowadays, E-commerce and digital economy have been developed massively which digital technologies are important tools in supporting working processes. According to developing e-commerce and digital economy, it is developing effectively in an economic structure such as productions, commercials, services, and other social activities especially human interaction. Over the years, trends of applying the technologies to use in daily life are very popular in recent years, science development and technology development are mostly used in communication developing which affected the producer can work faster. Including business operations and daily life has been changed in massive ways. [1]

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A human can communicate with each other by using images, sound, and video widely with a borderless platform. as a result, it might be increased business and transaction in digital platforms. On the other hand, customer's behavior also changes to use digital technology which can response and estimate their communication quickly and they have been learned and applied how to use that technology simply. As a result, digital technologies and modern digital platforms became the foundation of living in present-day for example fastest internet, online shipping, smartphone, and other gadgets which were used as main communication tools and driving our life. Which is always connects the internet for the whole day. So, the largest information center in digital platforms that everyone can access easily, people can search and educate what they want efficiently through the completely digital platform.[2] In terms of business, digital technology becomes to be a marketing tool that producers can promote some products to their clients effectively. Because offline marketing can not serve some information or some service to their clients directly. Which television and books are difficult to serve effective content for their clients and offline marketing is not suitable to serve updated content.[3]

Digital transformation is important to define the way they communicate a touching point to the client. The touching point is a combination method that merges technology, production, and services for getting the highest performance which will lead the company to lead out the best products and services.

In the case study, the government's operation which does business or producing a Playing cards and Security printing technology such as tax stamp, trade-mark stamp.

2. METHODOLOGY
Digital transformation is business change by using digital technology as a tool to adjust to be more ready in the digital world. Especially, strategic planning or concepts of participation of personnel in the organization including to the vision of leaders who are accept changes. Furthermore, having and using innovations for the benefit and collection of various data for analysis.

The mission is to increase the capacity of everyone and every organization in the world to achieve more. In which technology can grow with details follows;

1. Engage your customers: getting your customers to participate will help the organization to be more streamlined.

2. Empower your employees: Creating technology and environments so that employees can create technology and make things that are beneficial to the organization. To attract and retain

talented people with the organization which must provide a modern workplace which will help employees become more successful while supporting different working styles.

3. Optimize your operations: Digital technology can help increase efficiency and improve business results. By using the automated processes and controls of the Internet of things (IoT) and able to effectively address customer needs before that become a problem in the future.

4. Transform your products: Application needs to be able to deliver digital changes, product connections and the introduction of digital services has become the new norm.

The methodology of this paper (Fig. 1) is based on the following steps:

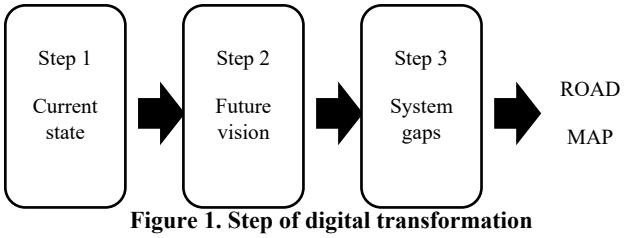

Figure 1. Step of digital transformation

Step 1 Current state assessment, it be assess the current situation of the organization in all aspects that divided analysis 2 environments (fig. 2)

The"internal environments use"strength factor and"weakness factor in SWOT analysis tool. Also, the external factors use opportunity factor and treat factor in SWOT analysis including to PEST analysis.

In SWOT these factors are grouped into four parts called SWOT groups: SO strategies, WO strategies, ST strategies and WT strategies. By applying SWOT in strategic decisions, the purpose is to select or constitute and implement a strategy resulting in a good fit between the internal and external factors.

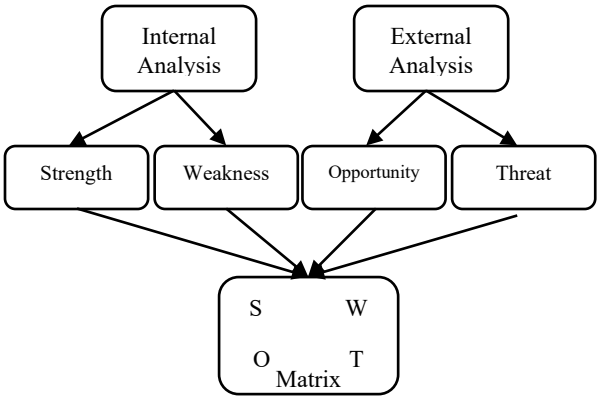

Figure 2. SWOT analysis framework

Step 2 Future vision is specify future of the organization. Determine the future picture by using the SWOT matrix to adjust with the Thailand 4.0 policy to find the point where the factory wants to see the future.

Step 3 Systemic gap is estimate the gap between the present and the desired vision.

Step 4 Roadmap, set business goals and strategic plan.

The process of strategic management begins with analyzing internal strengths and weaknesses of the organization and external threats and opportunities of the organization called SWOT analysis, and the data obtained in the previous stage are used for the development of a strategy for the organization. [4] Then, PEST analysis is visible the opportunities and threats of the external environment affecting the organization. Lastly, Thailand 4.0 Policy is the government framework. It is the economic model will bring Thailand out of the middle-income country, inequality and imbalance. As well as changing Thailand through to “First world countries that are stable, wealthy and sustainable” in the context of the fourth world revolution.

As a result, creating a strategic plan to prepare the organization for digital transformation.

The details are as follows;

2.1 The Case Study Factor Information

To give you some background about case study factory information. Products of this factory be divided 2 parts,

1. Printing it be subdivided 2 parts are general printing and security printing.

2. Playing cards

The vision is “To be the leader in public security forgery with operations that have efficiency” with the mission is take services of General printing, Security printing and Playing cards.

2.2 SWOT Analysis

SWOT is a consideration of the various elements in the business environment that is being analyzed, consisting of 4 important factors. It’s focusing on Strength, Weakness, Opportunities, and Threats that point of study SWOT is setting a foundation of strategy which depends on the strength of company’s resources and solving weakness point of resources, the objective is aiming to find out the good opportunities and prevent future threats. [5]

By SWOT theory, business is divided into internal factors and external factors as follows;

Internal factors refer to the internal environment of the organization that affects the business operations divided into Strengths, it’s the advantage of the business means the characteristics or characteristics of the organization that are conducive to success can be utilized and used to compete with rivals. And Weakness, disadvantages or problems within the organization that affect business operations that can lead to business failure.

External factors are external conditions of the organization. That may have an impact on the business operation are Opportunity, a factor that affects in terms of providing benefits to the company's business operations. Opportunities are different from the strengths that is a factor comes from outside the organization but has a positive effect on the organization. An advantage that is conducive to the success of the business. And Threats,

disadvantages from external factors that affect the business May lead to problems And the failure of the business.

Table 1. SWOT analysis of Playing Cards

SWOT	Playing Cards
Strength (**S**)	(S1) The factory is a monopoly business that no legal competitors. (S2) The factory has fully integrated features including production and distribution. (S3) The sales contract system is a stable income for the factory. (S4) Production capacity can support the demands of the internal market.
Weakness (**W**)	(W1) Low product awareness0 (W2) Distribution channels are limited. (W3) No e-commerce system. (W4) No service for logistic.
Opportunities (**O**)	(O1) The ASEAN community is helping to find new customers. (O2) Thailand's 4.0 policy is to support product development.
Threats (**T**)	(T1) The rising trend of online shopping and e-commerce makes it easy to access cards that are illegal.

Table 2. SWOT analysis of Security printing

SWOT	Security printing technology
Strength (**S**)	(S5) Government agencies that receive ongoing print jobs**.**
Weakness (**W**)	(W5) Most of the technology and production machinery is not up to date. (W6) Unable to complete production operations, that be outsourcing.
Opportunities (**O**)	(O3) According to the law, agencies under various ministries must hire government agencies first. Nowadays, and they use a lot of publications. (O4) Security technology has increased demand in stamps, tickets and brand protection.
Threats (**T**)	(T2) The tendency for demand for print jobs decreases globally. Due to the growth of digital systems. (T3) In terms of printing, there are many small traders and compete with the price.

Next, different types of strategies were transferred to the strategic planning table after the examination of specific components of SWOT, it is comprised of a two-dimensional coordinate table; each of its four areas is the marker of a group of strategies. [6]

Table 3. SWOT matrix

	Strength	Weakness
Opportunities	SO strategies 1. Research and develop new products in accordance with market demand. (S4, O3, O4) 2. Use e-commerce sales channels. (S1, S2, S3, O1, O2) 3. Expanding the market to various government agencies and expanding the business of playing cards in foreign markets (S1, S5, O1, O2, O3)	WO strategies 1. Provide modern machinery to support new needs in the future. (W5, W6, O4) 2. Make a marketing plan for brand awareness and increase sales channels. (W1, W2, W3, W4, O2, O4)
Threats	ST strategies 1. Design products for use in activities other than gambling. (S2, S4, T1) 2. Study the suitability, format, and business expansion of Digital printing solutions. (S5, T2, T3)	WT strategies 1. Create awareness of illegal products. (W1, T1) 2. Plan to expand investment in new business appropriately. (W1, W2, W3, W4, T3)

2.3 PEST Analysis

PEST Analysis is an external factor analysis tool. It is an analysis of the uncontrollable factors that affect business operations. PEST analysis will show which areas are opportunities and what are the threats.

PEST analysis consists of 4 external factors including to Political (P), Economic (E), Social (S) and Technology (T).

But in the part of Economic (E), it is found that there is uncertainty in the economics factors causing the inability to the above factors can be analyzed. This research therefore uses environment factors instead. [7]

According to the external environment of operation, from analyzing of PEST analysis was found the important factor which affected to factory are;

Politic (P) that divide by ASEAN Economic Community - AEC and the development of Thailand 4.0

Environment (E) that divide by important resources which are paper and ink that are supposed to use a natural resource that requires the environmental concern. Nowadays, there is Paperless trend that becomes to use instead of the natural paper.

Social (S) that divide by supporting the government and accessibilities of clients in the digital platforms.

Technology (T) that divide by digital printing which is the printing method without printing forms such as inkjet.

2.4 Thailand 4.0 Policy

Thailand 4.0 policy is another policy that laid the foundations for national development in the long term. It is driving model for

prosperity, stability, and sustainability. The government has set the direction for the development of Thailand 4.0 driving model on sufficiency economy philosophy consists of;

Firstly, preparing human resource to be quality resource, that is people who have intelligence, skill, health and subconscious mind.

Secondly, development cluster technology and future industry, focus on extension of 5 original industries – consist to Next-Generation Automotive, Smart Electronics, Affluent, Medical, and Wellness Tourism, Agriculture & Biotechnology and Food for the Future – In addition, that creating 5 new industries that consist to Robotics, Aviation & Logistics, Biofuels & Biochemicals, Digital and Medical hub.

Next, incubating entrepreneurs and develop innovative enterprise-driven networks. With a context changing from the industrial age to the digital age include connectivity, interactive and mobility.

Next, strengthening the domestic economy. Focus on creating a society of equality, creating fair access to resources and building people's ability to increase income, reduce costs, and improve quality of life.

Lastly, integration ASEAN connected Thailand to the world community.

In summary, the most important thing that can make Thailand policy successful is the cooperation and determination of Thai people, both the public and private sectors. And give importance to development human factors.[8]

3.RESULTS AND DISCUSSION

According to research's comparison, SWOT analysis, PEST analysis of factory and Thailand 4.0 policy. It obviously shows the factory is;

1. Lack of brand awareness
2. Operators are doing redundant work.
3. The overall of system is not complete.
4. Operators are lack of digital skill.

This paper is intended to analyze the business plan for supporting future changes in technologies digital. (fig3.1)

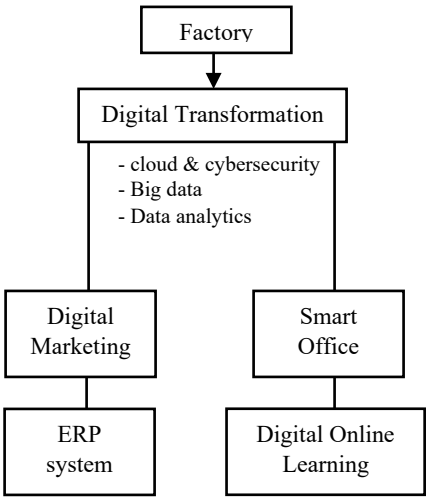

Figure 3. Digital transformation program approached

Implementing cloud & cybersecurity in application services and storage. To processors that can be used via the internet that has security systems supported. Meanwhile, Big data is data collection and data exchange digitally and uses it to analyze in a specific format called Data Analytics.

To achieve the objectives, a plan was created to support digital transformation. The details are as follows;

1. Digital Marketing regarding the development of brand awareness.
2. Smart office to paperless campaign and increases work efficiency. For example, each department can share information which is to reduce the workload of employees.
3. Improving and extending the ERP system to be able to work with full efficiency. To support working on a computer system.
4. Digital Online Learning refers to train employees to learn by themselves. Wherever and whenever.

3.1 Digital Marketing

Recognizing the image of an organization from outsiders is important and necessary in order to proceed to sell products and services which will attract more people to buy products and use services. Therefore, the card factory should create more awareness via digital media and able to communicate with users like Two-way Communication. It will add a positive attitude to the activities and operations of the factory and help promote a better understanding of the products and services of the factory.

Creating brand awareness about the new image of the factory which will make the factory to be widely known. Creating a modern website page that shows information, images, products, and services. Including obvious details of products and services with content to present the types of cards and various playing methods. Meanwhile, offering various printing technology styles of modern factories ready to support a variety of customer needs. And another important thing is to update the information about doing business regularly.

In addition, the factory should be able to advertise products and services through Facebook, Instagram, Twitter, and YouTube to increase communication channels through online media for customers.

3.2 Smart Office

"Documents" still have an important and necessary role for the organization's operations. If the department does not store documents Or inefficient document storage. It may affect the operations cause delay, not timely. Therefore, various departments need to keep documents for the benefit of the entire organization.

Nowadays, technology is changing to Industry **4.0**, using the information to reduce business costs is something that can be achieved and clearly seen. The paperless electronic document storage system of the factory is one that uses that information in response to the digital stream and the development of work processes within the business. That it helps work processes become clearer and faster. Orderly document management that makes the tracking of internal processes of the organization clear. And helps to upgrade the organization to work efficiency in various processes.

Reducing the use of paper in the workplace considered as part of preparing the organization to be Smart Office, which means the introduction of new technologies, such as the introduction of the Internet of things (mobile phone operations) into an organization to increase efficiency and create sustainability to the environment. Makes it possible to reduce problems caused by document delays better editing or receiving/sending urgent data that resulting in all sectors working together smoothly and achieve maximum efficiency.

3.3 Improvement ERP systems

The integration of Back-end's system and Front-end's system. It effectively supports the external service and internal services which are necessary to work on integration and interconnectivity in each system of the information center with each device. Back-end and Front-end both also make a smoothly working process.

3.4 Digital Online Learning

The introduction of a platform for Digital Online Learning Solution will help change the development of personnel in the organization to learn and develop in the form of E-learning with efficiency. Services combine high speed communication technology and security, training is more convenient and reduces time, budget, and security controls. There is a teaching system on the cloud which can be used both at work while working off-site or even the home can be used without restrictions.

Digital technology will be a tool to empower everyone. Most people using technology and information in their work. Training will help employees easily understand and access to new technology systems.

In addition, employees must adapt to technology. Not blocking new knowledge which will make the work easier, faster, and more efficient. To bring the organization to develop at all times through modern technology and equipment. Enhance the factory into an important learning organization in the future.

4. ACKNOWLEDGMENTS

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B2B and B2C E-commerce Platform for Mining Equipment Suppliers

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ABSTRACT
E-commerce is widely used for buying and selling of products using the internet. It is the preferred way of shopping because of its convenience. This paper discusses the development of an ecommerce platform with inventory integration for a mining equipment supplier companies. Because of e-commerce's low barrier of entry, many vendors and distributors sell directly to customers. With this, there is an opportunity to automate the business processes of the mid-size mining equipment supplier company to improve the service and sales performance. In turn, it can ease the management profit of the distributor channel. The system produces an e-commerce web application that can be overall access by the administrator. Likewise, distributors and customers' accounts can be partly access through the web application. This research includes modules to improve the system such as admin module, vendor module, distributor module, customer module and IT management system.

CCS Concepts
• **Information systems→ Information systems applications**

Keywords
E-commerce; B2B; B2C; distributors; customers

1. INTRODUCTION
People go to the internet to get information about food, information, products, and more. Among others, people also go online to find what they want to buy. Using the internet, people can access data instantly. At the same time, it enables businesses to get products from other business and also sell their products to the public. However, for a growing company, a simple post on the internet is not enough to manage the process that they need which ensures that all their products and sales are accounted for.

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A proper IT management system must be placed to help them grow and reach their potential, reach their customers, and keep track of the products**.** Unlike the physical stores where waiting for hours into queues is the norm, e-commerce enables the ease of access to any store located across any part of the globe at any point of time with absolutely no waiting time involved. It can be accessed anytime and anywhere. It can also accommodate large number of items in the inventory storage. With this transactional facility, the system enables the production and accurate reports to which distributor channel can depend on how their business is going.

The study aims to address the issue on limited promotion because by using an online tool, the vendor can have easier access to the distributor. By using the tool, the distributor company will also be able to generate revenue by placing ads to the pages to be viewable by the public.

2. OBJECTIVE
This study aims to develop a web-based, business-to-business (B2B) and business-to-customer (B2C) e-commerce solution for mining supplier companies. This captures the B2B and B2C processes that can be incorporated within a network of resellers and customers.

Specifically, the development of this prototype aims to:

- Create multiple modules such as tools to facilitate the creation of account for both distributor and vendor in order to record all transactions;
- Add the automated process to the current process so that reports can be generated more accurately and reduce the error of the data which is usually encountered in manual reporting; and, Create a module that serves as administrator for all the data maintains all records and all the tools, and manipulates accounts.

3. SCOPE
The project is a web-based application that handles the vendor, administrator and distributor part for data entries, notifications and generation of reports. Also, customer for the purchasing of the products shall have cart to store the selected items. The web-based

application is created using PHP, jQuery and Bootstrap as its frontend and MySQL as its backend along with PayPal API. The web-based application can be accessed through the domain name using a web browser. The use of PHP, jQuery and Bootstrap for the software development project because it is a server-side scripting language that runs in a web server designed to make dynamic pages and applications. It also reduces the time for the conducting the transaction.

4. REVIEW OF RELATED STUDIES

Several past studies revealed the difference between shopping in the traditional shopping channel and online shopping channels. In the traditional shopping environment, there are four unique characteristics of services which differentiate services from goods. These characteristics are generally summarized as intangibility, inseparability, heterogeneity and perishability. However, due to the lacks of social presence and product presence in the ecommerce environment, consumers may have different perceptions of the differences between goods and services in the e-commerce environment, compared with the situation in the traditional shopping environment [1].

Alibaba Group is a Hangzhou-based Chinese private consortium dedicated to e-commerce, including business-tobusiness processes, retail, and consumer sales portals. It also offers online payment services, a price comparison search engine, and cloud data storage services. In 2018, Alibaba reached 580 million monthly active users and announced its plan to invest an additional $2 billion in the company, totaling a $4 billion investment. In 2012, two Alibaba portals together handled 1.1 trillion-yuan (170 000 million dollars) sales, which is more than its competitors both eBay and Amazon.com combined. The company operates mainly in the People's Republic of China, and in March 2017 the economist estimated that the consortium could be valued at between $ 55 billion and $120 billion. During 2017, it achieved revenues of approximately US $ 7.5 billion and had approximately 22,000 employees in March 2018. Alibaba has shares in all types of business operations. But the company operates mainly through three sites namely, Taobao, China's largest shopping site namely: Tmall: Resembles Taobao, but the products on offer are of the highest quality; and Alibaba.com, which connects Chinese exporters with companies in other parts of the world. [2].

DHgate is a business to business (B2B) platform that allows importers from the world to buy small volumes of Chinese goods at wholesale price. Here you can find electronic gadgets, clothing, decorative items, sports accessories, etc. DHGate markets more than 30 Million products in 227 countries worldwide. It has more than 5 million customers worldwide and is currently among the 2100 most visited pages on the internet. Some suppliers at DHgate offer products with Common Era (CE), Restriction of Hazardous Substances (RoHS) and Federal Communications Commission (FCC) certificates. The easiest way to avoid uncertified products is to enter the product name along with the certification standard in the search field. Individual products in the United States and the European Union require compliance with certain standards such as FCC, CE, and EN71. Very few products on DHgate.com meet European and American product standards. While there are many quality products to buy at DHgate.com, we recommend American and European buyers avoid certain products such as toys, electronics, baby products, vehicles, cosmetics, and chemicals

[3].

Global Sources are one of the first B2B platform that was listed in NASDAQ under the name GSOL. The B2B platform is famous for its quality suppliers from different industries. Many Chinese manufacturers choose to pay a significant amount of money to become a verified supplier on this portal. Established in Singapore in 2000, Global Sources facilitates international trade, focusing mainly on bringing the traders around the world closer to each other. Alibaba has shares in all types of things, but the company operates mainly through three sites: Taobao, China's largest shopping site; Tmall: Resembles Taobao, but the products on offer are of the highest quality; and Alibaba.com, which connects Chinese exporters with companies in other parts of the world [4].

eWorldTrade is a new online B2B site that has been growing fast and is creating a new and improved way for the buyers and sellers to reach each other. eWorldTrade is a subsidiary of Reckon Media LLC from United States, experienced in digital media and technological service providing. Headquarters of this eWorld trade site is located in the Dallas, Texas and it is running all its major operations from Karachi, Pakistan. It has now become a part of China-Pakistan Economic Corridor (CPEC) to make better trade relations between Pakistan and China. The main aim that this site is to help the Chinese suppliers, dealers and manufacturers reach their potential audience. This online global B2B platform is said to be one of the fastest growing online marketplaces where thousands of sellers, dealers, suppliers, manufacturers, and vendors are registering every day and meeting their potential clients from around the world. Thousands of manufacturers from different cities and countries are registering themselves on the website every day, and it can be seen that this platform will be great competitors to all other B2B platforms. eWorldTrade.com offers everyone a chance to become a reseller of different products and services. It has proved to be beneficial for small businesses and manufacturers in China who are willing to globalize their businesses [5].

E-commerce, driven by computer and internet technology, has experienced a significant growth in almost all fields during the past two decades. E-commerce has significantly changed the rules of business. Numerous research institutions and enterprises have made e-commerce more intelligent and convenient. Here, we propose a novel prototype of nextgeneration e-commerce platform with an architecture framework and theoretical models [6].

The online selling field may seem infinite in scope, too, with millions of potential customers worldwide. But, success in selling collectibles on the Web is gained in much the same way as it is in the physical world, by knowing buyers' needs and meeting them. Success can depend to a great degree on whether or not you are offering collectible properties able to meet at least one of these three key commercial elements: Not easily obtainable locally [7].

“Purchasing decision process” is when the relevant information is searched by the consumers that are motivated by the fulfillment of demands according to personal experience and the external environment; then after accumulating a certain amount of information, they begin to evaluate and consider; and finally, after comparison and judgement, they make the decision on certain products. Another factor that influences the customer’s intention to purchase in online is the previous online shopping experiences [8].

5. METHODOLOGY

The researchers used the agile methodology process that encourages frequent adaptation to reach the clients requirements in a specific time period. By using this process, the researchers were

able to create a system with clear and precise objectives relevant for a web-based project. The initial planning covered studying different kinds of technology and combining it to develop a project that would ease the current and previous processes. During the requirements gathering, the researchers gathered important functions, through interviews, survey to distributors and customers and site observation. After gathering the requirements, the researchers proceeded with the analysis and design, testing and evaluation. It used the information gathered from the basic research phase in order to create the system that would satisfy the researcher's objectives. Finally, the researchers conducted a survey to gather the results needed to create a conclusion for the research and development phase.

6. RESULTS AND DISCUSSION

The project is composed of four main processes. It starts from the vendor who uploads his/her products. The vendor and administrator are included in the first process. After uploading products, the administrator shall be notified by the system. The second process shall be covered by the administrator and distributor. All the products that the administrator approves as requested by the vendor can be posted on the catalog page. The distributor can choose the products that he/she can resell on the web application. The reseller can also upload his/her own products to the web application. All distributor's products shall be displayed to the home page. The third process covers the distributor and customer. It entails the usual consumer purchasing. For the purchasing transactions, the web application offers various modes of payment, including PayPal, bank deposit and cash on delivery. The fourth main process occurs when the customer apply as distributor. In this process, the web application enables the customer to upload necessary requirements. In turn, the administrator can approve or reject such customer's request to become a distributor. Should such request be approved, a distributor account shall be assigned to his/her name. All uploaded information shall be saved on the database. Apache is used as a server for accessing it on the web. Figure 1 shows the proposed flowchart of the e-commerce platform.

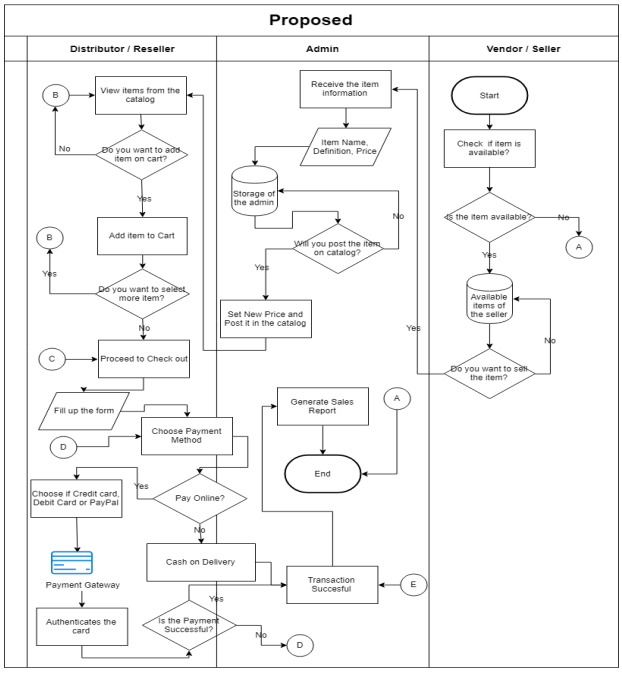

Figure 1. Propose Flowchart

The web application for the mining company consists of recording sales and conducting inventory of products and accounts. The website is the platform for buying and selling mining equipment products in the most efficient and convenient time. This website provides opportunities for reaching broader markets. Thus, it helps in the improving the sales and in strengthening communication line. With the easy interface, people of all ages can understand how to use the website such as in browsing and purchasing of the products.

6.1. Administrator Module

The administrator module contains features that manage the overall website. This module is used for sales and inventory management, vendor management, distributor management. In sales and inventory management, it manages the products being purchased and the stocks of the products. In the vendor management, it handles the vendor accounts and the products being uploaded. In the distributor management, it oversees the distributor accounts and approves or rejects customers that apply for distributor account. A screenshot of the administrator page is shown in Figure 2.

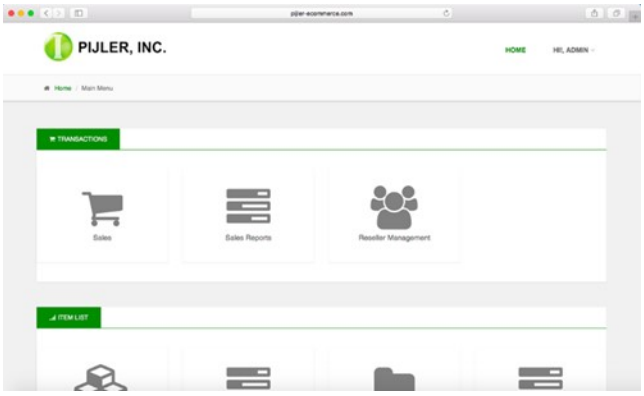

Figure 2. Administrator Page

6.2. Vendor Module

The vendor module permits the vendor to add their products and allows the administrator to approve it on the catalog page, where the wholesale price is changed. Only the administrator can add vendor accounts on the website. A screenshot of the vendor page is shown in Figure 3.

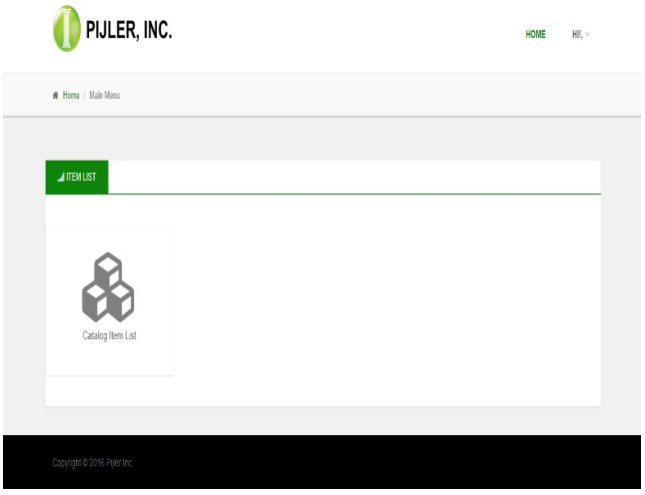

Figure 3. Vendor Page

6.3. Distributor Module

The distributor module has the same module with the admin module but they are focused more to customers' transactions. It has sales and inventory management that tracks the products which the customer purchased and product stocks. Thus, it can produce accurate reports. It also buys products from other distributors via PayPal, bank deposit and cash on delivery as their mode of payment. A screenshot of the distributor page is provided in Figure 4.

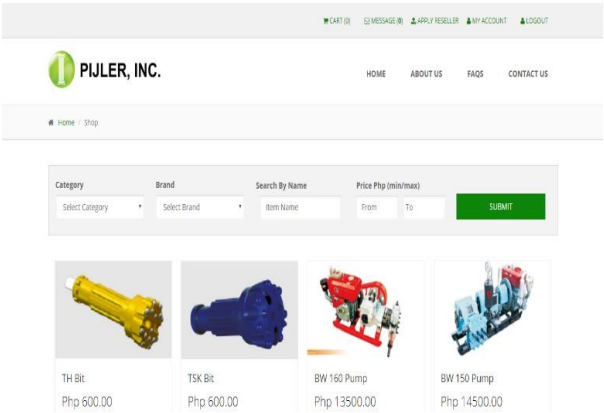

Figure 4. Distributor Page

6.4. Customer Module

The customer module is where the customers view and add to cart his/her products which he/she seeks. He/she can't buy directly from the vendor as a part of agreement with the administrator. It can also send messages for their inquiries. For the purchasing transactions, they can pay via PayPal, bank deposit and cash on delivery. A screenshot of the customer page is provided in Figure 5.

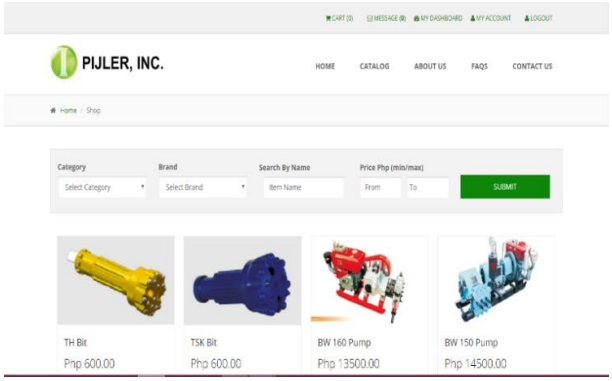

Figure 5. Customer Page

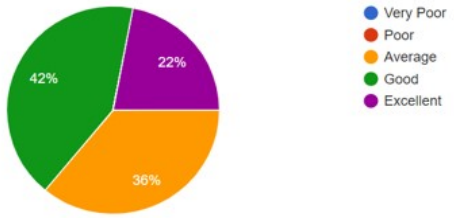

Figure 6. Test Results on functionality

Q2. How easy do you find the information you are looking for using the system?

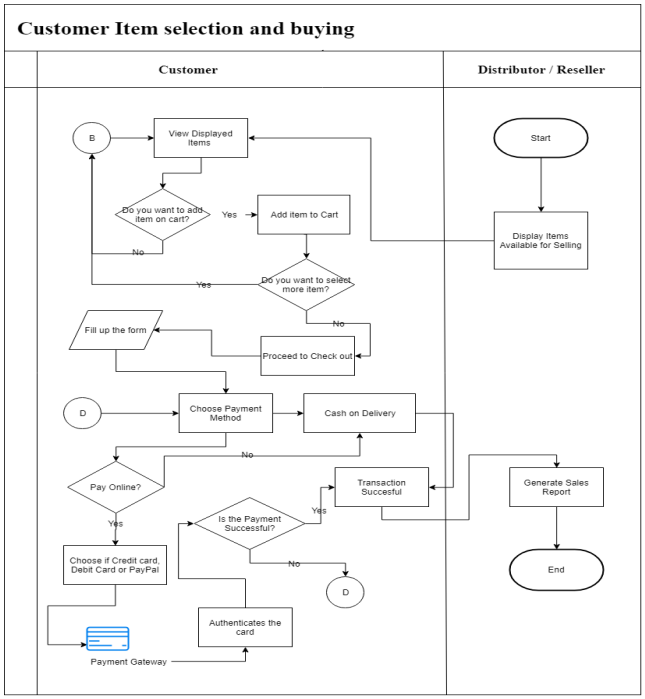

Figure 7. Customer item selection and buying process

The flowchart explain the process flow on how the buyer or customer select an item and buy products from the reseller or distributor. In order to proceed, the customer/ buyer should create an account and fill up the necesary information.

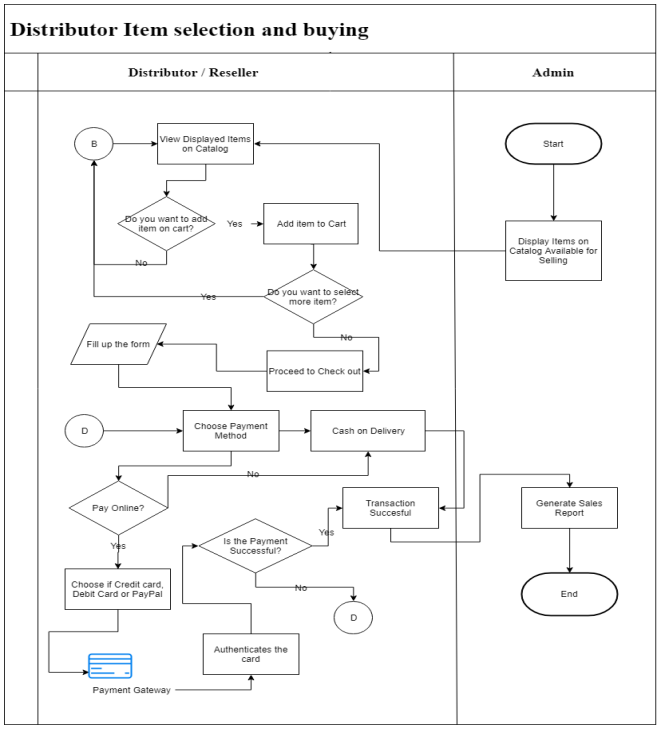

Figure 8. Distributor item selection and buying process

Figure 8 shows the process flow on how the reseller or the distributor buy prducrs from vendor/ admin. To proceed with the transaction, the reseller or distributor should complete the needed requirements to approved by the admin.

7. SYSTEM TESTING

This section discusses the results of the survey conducted with thirty (30) respondents comprised of vendors and customers. It uses Google Form to disseminate the questions. Below are the specific questions and respective results as also shown in Figures 6 to 10. The given percentages of the results show that using the proposed system is more favorable to the users.

Q1. How do you rate the functionalities of the system in terms of performance?

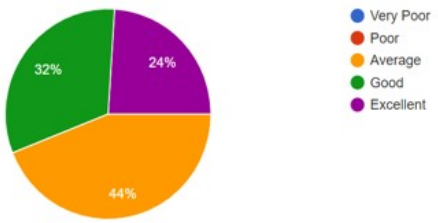

Figure 7. Test Result on usability

Q3. How do you rate the design of the interface of the system?

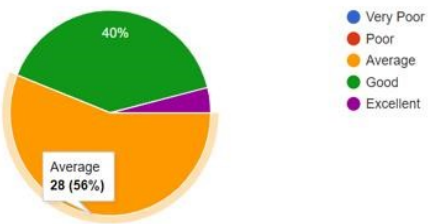

Figure 8. Test Result on User Interface Design

Q4. How the system satisfied your requirements for online business?

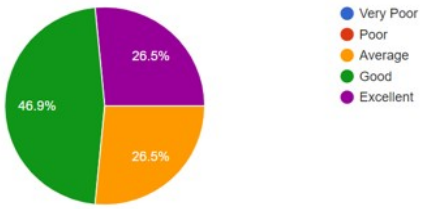

Figure 9. Test Result on User Satisfaction

Q5. Do you think the system is better than the traditional approach?

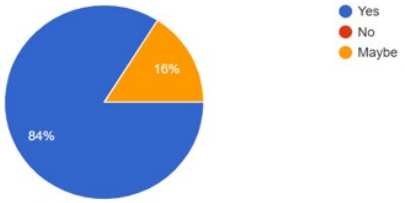

Figure 10. Test Result on User Preference

8. CONCLUSION

The E-commerce platform will definitely help the small to midsize mining equipment companies to have more efficient transactions. For the distributors, it will help them reach more customers and increase their sales performance.

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Applying The Dynamic Network DEA Model to Evaluate The Chinese Regional Sustainable Performance

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ABSTRACT
The purpose of this paper is to investigate the regional sustainable development performance of 30 provinces in China from 2012 to 2017, based on a dynamic network slacks-based measure (DNSBM) approach. We construct an evaluation framework with a dynamic two-stage model with serial connection. The major difference between this paper and previous literatures is the assumption of installed capacity, defined as a carry-over linking between two consecutive terms. The empirical result of the average regional sustainable development performance is 0.3487 for 2012-2017, due to lower average performance in the electricity portfolio stage than that in the energy productivity stage. The results from the model suggests that the provincial and central government should be put more efforts in the electricity portfolio, such as raising the zero-carbon capacity, to mitigate CO_2 emission.

CCS Concepts
• **Law, social and behavioral sciences → Economics**
• **Operations research → Decision analysis**

Keywords
Dynamic network model; Two-stage system; slacks-based measure; Sustainable development

1. INTRODUCTION
The effort to limit the Earth's temperature rise within 1.5oC above pre-industrial period, by controlling CO2 emission, is the major initiative fighting against climate change that threats the living environment of all species on the planet [1-2]. Sustainable development thus has become the priority on every government's policy directions, and China is no exception, since it become the world's largest GHG emitter alone its economic growth [3].

China has laid out a set of energy policies in its strategic planning on national development, i.e., the 11-13th Five-year Plan (from 2006 to 2020), and also participates in the Nationally Determined Contribution (NDC) that formulates the objectives for CO2 abatement by 2030. In addition, China has long been involved in renewable energy investment, and making structural changes in electricity mix by raising renewable energy share. Yet to maintain economic competitiveness, while fulfilling the international climate responsibility, it is important for the government to evaluate the consumption of primary energy and electricity mix, the current state of CO2 emission and economic performance as a whole.

In this paper, we used a sample of 30 provinces in China that had implemented regulations for environment protection, to estimate their regional sustainable development performance over the period 2012-2015, in terms of performance in electricity portfolio and energy productivity. We wanted to evaluate the regional sustainable development performance with the intertemporal effect, which was the carried-over activity linking two consecutive periods in the electricity portfolio stage. The proposed evaluation framework made not only measure the overall and stage performance and observe their dynamic change possible, but could also identify the variables that contribute to improvement on each performance stage, which could be used to plan future policy.

The main findings of this paper can be summarized as follows. First, we found that the average sustainable development performance in provincial administration level was not very high, mainly because the average performance in the electricity portfolio stage was obviously lower than that in the energy productivity stage. This suggested the provincial and central government should put more efforts in adjusting the electricity portfolio by measures such as adding zero-carbon capacity to mitigate CO2 emission. In addition, except of the nuclear, other renewable energies capacity should built near the region to satisfy the requirement of the electricity due to its unstable characteristics.

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Second, since the eastern region showed the best energy productivity performance, following by the western region, while the central region demonstrated the worst performance, it was not surprising to see the eastern region had achieved the impressing economic performance after the policy reform in 1978. This suggested by improving the performance in the electricity portfolio, a region could boost both its sustainability and economic performance.

The remainder of this paper is structured as follows. Section 2 introduced the research methodology. The conceptual two-stage evaluation framework of regional sustainable development performance and the definition and data source of variable selection were presented in Section 3. In Section 4, we presented the empirical results for the regional sustainable development performance on provincial level and classified into area in China. Finally, in section 5 we concluded our research with discussion of policy implication.

2. RESEARCH METHODOLOGY

2.1 Dea Methodology

We used the useful quantitate tool, data envelop analysis (DEA), to estimate performance score among evaluated homogenous decision making units (DMUs). Tone and Tsusti [4] argued that traditional DEA models focusing on each DMU with multiple inputs and outputs in the separate time period worked independently. There were some approaches, such as windows analysis and Malmquist index with dynamic DEA structure, that can be used handle the specific characteristic of time effect under the DEA-based framework. In a real business environment, however, for managers responsible of long-term strategic planning, it is important to consider intertemporal effects in order to assess a DMU's efficiency comprehensively. While previous models had not taken the impact of carry-over activities between two consecutive periods into consideration, we have incorporated the carry-over activities into our DEA-based evaluation framework.

Dynamic DEA models with inter-connected activities had been proposed to evaluate relative performance behavior of DMUs in a intertemporal setting for long-term optimization. The sequent development was proposed by Guo et al. [5] for further applications. Tone and Tsutsui [6] also expanded dynamic DEA in terms of slacks-based measure (SBM) and introduced the dynamic network SBM model to evaluate performance.

Furthermore, traditional DEA treats the operational structure of each DMU as a black-box to be ranked and thus inefficient ones were exposed. Unfortunately, it also omits valuable managerial information to manager as how to improve efficiency in the value-creation chain. Under the two-stages framework, nonetheless, we were able to open the DMU black-box, decompose it into stages, or divisional structure with network connection. This method is commonly used to depict the operational structure in many industries [2, 7-9]. In this paper, we adopted assumptions of Tone and Tsutsui [6]. The model is presented in the following section.

2.2 The Two-Stage Dynamic Network Slacks-Based Measure

The two-stage dynamic network structure with serial connection in this empirical study was a variation of the general network DEA. Consider that there were n provinces/regions $(j=1,2,3,...,n)$ treated as DMUs, and that each DMU was involved in two stages as the electricity portfolio stage (k) and the energy productivity stage (h) during T terms ($t=1,2,3,...,T$). There were L_{hk} serial connection link between the electricity portfolio stage. The energy productivity stage in period t was donated by $(k,h)_1^t$ $(l=1,...,L_{hk})$. In the electricity portfolio stage, a regional sustainable system consumes m_k^t inputs at time t was denoted x_{ijk}^t $(i=1,...,m_k^t;\ j=1,...,n;\ t=1,...,T)$, while the number of intermediate outputs was donated $z_{i(h,k)l}^t$ $(j=1,...,n;\ l=1,...,L_{hk};\ t=1,...,T)$. There were L_k carry-over activities between two consecutive periods in the electricity portfolio stage (k) denoted as $c_{jkl}^{(t,t+1)}$ $(j=1,...,n;\ l=1,...,L_k;\ t=1,...,T)$. In addition, at the energy productive stage, a regional sustainable system would consume u_h^t and $z_{i(h,k)l}^t$ units of the intermediate output in the electricity portfolio stage, to create r_h^t desirable output and b_h^t undesirable output at time t, respectively. y_{rjh}^t $(r=1,...,r_h^t;\ j=1,...,n;\ t=1,...,T)$ was the desirable output, produced from the energy productive stage, with undesirable by-product y_{bjh}^t $(b=1,...,b_h^t;\ j=1,...,n;\ t=1,...,T)$.

We used dynamic network slacks-based measure (DNSBM) to evaluate regional sustainable development performance. Eq. (1) estimated the overall performance of observed DMU_o $(o=1,...,n)$:

$$\theta_0^* = \min \frac{\sum_{t=1}^{T} W^t \left[\sum_{k=1}^{K} w^k \left[1 - \frac{1}{nd_k^t + m_k^t} \left(\sum_{kl=1}^{nd_k^t} \frac{s_{oklbad}^{(t,t+1)}}{c_{okl,bad}^{(t,t+1)}} + \sum_{i=1}^{m_k^t} \frac{s_{iok}^{t-}}{x_{iok}^t} \right) \right] \right]}{\sum_{t=1}^{T} W^t \left[\sum_{k=1}^{K} w^k \left[1 + \frac{1}{lino_k^t + r_h^t} \left(\sum_{ou1=1}^{lino_k^t} \frac{s_{o(k,h)out}^t}{z_{o(k,h)out}^t} + \sum_{r=1}^{t_h^t} \frac{s_{roh}^{t+}}{y_{roh}^t} \right) \right] \right]} \quad (1)$$

3. MODEL BUILDING AND DATA COLLECTION

3.1 Conception Framework

Fig. 1 illustrated the logic behind the evaluation framework used in this paper to estimate the Chinese regional sustainable development. The operational structure was decomposed into two stages with serial connection and intertemporal relationship, while with different objectives of the stages in the entire energy-economic-environmental (EEE) chain.

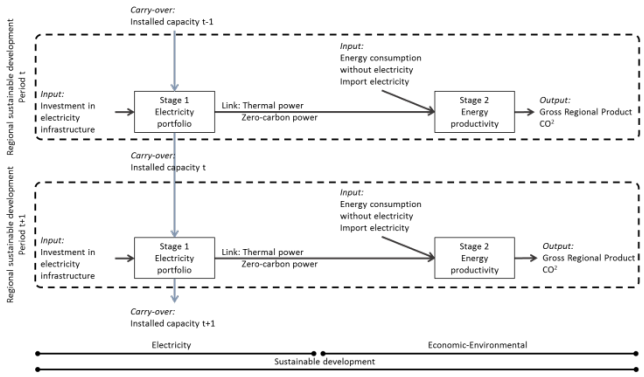

Figure 1. Dynamic two-stage network structure for regional sustainable development

Stage 1 was called the "Electricity Portfolio" from energy efficiency perspective. In this stage, the DMUs used standard inputs investing in energy infrastructure, to add on or replace the power plant capacity. In addition, there was a carry-over activity as an important factor in stage 1 between two consecutive periods, resulted from each provinces' energy industry who had controlled the power plant capacity in response to electricity demand from housing, industrial, and commercial activities.

Stage 2 was the period for "economic development and environmental protection;" the objectives were promoting regional economic growth and the sustainable development at the same time. Both the electricity from thermal power plant and nuclear or/and renewable energies, which were the intermediate outputs from stage 1, become the intermediate inputs to stage 2. The desirable and undesirable outputs of stage 2 were: (a) regional gross product and (2) CO2 emission. Note that in stage 2, total primary energy consumption (excluding electricity) were added as an extra input to stage 2. The detailed explanations of variables were found in section 3.2.

3.2 Inputs and Outputs Indicators

In line with the illustration in Fig. 1, we employed 8 variables to construct an evaluation framework to estimate regional sustainable development performance: in stage 1 there was only one input; in stage 2 there were two inputs, two intermediate outputs/inputs derived from stage, and one carry-over variable between stage 1 in two consecutive periods, one desirable output, and one undesirable output. The input variable was investment in electricity industry, the intermediate outputs/inputs were thermal power and zero-carbon power, the desirable output was regional gross product, the undesirable output was CO2 emission, and the carry-over variable was power plant capacity. We illustrated the definition of selected variables in Table 1.

Table 1. Variables definition

Indicator	Definition	Unit
Investment (Input)	The investment amount in electricity infrastructure	100 million RMB
Installed capacity (Carry-over)	The installed capacity for electricity generation	MW
Thermal power (Output/Input)	The electricity generation from thermal power plant	100 million kWh
Zero-carbon power (Output/Input)	The electricity generation from nuclear and renewable energies	100 million kWh
Primary Energy consumption (Input)	The primary energy consumption without electricity	Million ton of oil equivalent
Imported Electricity (Input)	The electricity import from other provinces and/or regions	100 million kWh
Regional gross product (Output)	Gross product produced from province and/or region	100 million RMB
CO2 emission (Output)	CO2 emission produced from energy consumption attributed to province and/or region	Million ton

3.3 Data Collection

The evaluation framework and methodology described in section 2.2 and 3.1 were applied to the a sample of 30 the Chinese provincial regions to estimate the regional sustainable development performance for the period 2012-2017. We selected the regional units with the most complete statistics for the variables used in our model.1 The data of the original values of investment, installed capacity on electricity generation, thermal and zero-carbon power, primary energy consumption, and regional gross product were from China Energy Statistics Yearbook and China Electric Power Yearbook. Imported electricity was measured by the result of total electricity consumption minus the electricity generation in a specific region during a certain period. The data on CO2 emission were calculated by the amount of regional consumption of coal, oil, natural, and electricity, times their corresponding CO2 emission coefficients, according to the Intergovernmental Panel on Climate Change (IPCC) Guideline for National Greenhouse Gas Inventories [10], as shown in Eq. (2):

$$\sum_{i=1}^{E} CO2_{ijt} = E_{ijt} \times NCV_i \times CEF_i \times COF_i \times (44/12)$$

(2)

where $CO2_{ijt}$ denoted the CO2 emission from energy type i, such as coal, crude oil, natural gas, and electricity in a region j at year t; E_{ijt} denoted the total consumption of each type of energy from region j in year t; NCV_i was the net calorific value of each type of energy; CEF_i denotes the carbon emission factor of each type of energy; and COF_i denotes the carbon oxidation factor of each type of energy. The constant value of 44 and 12

[1] Tibet was not included in this paper due to the lack of data.

were the molecular weights of CO2 and carbon, respectively. The descriptive statistics of variables were summarized in Table 2. It should be noted that all monetary variables used in this paper were in 2012 RMB, which have been deflated with the customer price index (CPI index 2012 = 100).

Table 2. Descriptive statistics

Variables	Mean	Std. Dev.	Max	Min
Inputs-R&D				
Investment	567.83	376.92	2,214.23	73.10
Intermediate outputs				
Thermal power	1,420.17	1,131.58	4,671.00	120.00
Zero-carbon power	479.61	606.89	3,215.00	4.90
Carry-over				
Thermal Capacity	3,217.33	2,312.75	10,335.00	230.00
Zero-carbon Capacity	1,629.91	1,572.94	8,059.00	23.70
Inputs-Commercialization				
Primary Energy consumption	143.97	99.04	482.90	15.85
Imported Electricity	1,394.81	607.65	3,144.00	1.00
Final outputs				
CO2 emission	526.79	346.09	1757.02	75.62
RGP	22,282.84	16,804.72	81,571.96	1,893.54

4. EMPIRICAL RESULTS

4.1 Efficiency Analysis of The Regional Suatainable Development

In order to estimate the regional sustainable development performance of each region in China in the period 2012-2017, it was important to choose suitable weights for time period and stage in Eq. (1). Per Tone and Tsutusi's suggestion [6], the last period T can be treated as having the largest contribution to the evaluation framework. Therefore, we reckoned that the weight of period-efficiency in the regional sustainable development performance should increase yearly. We used a year's 4 digits to calculate the weight for each period. As such, the preferred weights assigned to the year during 2012 to 2017 were as followed: 2012=0.048, 2013=0.095, 2014=0.143, 2015=0.19, 2016=0.238, and 2017=0.286. In addition, it would be reasonable to assume the overall performance of two-stage DEA framework with serial connection as the weighted sum of the performance behavior of the individual stages [7]. Thus, in this paper we assumed that both the electricity portfolio stage and the energy productivity stage have the same contribution to the regional sustainable development, and assigned each stage with the same weight of 0.5.

From Eq. (1), we calculated the sustainable development performance of each region in China and the results were listed in Table 3. In Table 3, we could see that only Hainan and Sichuan were deemed as well-performed in sustainable development during 2012-2017. Yunnan, Hubei and Guizhou had the third- and fourth- largest sustainable development performance score, i.e., 0.9108 and 0.8145, respectively. These results also echoed their stage-wise performance, such as that Hubei had much higher electricity portfolio stage efficiency. Tianjin's sustainable development performance score was 0.0223, ranking at the bottom of the selected regions. For specific stage evaluation results, we found that only Hainan was deemed efficient in the electricity portfolio stage, while six other regions, i.e. Beijing, Inner Mongolia, Jiangsu, Guangdong, Hainan and Sichuan, were efficient in the energy productivity stage.

From the results, one can see that most of the Chinese regions had good performance scores in the energy productivity stage. This suggested that the electricity portfolio stage might be the main culprit for the weak performance of regional sustainable development.

Table 3. Efficiency analysis and ranking by provinces and/or regions

DMU	Electricity Portfolio efficiency	Energy Productivity efficiency	Regional Sustainable Development	Rank
Beijing	0.0273	1.0000	0.0591	29
Tianjin	0.0123	0.7516	0.0223	30
Hebei	0.0696	0.3160	0.0988	22
Shanxi	0.0638	0.2389	0.0823	25
Inner Mongolia	0.1385	1.0000	0.3020	14
Liaoning	0.3195	0.3298	0.2962	16
Jilin	0.1255	0.6516	0.1943	18
Heilongjiang	0.1300	0.4682	0.1820	19
Shanghai	0.0518	0.6941	0.0817	26
Jiangsu	0.0937	1.0000	0.2047	17
Zhejiang	0.2936	0.7772	0.4200	12
Anhui	0.0447	0.5848	0.0708	28
Fujian	0.3699	0.7829	0.5013	8
Jiangxi	0.1851	0.6584	0.3005	15
Shandong	0.0345	0.7231	0.0824	24
Henan	0.0526	0.5665	0.0894	23
Hubei	0.8549	0.7776	0.8145	4
Hunan	0.3529	0.7483	0.4668	9
Guangdong	0.3475	1.0000	0.5503	6
Guangxi	0.3971	0.5604	0.4606	10
Hainan	1.0000	1.0000	1.0000	1
Chongqing	0.3209	0.6835	0.4315	11
Sichuan	0.9999	1.0000	1.0000	1
Guizhou	0.9152	0.4282	0.5666	5
Yunnan	0.9968	0.9948	0.9956	3
Shaanxi	0.0540	0.4443	0.0812	27
Gansu	0.3807	0.2817	0.3075	13
Qinghai	0.3907	0.9363	0.5293	7
Ningxia	0.1254	0.1414	0.1255	21
Xinjiang	0.1303	0.1823	0.1424	20
Mean	0.3093	0.6574	0.3487	

4.2 Efficiency Analysis on Regional Discrepancy

Based on the geographical location and economic development, the 30 regions in the research sample could be grouped into three areas: the east, the central and the west, as listed in Table 4.

Table 4. All selected provinces classified into three areas in China

Areas	Provinces and regions
East	Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Central	Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan
West	Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang

Table 5 demonstrated sustainable performance and stage-wise performance of each area group. One could see that the results of these three area group were very difference, while the performance in the electricity portfolio and energy productivity stages remained similar. The East Area ranked first in the energy productivity stage, which could be due to significant effort it had put on to promote economic growth. The West Area ranked first in the electricity portfolio stage, which could be attributed to the effort on the improvement of electricity mix with lower CO2 emission. In summary, because the economic performance was still a crucial criterion for the political ascension, it was natural for regional administration to focus on economic performance more. However, since the performance of energy productivity also played an important role in regional sustainable development, China's central government should pay more attention to the performance of the electricity portfolio stage regardless, as it would translate into better regional sustainable development.

Table 5. Regional sustainable development performance scores of the three areas in China

Electricity Portfolio efficiency			
Region	Mean	Efficiency	Inefficiency
Eastern Region	0.2382	1 (9%)	10 (91%)
Central Region	0.2262	0 (0%)	8 (100%)
Western Region	0.4409	0 (0%)	11 (100%)
Energy Productivity efficiency			
Region	Mean	Efficiency	Inefficiency
Eastern Region	0.7613	4 (36%)	7 (64%)
Central Region	0.5868	0 (0%)	8 (100%)
Western Region	0.6048	2 (18%)	9 (82%)
Regional Sustainable Development			
Region	Mean	Efficiency	Inefficiency
Eastern Region	0.3015	1 (9%)	10 (91%)
Central Region	0.2751	0 (0%)	8 (100%)
Western Region	0.4493	1 (9%)	10 (91%)

5. CONCLUSION

We used the DNSBM approach in this paper to construct the two-stage evaluation framework with serial connection and carry-over activity, to estimate the regional sustainable development performance at provincial level in China over the period 2012-2017. The main findings of this paper can be summarized as follows.

First, we found that the average sustainable development performance at provincial level was not very high, mainly because the average performance in the electricity portfolio stage was lower than that in the energy productivity stage. It suggested the regional and central government should put more efforts to improve the electricity portfolio, such as adding more carbon-free capacity to reduce CO2 emission. In addition, except of the nuclear, other renewable energies capacity should built near the region to satisfy the requirement of the electricity due to its unstable characteristics.

Second, the eastern region showed the best energy productivity performance, followed by the western region, while the central region demonstrated the worst performance. This suggested that the efforts to improve energy productivity could play an important role for eastern region to achieve the impressive economic performance since the 1978 political reform. To make the most out of economic and energy investment, all regions should be encouraged to make more efforts to improve performance in the electricity portfolio stage. As we know that the electricity consumption is encouraged to be an effective strategy to mitigate the demand of primary energy with lower CO2 emission for supporting the economic activities.

6. ACKNOWLEDGMENTS

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The Transformation Path of Sports Brands in the Context of Consumption Upgrading

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ABSTRACT
With the change of the main groups and consumption preferences in the China's market, the consumption structure of China residents is transitioning to development and enjoyment. Therefore, in order to better meet consumers and improve market competitiveness, China's domestic brands are facing transformation and upgrading. This article selects four sports brands - Li Ning, Anta, Xtep and 361°- as research objects in the context of consumption upgrade. This article compares and analyzes their brand transformation measures and present management situation, and makes further recommendations about the transformation of China's sports brands.

CCS Concepts
• General and reference→ Document types • Surveys and overviews

Keywords
consumption upgrading; brand transformation; sports brand

1. INTRODUCTION
The per capita disposable income of residents increased with the steady growth of the economy, and the consumer demand of residents gradually diversified and refined. Residents' consumption upgrading has become an irreversible trend[11]. In the consumer goods market, human demand is an important factor to promote consumer behavior. According to maslow's hierarchy of needs, human needs are divided into two categories: high and low. When the low-level physiological needs are met, people's enthusiasm for the pursuit of high quality of life increases, and the consumption structure also changes.[1]

In the context of consumption upgrades, China sports brands 'operations have been affected to a certain extent due to their unclear positioning, weak brand awareness, and inability to meet consumers' requirements for design and high performance.Many brands that failed to make corresponding adjustments in a timely manner have waned during the consumption upgrade process. In order to get rid of this unfavorable stereotype and better meet consumer needs. In recent years, the brand awareness of China companies has gradually risen, and they have begun to use multiple channels and methods to change brand image in the eyes of consumers. For consumers' increasingly diversified and refined needs, companies need to have a more acute market insight, reasonably control the degree of product differentiation, and avoid product homogeneity.

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2. OVERVIEW OF CHINA SPORTS BRAND MARKET

2.1 Introduction to The Four Major Sports Brands
The Li Ning brand was founded by "Prince of Gymnastics" Li Ning in Sanshui, Guangdong, China in 1990, and was listed on the main board of the Hong Kong Stock Exchange in 2004. The Anta brand was established in Jinjiang, Fujian, China in 1991, and was listed on the main board of the Hong Kong Stock Exchange in 2007. The Xtep brand was established in Quanzhou, Fujian, China in 2002, and was listed on the main board of the Hong Kong Stock Exchange in 2008.The 361 ° brand was established in 2003, in Quanzhou, Fujian, China, and was listed on the main board of the Hong Kong Stock Exchange in 2009.

2.2 Status of Operation of Four Sports Brands
According to CNPP China's top ten sports shoe brand rankings, at present, Li Ning, Anta, Xtep and 361 ° are better performing in CHINA local sports brands[1]. As can be seen from Figure 1, Li Ning Company had the highest operating income before 2011, and Anta had the highest operating income after 2011. The operating income of the four brands all declined around 2012. And the main reason is that on the one hand, labor costs Rising and stricter environmental protection policies have reduced the profit margins of enterprises; on the other hand, the backlog of corporate inventory and the homogeneity of products have led to the loss of market competitiveness. Then in 2014, the operating income of the four brands began to pick up. As of 2018, Anta's revenue was growing fastest, followed by Li Ning, and Xtep and 361°'s revenue has remained roughly the same. As can be seen from

[1]Data source https://www.china-10.com/china/023ydx_index.html

Figure 2, the current scale of Anta's enterprises is the largest[2], and the gap between other brands is not large. The scale of four enterprises is keeping growing on the whole. However, compared with international famous sports brands such as adidas and Nike, the enterprise scale of four brands in this paper is relatively small and the brand competitiveness is relatively weak. To some degree, this shows four brands still have large improvement space, urgently needing to find a better development path.

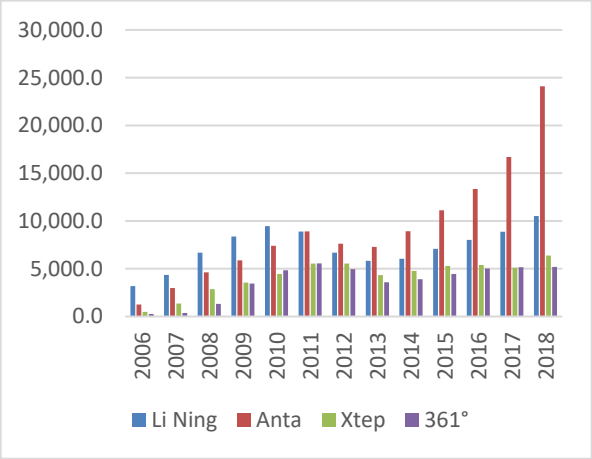

Figure 1. Operating revenue of the four major brands from 2006 to 2018 (Unit: million yuan)

Data source: official websites of various brands

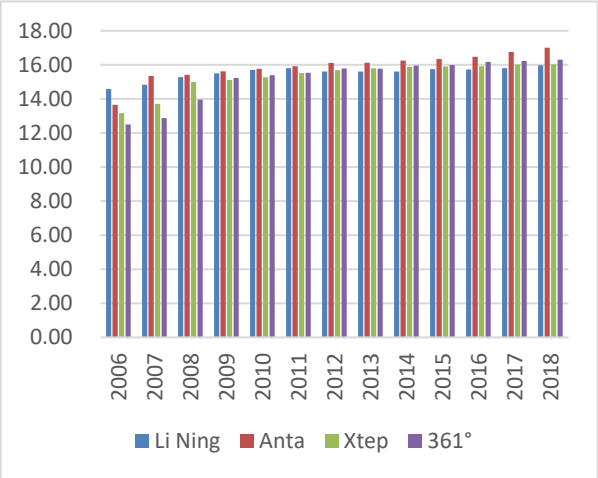

Figure 2. Scale of the four major brand enterprises from 2006 to 2018

Data source: official websites of various brands

3. TRANSFORMATION MEASURES OF CHINA SPORTS BRANDS IN THE CONTEXT OF CONSUMPTION UPGRADE

3.1 Multi-brand Strategy

After the financial crisis in 2008, China's capital was very active in cross-border mergers and acquisitions. In this article, Anta is the typical representative. In 2009, Anta obtained the operating rights of FILA, FILA Kids, and FILA Fashion in mainland China and Hong Kong and Macao, which not only made Anta's operating revenue increased substantially also allowed Anta brands to own mid-to-high-end products. In addition to FILA acquisitions, other brands acquired by Anta were also mid-to-high-end brands.

Similar to Anta, Li Ning also has many sub-brands. Li Ning builds a brand system with five product categories consist of basketball, running, training, badminton and sports fashion, and its acquired brands can fill the gap in the brand system. Xtep in 2019 Successfully acquired E-Land Footwear USA Holdings Inc. to become the ultimate owner of the K-Swiss, Palladium, and Supra brands, further enriching the brand portfolio. Among the four brands, 361° has the fewest sub-brands and has just acquired the ONEWAY brand since its establishment. As shown in Table 1, all four brands have established children's sub-brands, and Li Ning subdivided children's sub-brands into young children and adolescents.

Table 1 Statistics of subsidiary brands of each brand

brand name	Sub-brand
Li Ning	Li Ning Kids, Young, LNG, Double Happiness, Kason, lotto, DANSKIN, AIGLE
Anta	Anta Kids, FILA, FILA Kids, FILA Fashion, Kingkow, KOLON SPORT, DESCENTE, Sprandi, Amer Sport, ARC'TERYX
Xtep	Xtep Kids, K-Swiss, Palladium, Saucony, Merrell, Supra
361°	361°Kids、ONEWAY、

Data source: official websites of various brands

3.2 Multi-channel Sales Strategy

The prosperity of Internet technology has made traditional retail cease to be the mainstream method of merchandise sales. New retail has emerged at the historic moment. The organic combination of online and offline and the simultaneous development of domestic and foreign countries is the sales method chosen by most brands. Online sales are mainly based on e-commerce B2C. The format is expanded, and brand is set up their flagship store in Tmall, JD.com and other apps. In addition to opening traditional stores in the offline sales mode, brands will now choose to set up new forms of stores such as experience stores, concept stores, and fashion stores. In order to further increase product sales, all brands are actively expanding overseas market. At the current stage, the active export regions of the brand are mainly Southeast Asian countries and African countries when sports brands implement international strategies, and there also have corresponding market strategies in Western developed countries such as the United States.

3.3 Brand Repositioning Strategy

A variety of factors can lead to the occurrence of repositioning, which can be summarized as follows: 1.Incorrect initial positioning; 2.Successful extension of the brand; 3.The product

[2] Enterprise scale is equal to the natural logarithm of the total assets of the enterprise.

has entered a recession period; 4.The expansion of product functions; 5.Consumption concepts and consumption behaviors changed tremendously[2]. According to the previous description, it is known that the factor that promotes brand repositioning in this article is the fifth. Now the consumer group in the China sportswear market is younger, and the proportion of people under 35 is nearly 90%.[3] In the context of consumption upgrades, product prices are no longer the main factor that most consumers consider when purchasing products, and younger consumers pay more attention to brand personality, product design and product performance. In order to meet new consumer needs, brands are gradually shifted their product position from low to mid-to-high end, and in like manner product development have began to be valued.

The "Chinese style" that has risen in the past two years is one of the measures for the brand to reposition its own products. Li Ning entered the New York Autumn and Winter Fashion Week in February 2018 as a representative. From the existing show clothing of Li Ning, the brand has regarded their founder Li Ning as the most core design element, and every show design would be used available elements from Li Ning's own life experience. After each show, the public's recognition of the Li Ning brand would further deepen. A unique brand personality has been formed. The brand clothing design elements are flexible in use, harmonious in color matching, and adhere to the integration of Chinese character art and traditional embroidery craftsmanship in the products, all of which have met the requirements of the young generation for product design.

3.4 Comprehensive Marketing Strategy

Sponsoring sports competitions, endorsements of well-known athletes, etc. are more traditional sports brand marketing methods, which are not enough effective for the generation Z who has grown up with the development of the Internet. The characteristics of generation Z consumers are characterized by their strong curiosity, being crazy about use the social media, the courage to express their views, etc., the continuous evolution of mobile electronic devices has also made daily information more accessible to the Internet. With the help of big data technology, online advertising can be accurately placed to increase brand exposure.

As ordinary advertisements can no longer effectively attract consumers' attention, in addition to establishing official accounts in social media such as WeChat and Weibo, KOL marketing has become a new choice for brand marketing. Brand endorsements have also occurred changes in recent years, celebrity experience officers, celebrity designers, etc. are all new forms of brand spokespersons. Stars or KOLs often share and interact with consumers in a VLOG manner, or brands will allow consumers to interact directly with spokespersons in offline meetings, in order to enhance the brand's image in the minds of consumers. Meanwhile, the same star style, brand joint and limited edition have brought a high degree of attention to the brand, and adequately meet the brand's personality demand.

[3] Data from http://ecoappimg.qianzhan.com/files/201907/02/20190702-7a745a79b3e94d70.pdf

4. ANALYSIS ON THE TRANSFORMATION MEASURES OF CHINA SPORTS BRANDS

4.1 Increased Brand Exposure and Increased Attention

In February 2018, Li Ning entered the New York Autumn and Winter Fashion Week, bringing China's elements to the International Fashion Week, which opened the first year of the "national tide" of China's local clothing brands. As can be seen from Figure 3, the appearance in New York Fashion Week that let Li Ning achieved unprecedented domestic attention, and its attention has been significantly higher than other brands in the following six months. Similarly, it can be seen from Figure 4 that Li Ning's external attention has also increased obviously in February 2018. The next half year also showed a higher degree of attention than other brands.

It can be seen from Figures 3 and 4 that the exposure and attention of the four brands are different at home and abroad. There is a clear stratification in the attention of the four domestic brands. Li Ning's attention was the best, Anta second, Xtep and 361 ° were both relatively low. While the external attention of the four brands is not much different, only Li Ning's attention wouldl be higher.

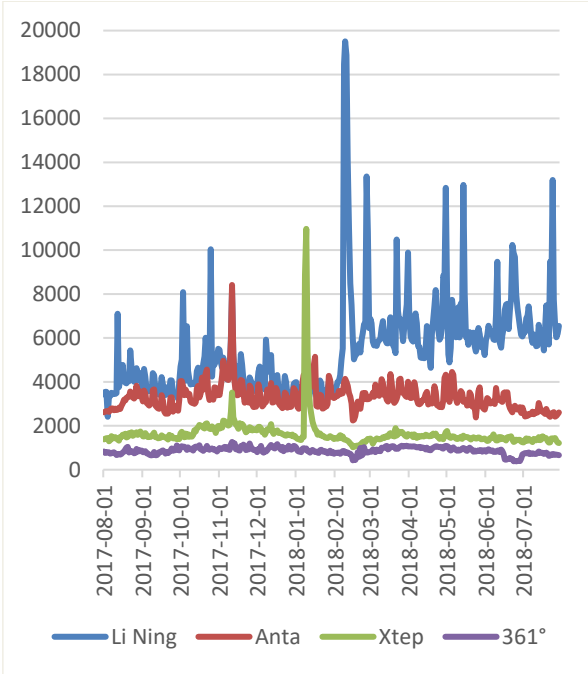

Figure 3. Baidu Index of the four major brands 2017.8.1-2018.7.29 [4]

[4] Data source: Baidu index http://index.baidu.com/

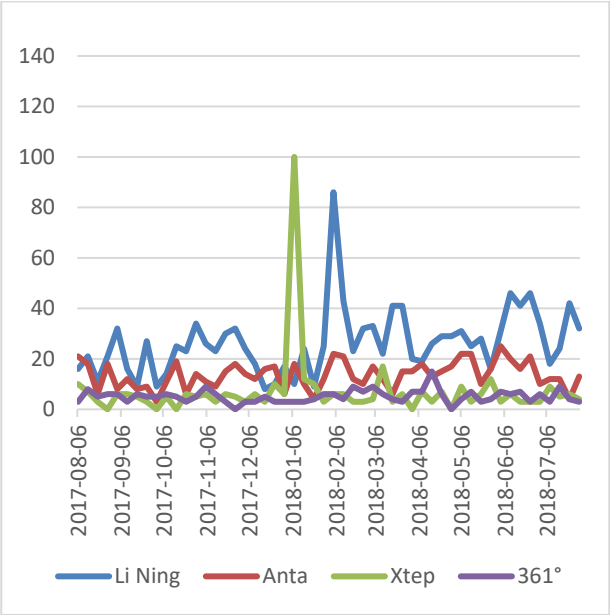

Figure 4. Google Trends of the Four Major Brands 2017.8.1-2018.7.29 [5]

This shows that on the one hand, entering the New York Fashion Week have separated Li Ning from other brands in the minds of domestic and foreign consumers; on the other hand, it indicates that China's sports brands have problems in overseas marketing, and brand marketing has failed to truly grasp the behavioral psychological characteristics of foreign consumers.

4.2 Increased Brand Awareness

Brand awareness is the core of the company's business philosophy.The presence or absence of awareness can directly determine whether the company can fully use the effectiveness and value of the brand and indirectly determine the success or failure of the business[3]. In recent years, each brand has begun to attach importance to the overall construction, then the quantity and quality of its products have been valued. The development of brand itself and the pursuit of external cooperation have been carried out simultaneously. Establishing a brand personality and improving product identification have become the business direction of the enterprise. Brands are more inclined to corporate with high-tech, high-performance technology companies when looking for partners for which consumers have gradually paid attention to product fabrics and the need to strengthen product quality. And that brand co-branding is no longer limited to design co-branding. For example, Anta was co-branded with the textile raw material giant SORONA®. According to the current market performance of the four brands, their brand awareness has basically been strengthened, and they have been actively planning so far.

Under the background of consumption upgrading, the future development trend of consumer goods brands is high-end, niche and customized. So the brand needs to find the correct positioning, establish a strong brand image in the hearts of consumers, and improve consumers' brand familiarity. Brand familiarity can effectively influence consumers' treatment of media news and advertisements related to brands, which is conducive to expanding new markets[4].Taking this one step further, in a homogeneous mass consumer market, customers will take brand familiarity as one of the purchasing reference indicators[10].

4.3 Insufficient R & D Investment

In this article, the ratio of R & D investment to annual income is used to represent the strength of R & D investment of brands. The trend of R & D investment intensity of each brand is shown in Figure 5. As can be seen from the figure, only 361° R & D investment intensity has continued to increase, and its intensity is currently the largest of the four brands. Before 2015, Li Ning's R & D investment intensity was significantly higher than other brands, but it declined sharply in 2015. It is currently the smallest of the four brands. Anta possesses the largest scale and the highest annual income, but its R & D investment intensity is maintained at about 2%, which is similar to Xtep's R & D investment intensity which annual income and scale are smaller. In other words, there is no consistency between brand operating income and R & D investment intensity, and brand's emphasis on R & D does not increase with the increase of operating income.

Lacking of long-term brand management is the main reason for the insufficient of R & D investment of sports brands. On the one hand, R & D investment brings long-term benefits and there is a certain lag[5]. On the other hand, there is a time cycle for product design and development that asks brands to be patient. Under the circumstances of drastic changes in the external economic environment, brands are more eager to get short-term returns, and R & D investment is not a brand's hard spending. In fact, R & D investment brings the core competitiveness to the brand, which is conducive to the brand's promotion of influence. In a word, R & D investment not only increases tangible assets but also enriches intangible assets[6].

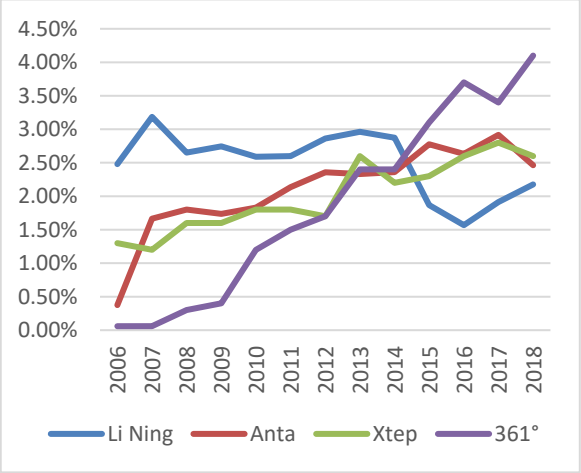

Figure 5. R & D investment intensity of the four major brands from 2006 to 2018 [6]

4.4 Slow Brand Internationalization Process

The comparison between the domestic market and the foreign market shows that the sales status of four brands in the

[5] Data source: Google Trends http://www.google.cn/rebang/home

[6] Data source: annual report information of various brands

international market is not optimistic, and the proportion of foreign operating income in the total revenue is very low. While brands have been enter international markets for some time, it appears to have little effect. What's more, brand internationalization measures are relatively single, mainly relying on cross-border M & A of other brands. In addition, the operation and management after M & A is a common problem faced by brands, whether the brand can increase its international market share is highly uncertain. Compared with the existing international famous brands, the four brands are in a weak position. In the future, brands need to focus on the exploration of the international market. Relying on the domestic market alone cannot meet the long-term sustainable development of brands. To accelerate the process of brand internationalization, the biggest benefit is to improve the brand market structure, enhance the comprehensive strength.

5. SUGGESTIONS AND CONCLUSIONS

5.1 Suggestions

Through the foregoing discussion, we can make the following three suggestions for the transformation of sports brands. First, brands should pay more attention to after-sales service and show consumers what countermeasures the brand has to counterfeit goods, so as to reduce consumer worries about shopping. When consumers buy fake commodities, the shopping experience drops sharply and the possibility of making a second purchase is reduced. Next, brands can carry out more brand activities, inviting more ordinary people to participate in the process, and narrowing the distance between the brand and consumers. Similarly, the brand side can also choose to establish a brand community, to some extent to achieve the integration of production, transmission and marketing[7]. Brand sponsorship can be not limited to sports-related events, and also can focus on the factors of fashion and leisure to liberate the brand image from sports. In the end, brands should avoid the brand management myopia and need to pay more attention to research and development investment to maintain its stability. In the long run, R&D investment not only can increase brand value and promote brand sustainability[5], but reduce the risk of brands appearing in the middle of the smile curve.

5.2 Summary

With consumption upgrading accelerating industrial structure upgrading, brands have different forms of strategic transformation. The strategic mode implementation by sports brands roughly includes brand extension strategy mode, independent high-end brand strategy mode, brand M&A strategy mode and brand joint strategic mode[8]. For brand transformation, these transformation strategies are not independent and lacerate. Brand refers to the combination of different strategic models and the selection of the most conducive to the development of the organization plan for implementation. Brand transformation is a systematic development process, during which comprehensive, balanced and can reduce the difficulty of brand transformation.

In the new economic era, brand transformation and upgrading has become an inevitable choice. Cultural innovation, green management, information and knowledge systems, etc. have all become ways to promote brand transformation and upgrading[9].In a changing global socio-economic environment, brands need to have more acute insights to avoid a collective decline in brand operating performance around 2012. Brand operations need to make overall plans for long-term strategic planning, and continue to improve during the development process The existing organizational mechanism pays sufficient attention to the factors that can affect performance. In the same way, the international operation of China's sports brands just have a short start, and there is still a long process in the future. Brands need to have complete plans and sufficient perseverance.

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Thailand Automotive Industry: Road to Smart Manufacturing

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ABSTRACT
Rapid ICT growth has resulted in many technologies such as cloud computing, the Internet of Things (IoT), and big data. These innovations now reach almost all sectors including automotive sector which is one of the main industries in Thailand, In order to advance research and implementation of smart manufacturing , authors present a conceptual framework of smart manufacturing. Core innovations such as IoT, Cyber Physical Systems and Visual Analytics for Smart Manufacturing Systems will be captured on the basis of demonstrative scenarios. Also highlighted are today's challenges and future prospects.

CCS Concepts
•General and reference→ Cross-computing tools and techniques→ Verification

Keywords
Smart Manufacturing; Automotive Industry

1. INTRODUCTION
The automotive industry is a leading industry in the generation of the country's gross domestic product (GDP) in Thailand, making significant contributions to Thailand's economy, employment, automotive technology developments, expanding its support to supply chain and logistics-related industries, creating economic value for the country. With the need to develop a competitive position in today's global market, organizations need to realize the value of technology and innovation, which is widely regarded as one of the most common sources of competitive durability [1].

A 2014 MESA study on a supplier survey found that the performance metrics [2] used by industry-wide manufacturers to make themselves more competitive are the ability to launch, deliver new products on time. Its ability to meet these performance requirements relies on several main skills from the perspective of manufacturing operations. These capabilities include [3] the rapid establishment or modification of production facilities for new products and product variations; [4] the identification of data required to maximize operational efficiency; and [5] the provision of reliable production time estimates.

This paper aims to develop a set of obligations and participating devices in establishing new manufacturing and refurbishing or modifying existing ones to improve performance or adapt the factory to introduce a new or product variation. This design will support manufacture from preparation to service throughout the entire life cycle. Using the template, it will be easier organized to schedule new product introductions. Data to be obtained to aid in decision-making will be clearly defined and evaluated throughout the activities. Systems to be used to collect data together with standards will be more readily available to enable the activities to be effectively carried out within and across organizations. Since the dawn of the industrial revolution, factories have been set up and designed to develop them. Access to new technology, however, helps manufacturers to develop these practices dramatically.

Since the discovery during the late of 18th century of the mechanical potential allowed by thermal and kinetic energy, our lives have been reshaped by the growth of the industrial sector. As the first industrial revolution, the resulting innovations are known. Therefore, appliance through the mid-19th century constituted, in particular, The advent of a mechanism of electrical engineering [6].

Manufacturing companies are facing many challenges today, such as a shorter innovation and technology life cycle and a requirement for customized products at the mass production cost [7]. However, industry's emergence in emerging countries has generated the global market's aggressive competition. These industrial companies are capable of technological absorption and take action as manufacturing firms with low operating costs which will take market's share from developed countries (i.e. Germany, the United States, and Italy) [8]

At the beginning of this decade, the word I4.0 was used to define the subsequence industrialization. Sanders et al. [9] described I4.0 as "the fourth industrial revolution which applies the concepts of cyber-physical systems, the Internet and forward-looking technology and smart systems with improved paradigms of human-machine interaction" Wolter et al. [9] diffused this view throughout the value chain from the business model to low-level service offerings and work in process, defining I4.0 as "The resulting consequences have also an effect on the value chain, the business models, the downstream services and the work in progress". Akeson [10] pointed out the need for customization as "It is geared towards increasingly individualized customer requirements"

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2.1 Benchmark of Smart Manufacturing

Premkumar and Roberts indicated a study describing three parameters that impact the acceptance of new technologies in businesses: creativity, organization, and atmosphere [11], they are considered as key component of business success [12]. The principle motivation for business owner to adopt new technologies is the expected profit they would produce to the business. Nevertheless, before businesses will able to create benefits , they must first be aware of their need for creativity and how this can be implemented in order to accomplish real performance or explore new opportunities [11]. Mintzberg [13] determined the organizational structure as the framework of the relations on works, systems, operating process, people, and groups making efforts to achieve the goals. M. Mehrpour et al. indicated that strategy, environment, goals, organizational size and technology can influence the organizational direction, author also described a structure of organization in three principles. First, it defines and records hierarchical relationships that will help determine the number of levels in the hierarchy and the degree of managerial power. Second, it defines people's status as working in a unit community and separates the units throughout the organization. And the third includes the design of systems through which all units are coordinated and the organization guarantees effective relationships. [14].

In terms of the environment facet, the external environment plays an important role in the incubate of new technologies [11]. In the macro environment, the following variables can be distinguished; social, economic [15], competition of industry. Considering industry competition, in order to gain competitive advantage in global markets, businesses need to approach customer-individual demands in the less time possible [16].

Governments and private companies should take action to adapt and incorporate Industry 4.0 innovations in the manufacturing and service industries [17]. Governments could begin to promote Industry 4.0 technologies, such as: familiarizing companies with the concept of emerging technologies, providing implementation support (through national programs) and raising awareness on these topics, conducting application-oriented research, or providing consulting services may help improve the relationship between MSMEs and Industry 4.0 [18].

A recommended framework is introduced in this section to help identify and describe the system of the smart factory. We propose requirements to be met by a factory to increase its smartness. Most of the literature focuses on the smart factory's design principles. We tried to look to the future as possible, but with existing technology, the focus is on what is currently possible, which are presented below as guidelines in order to meet the benchmark requirements.

2.1.1 Advance Manufacturing

Apparently infinite is the array of words associated with smart manufacturing. Just a few of the concepts used are smart factories, cloud manufacturing, smart technologies, advanced manufacturing, smart production, omnipresent manufacturing, big data and electronic manufacturing. Rather than trying to start with a detailed description, as some have tried in the last decade [19, 20], The definition of advanced manufacturing systems is described by the Council of Science and Technology Advisors (PCAST) of the United States President [19, 20], advanced manufacturing refers to a set of processes that concerning the use and coordination of information, automation, computer-based technology, software, sensing and networking, and/or use state-of - the-art materials and emerging capabilities enabled by the physical and biological sciences, such as nanotechnology, chemistry and biology. This includes all new ways of producing existing products, and especially the manufacture of new products emerging from new advanced technologies.

Smart production could be considered as the first part of this concept and is therefore only part of advanced production. Sensor data are used in intelligent manufacturing systems to control the flow of materials, goods and information. Through incorporating connectivity, smart manufacturing links means of production within or outside the physical boundaries of the production facility with each other and with any other computer. This not only allows producers to model and monitor production processes from anywhere, but also enables them to exchange production process knowledge with other parties within and outside the value chain. [11].

2.1.2 Service orientation

This refers to the approach that businesses should transition from the sale of goods to the sale of products and services. Because their goods have achieved economic parity, the manufacturing industries are becoming service providers. Using such a technique, a product with almost no margin or profit can be offered to consumers. Rather than concentrating on profit from the sale of the commodity, organizations concentrate on the sale of the service [21]. It will combine and market products and services together. Presently manufacturing industries regularly outsource some of their resources with an emphasis on their core businesses. Manufacturing industries in the smart factory are going to outsource some of their processes and concentrate on their core processes [22]. Such a policy encourages creativity in developing core processes where resources are concentrated and will not disperse. A manufacturing industry, in effect, will sell its core process(s) to another industry as a service. CM defines an infrastructure that uses the internet as a platform for the procurement and sale of services, where cloud computing plays an important role in allowing the supply of services on demand [23].

A reasonable organization and analysis of Smart Manufacturing applications would provide explicit solution for the application problems. The common application problems consist of smart maintenance, smart monitoring, smart planning, resource management, energy consumption management, quality control. In addition, sub-problems of them are related to at least one of the products, processes and facility. Therefore, analyzing the smart manufacturing applications via the relationship, smart manufacturing and precision management is conducive to realize.

2.1.3 Facility

The term facility for smart manufacturing is to discover problems, analyze them and solve them proactively. Real-time and precise control to the items on the production line, such as facilities, semi-finished/finished product, raw material and other items, is still needed in proactive operation and maintenance after the quick decision making. Furthermore, the closed-loop interaction of SPL can improve the robustness and stability of the production line. In addition to quick response and accurate transportation of the actuator, there still needs a proper control policy according to the decision and an actual status of SPL to strengthen the stability of operation process [24].

Smart facility sometime refers to Real-time capability (responsiveness), This refers to the system's ability to respond to timely changes, such as changes in customer requirements or internal production system status (e.g., malfunctions and resource

failures). Data should be obtained and evaluated in real time to meet customer requirements [25]. The program would explore the feasibility of achieving requirements using existing resources by reconfiguring or coordinating with other factories through CPS and CM requesting facilities (processes) not available in the factory [26]. To achieve such a reconfiguration, the machine should have ample modularity. It should be in real time to respond to internal changes, monitoring and regulating. Timely identification of disruptions and the system should be able to recover quickly.

2.1.4 Product

Use new technologies has powered creativity in the company. The so-called Smart Products have emerged as products capable of using knowledge about themselves and the world in which they work, and capable of communicating with other devices. This results in product features that outweigh those provided by the products of the competitors [27]. The modules should be defined by a manufacturer, providing all the details needed to complete the module process. RFIDs are added to the product in order to access information relevant to the product. The system should be able to recover in real time from disturbances [28].

2.1.5 Process

Production process is the core competitiveness of enterprises, and production line is the basic operation unit that can guarantee the output stability, quality, efficiency and punctual delivery date. Obviously, it can improve the operation environment and promote the efficiency when the production line rebuilds. In addition, it is the first step towards smart in manufacturing with the techniques improving and the customer needs boosting [24], In this section, these concepts will be explored and evaluated throughout terms of the nature of the smart process outlined as follows;

Virtualization: This involves both building an artificial manufacturing environment that similar to the actual environment with cyber physical system and being able to observe and control the physical processes [29]. A virtual system is implemented to monitor and direct its physical aspect, which transfers data to update its virtual model in immediately [30]. A virtual system enables the implementation of designs, creating digital prototypes that are very similar to the real ones [31]. The specification can be reviewed, updated and tested in the physical system before it is ordered. Moreover, a virtual framework is useful for other concerns such as educating the workforce, directing the workforce when conducting manual procedures, diagnosing and predicting failures, and guiding maintenance tasks to repair malfunctions. The integration of virtual reality and enhanced realism with mobile devices.

Online monitoring and control: Through predictive and reactive decision-making, the systems are monitored and controlled in real time [28].

Modular machine tools or workstations: Refer to the tools that could be applied to the versatility of the machines and workstations to be reconfigured to alter the layout of the shop floor and the process feature [28].

Modularity: This refers to the system component design. Modularity can be characterized as the ability to separate and quickly combine system components. System components are loosely coupled and can be reconfigured according to plug-and-play [32]. For example, modules can be added to the production line, rearranged or moved on time. The smart factory should be highly flexible, allowing the rapid integration of modules that multiple vendors can supply [36]. Modularity allows the system to adapt to changing customer needs and to resolve internal system malfunctions in real-time.

Multi-skilled workforce: This refers to the workforce's ability to perform different kinds of assignments, including decision-making, supervision, maintenance scheduling or manual assembly or procedure [28]**.**

2.2 Firm Performance

Corporate output is a multi-dimensional term [33] whose departmental metrics can be, such as production, finance or marketing [34], or other subsequence metric such as growth and profit [35]. Performance can be evaluated with objective or subjective criterion [36, 37]. In this paper, subjective measures of performance modified from Venkatraman [38] were adopted according to the difficulty of financial information collecting from private firms, in the absence of any publicly available objective data which includes the firms in the sample [39, 40]. The performance criterions described by Venkatraman [38] measures performance relative to those of the relevant competitors.

3. CONCEPTUAL FRAMEWORK

Figure 1 displays the framework's five main components. According to the literature examined, each construct is explained in the following paragraphs. These buildings were chosen because of their ability to explain the respective requirements of smart manufacturing in the automotive companies.

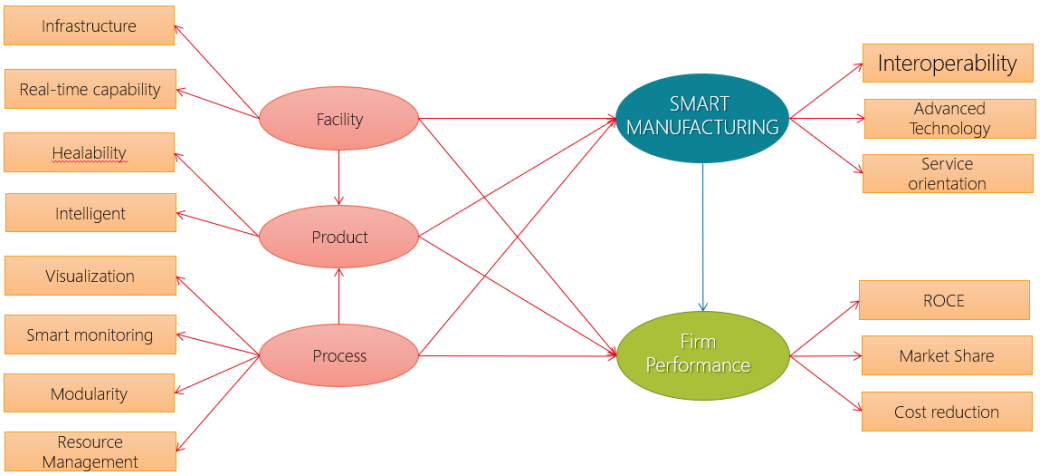

Figure 1. The conceptual framework

4. METHODOLOGY

4.1 Data Collection

The primary objective of the study is to explore the current status of smart manufacturing in Thailand automotive industry. To accomplish the predefined goal, a questionnaire-based pilot survey was carried out. The sample size of 40 used in the pilot study base on the recommendation of previous study obtaining approximately 10% of final study, for this study plans to obtain 400 samples. The final version of the questionnaire consisted of four major sections: (1) demographic items (2) perceptions of the firm performance, costs and benefits associated with it (3) perceptions of the smart manufacturing and (4) attributions of the smart facility, smart product and smart process. The questionnaire was administered to a sample of automotive employees in supervisor and/or senior level in Thailand. All respondents were prescreened.

Variable	Requirement	Question Interpretation	Question#
Facility	Infrastructure	It refers to the use of a generic supply system relating system components to all supply layers (i.e., Air Pressure, Current, Ethernet). Assorted vendors may supply system components.	15,16
	Real-time capability	Customization and ability in real time: this refers to the ability to comply in real time and to order only a single unit for manufacturing.	17
Product	Healability	In real time, the system should be able to recover from disturbances.	18
	Intelligent	Smart product: The modules should be described by a manufacturer, including all the details necessary to complete the module process. RFIDs are applied to the product in order to access information specific to the product.	19
Process	Visualization	A virtual repository or software package that functions as a virtual machine catalytic convertor, enabling for successful simulation.	20,21,22, 23,24
	Smart monitoring	Remote monitoring and control: automated and reactive decision-making is used to monitor and control the systems in real time.	25
	Modularity	Modular machine tools or workstations: These refer to the functionality of the machines and work stations that need to be reconfigured to alter the layout of the shop floor and modify the process feature.	26,27,28
	Resource management	Multi-skilled workforce: refers to the workforce's ability to perform various types of duties, including decision making, supervision, maintenance, programming, or manual assembly or processing.	29,30

Table 1. Question interpretation for smart manufacturing

4.2 Measurement Development

Multi-item scales evaluated each of the model's constructs. For the questionnaire, a 5-point Likert scale was used. Testing of the measurement model was critical to determining how well the metrics described the building. Therefore, the Cronbach's Alpha was used to test the reliability, the overall result is acceptable at 0.892, the result for each construct are also acceptable, firm profit contains 4 items the result is 0.725, smart manufacturing contains 9 items the result is 0.893, facility contain 3 items, the result is 0.711, product contains 2 items, the result is 0.931 and process contains 10 items with the result 0.859.

5. CONCLUSION

The present study confirmed that the variable of smart manufacturing and firm performance is acceptable with the result of reliability measurement, the development of this proposed model is acceptable for further study, however the adjustment may require appropriate study with different setting and environment. The current research is important because new insights into the study could be found within Thai Automotive Industry.

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Willingness to Use Self-Service Technologies Similar to Amazon Go at Supermarkets in Thailand

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ABSTRACT
Several businesses use self-service technology to help customers check-out and make payment without interacting with a cashier. Amazon also encourages this concept and uses Amazon Go technology on a customer's smartphone which automatically detects a customer profile using Artificial Intelligence. There have been very few studies conducted on self-service technology like Just Walk Out from Amazon Go in Thailand with the purpose of encouraging willingness to use. This paper focuses on a conceptual framework of self-service technology with willingness to use based on Technology Acceptance Model, Customer Satisfaction, Service Quality, Technological Innovativeness, Technology Anxiety at supermarkets in Thailand. Ultimately, this will provide profound insights into factors that influence willingness to use self-service technology at supermarkets in Thailand from the questionnaire which has tested the reliability and validity by using the Cronbach's alpha.

CCS Concepts
• **Information systems→ Information systems applications→ Enterprise information systems→ Enterprise applications**

Keywords
Self-Service Technologies; Service Quality; Technological Innovativeness; Technology Anxiety; Technology Acceptance Model

1. INTRODUCTION
Self-service technology (SST) is a digital framework allowing customers to use a service independently without direct service employees such as automated check-in machines (ATMs), voice processing and mail systems, telephone and internet services are all examples of SST [1]. Several businesses use SST to assist convenience shopping with check-out and payment without the need to interact with a cashier. Amazon also encourages this concept and uses Amazon Go technology on a customer's smartphone and automatically detects computer vision, sensor fusion, and deep learning technologies when products are removed from or returned to the shelves and tracks items in a virtual cart without the need for a customer to scan products. Customers will be charged upon leaving the store and a receipt will be sent automatically to their device. These new technologies are revolutionizing the consumer shopping experience and setting new expectations for what to buy in the future [2]. The Amazon Go Supermarket shopping experience continues at Alibaba online stores where using the potential of Artificial Intelligence (AI) in business is just a click away [3]. In addition, the significant role of technology innovation and technology anxiety in predicting consumer service quality and the perceived risk of using SST. As a type of attitude, the quality of service is the view that the customers have of customers as to how well the quality of the service meets with their standards of service. The quality of service can predict behavioral intent [4]. Service quality has been a subject of extensive research for years now in the form of SST, with profound effects on the interaction between customers and companies, to achieve positive results for customer service, customer satisfaction, loyalty, and behavior. The results of much research indicates that the quality of service, loyalty, and actions of SST contribute directly and indirectly to customer satisfaction and integrated with the Technology Acceptance Model (TAM) to better explain the customer's intentions of willingness to use while using SST [5].

In Thailand, supermarkets and convenience stores have been piloting counter for check-out without interacting with a cashier such as S BingoBox by SCG Experience. Wu et al. [6] explained that Bingo Box is the first unmanned convenience store where everything is automated in 2016 in major cities of China. When walking into the unmanned convenience store, customers only scan QR codes with their smartphones. They will receive a four-digit code if their first visit is via the micro-app Bingo Box, which they must enter to identify themselves. In the convenience store, each product has RFID tags that means that consumers have to scan their purchases. For example, they have more than five self-service products that identify each product and calculate the total number of products they own when they are ready to pay.

Moreover, there have been very few studies conducted on self-service technology like Just Walk Out from Amazon Go in Thailand with the purpose of encouraging willingness to use. Thus, this paper focuses on a conceptual framework of Self-service technology with willingness to use based on TAM, Customer satisfaction, Service quality, Technological Innovativeness, Technology Anxiety at supermarkets in Thailand. Ultimately, this will provide profound insights into factors that influence willingness to use Self-service technology at supermarkets in Thailand from the questionnaire which tested the reliability and validity by using the Cronbach's alpha.

This paper is organized as follows. Section 2 describes the theories, background of this research. Section 3 presents the conceptual

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framework and hypothesis. Section 4 presents Data collection and Measurements. Section 5 presents Reliability and Validity. Finally, Section 6 presents the Conclusion of this research.

2. THEORIES AND BACKGROUND

This section describes the theories and background of TAM and Willingness to Use SST, Self-Service Technologies (SST) Service Quality with AI and Customer Satisfaction, and Technological innovativeness and Technology anxiety.

2.1 Technology Acceptance Model (TAM) and Willingness to Use SST (WTUSST)

In 1986, for his Ph.D. thesis, Fred Davis presented the Technology Acceptance Model (TAM). TAM adapts the principle of reasonable measures to model the adoption of information systems or technology by consumers. After that, Venkatesh and Davis found that responsiveness and ease of use have a direct impact on conduct, thereby reducing the need to create a behavior [7] as shown in Figure 1.

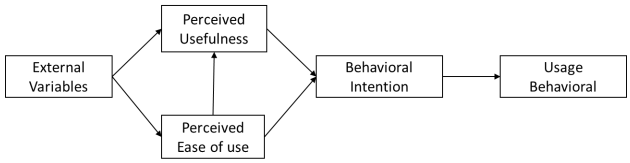

Figure 1. Technology Acceptance Model (TAM)

According to the research conducted by Chuawatcharin and Gerdsri [8], Just Walk Out Technology (JWOT) is one of the retail industry's new developments. This is the first empirical study to forecast the behaviors and preferences of Thai consumers to use JWOT. Bangkok is known not only for growing urban development but also for testing many rapidly changing consumer products. The objective of their study was to find important factors in the attitude to and intention to use JWOT among consumers in Bangkok, Thailand, and to explain the relationship between those factors. Data was collected from 400 respondents in Bangkok via an online questionnaire. The results show that the TAM structures are related to one external factor (social norm). Nevertheless, the preview of JWOT adoption does not include a perceived entertainment value, confidence and technology anxiety. Differences in population and consumer habits have been found to affect the overall acceptance of technology.

Another research conducted by Hong and Slevitch [9] researched the hospitality industry has brought Self-Service Kiosks (SSK) into operation as different industries have taken SSK technology. Nevertheless, it is not thoroughly investigated what drives customer satisfaction (CS) with the SSK since the technology is still new in the hotel industry. Their research established the impact of SSK on CS in the sense of the hotel such as ease of use, speed of delivery and monetary promotion. The study examined the relation between CS and willingness in the future to use SSK. The results of the study showed a positive connection with CS with ease of use and speed but showed no significant relation between monetary promotion and CS. Therefore, CS was positively related to the plan to use SSK in the future.

2.2 Self-Service Technologies (SST) Service Quality with AI and Customer Satisfaction

Iqbal et al [5] suggested, in his paper, that service quality in the context of SST deeply influences the way consumers engage with companies to create positive results of service, e.g. customer satisfaction, loyalty, and actions. They purposed to determine how services based on technology i.e. SSTs affect happiness, loyalty and compartmental intentions of customers in Pakistan's service industry. Through the online survey, data was collected from 238 SST users. To test the model, the LISREL program uses structural equation simulation. The results of this study indicate that the SST's level of operation, loyalty and compartmental expectations are directly and indirectly related to customer satisfaction. These findings provide insights into Pakistan's service sector investing in new technologies to improve consumer experience, happiness, loyalty and intentions. In addition, they proposed that SST Value 7 things consisting of (1) the function of the SSTs, including "reliability, accessibility, and responsiveness." (2) Pleasure applies to the customer's view of machine use. (3) Client's personal interests are related to security and privacy. (4) Overall system architecture is concerned with design. (5) Assurance reflects service provider competence and credibility. (6) Ease of consumer access to the services provided by the company shall be synonymous with convenience. (7) Customized services are expressed as the ability to understand and shape the needs and requirements of customers by co-production with the client. Moreover, Orel and Kara [10] examined the relationship between quality of perceived self-checking service, satisfaction and loyalty by using a structural model (SEM). They evaluated whether their proposed framework and self-checking quality measures are predictively accurate. It also confirms previous findings on the relation between the variables. The efficiency of self-checking systems is a secondary factor used to forecast satisfaction and loyalty.

In addition, Valle-Cruz and Sandoval-Almazan [3] suggested the artificial intelligence (AI), and it is important to mention that the relationship with other persons is the property of the intellect, not only of humans to reason, consider and learn. Intelligent machines are able to think, rationalizing and interpreting those commands that need to be followed or carried out. AI can be understood as an artificial intelligence, meaning knowledge shown by machines. Although most AI concepts apply to human behavior simulation, AI has extended into non-human behaviors. Currently, organic systems with models simulate the actions of various animals or viruses are available. Only virtual animals are made. AI is thus a simulation of the actions of living beings by intelligent machinery and software.

2.3 Technological Innovativeness and Technology Anxiety

The results of the research conducted by Lee and Lyu [4] shoes that though a proportion of the older population is growing, most research into behavioral acceptance of technology, such as SST, tends to focus on younger customers. Their research aims to examine factors that inspire older users to consider SST through the application of the Gatignon and Robertson broadcasting method models. 104 interviewees aged 55 or older and who have used automated checkouts in the past took part in the survey. The data has been analyzed with SmartPLS 3.0 software using slightly smaller squares. Results show that the expectations, including value, enjoyment, and tracking, of the SST characteristics of older consumers are indirect histories through the quality of service and/or perceived risk. Another important indicator of older consumers ' SST use is the effectiveness and reliability of SST before use. Results from this analysis add to the literature since little work has explored the use of SST for older consumers.

According to Roya et al. [11], they studied that in recent decades technology rapid progress has led to numerous groundbreaking new

innovations in internet technology. Their study explored the reception and resistance of consumers to smart technologies in the retail sector by combining literature on the model of technology adoption, device specifications, technology availability and the credibility of shops. Data was collected by a quantitative survey and analyzed by symmetrical PLS modeling of the path and asymmetrical fuzzy, and quality comparative analysis has been developed (fsQCA). The results showed complex relationships between perceived technology readily available, perceived accessibility, perceived efficiency, superior functionality, perceived adaptability and reputation for storing customers ' attitudes and compartmental intentions for smart retail. The findings also demonstrate that the readiness of technology does not have a direct effect on the attitude of the consumer but indirectly influences innovation. The findings show that retail shops can concentrate on easy, but enhanced consumer satisfaction through better shopping quality and smart technologies. Findings indicate that retail outlets can use brand management techniques to increase the acceptance of smart technology by consumers.

Moreover, Lian [12] conducted research on personal technology anxiety, the need for interpersonal interaction and anxiety in personal technology are critical factors impacting SST's purpose of continuous use. In addition, the user' s understanding of the quality of information and the SST system itself affects personal technical anxiety, influences the level of satisfaction and the desire to continue the system's use. Secondly, the perspective for the IS Success Model shows that the following determines the degree of perceived SST satisfaction: quality of knowledge, system efficiency, enjoyment, and design. Furthermore, the decision to continue using SST is only influenced by information quality and device consistency. They also noted that the desire to preserve the SST's consistency is dictated by satisfaction and the need for interpersonal interaction. Originality / Value–It shows that the IS performance model helps to understand the underlying reasons. These results can be cited by countries in which SST is not so common in order to support the creation of successful future SSTs. The theoretical construction of the IS performance model is further improved in their proposed model.

3. CONCEPTUAL FRAMEWORK AND HYPOTHESES

This paper focuses on a conceptual framework of Self-service technology with willingness to use based on TAM, Customer Satisfaction, Service Quality, Technological Innovativeness, Technology Anxiety at supermarket in Thailand. This will provide profound insights into factors that influence willingness to use Self-service technology at supermarkets in Thailand as shown in Figure 2.

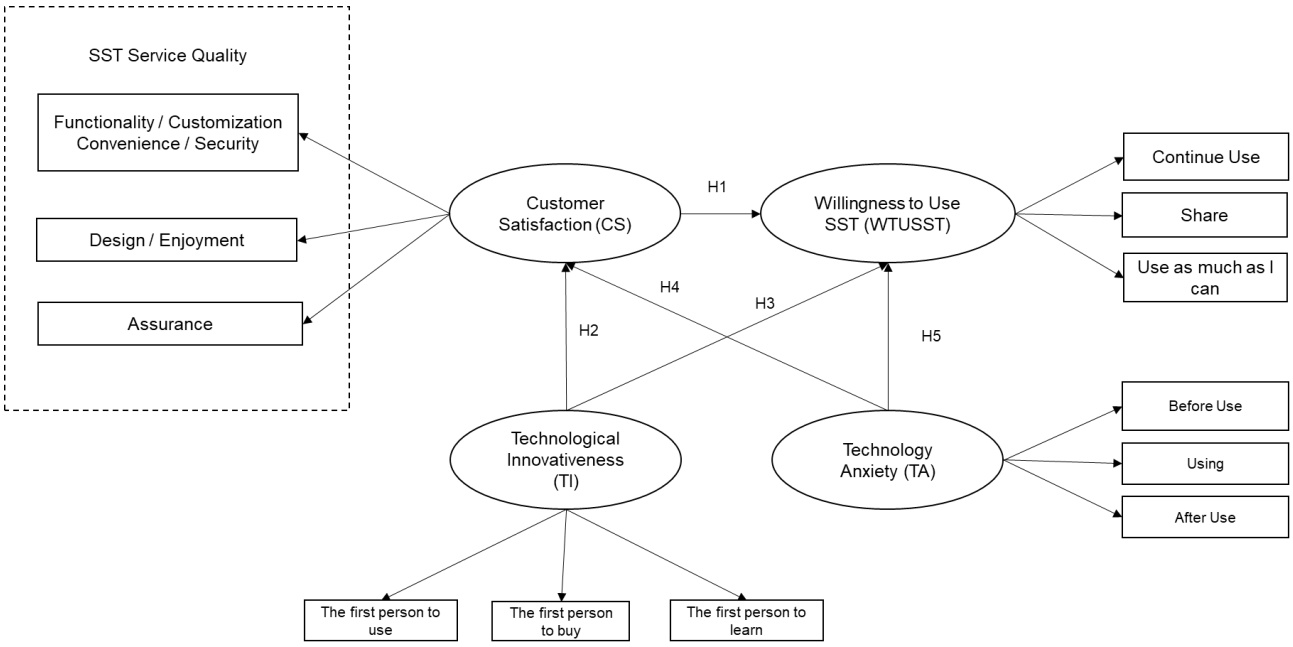

Figure 2. A conceptual framework of Self-service technology with willingness to use based on TAM, Customer satisfaction, Service quality, Technological Innovativeness, Technology Anxiety at supermarket in Thailand.

After taking previous studies and relevant literature into consideration, the following hypotheses have been proposed for this research study:

H1: CS has a positive and significant relationship with WTUSST
H2: TI has a positive and significant relationship with CS
H3: TI a has positive and significant relationship with WTUSST
H4: TA has a negative significant relationship with CS
H5: TA has a negative significant relationship with WTUSST

4. DATA COLLECTION AND MEASURE

We examined the proposed model on the reliability and validity of the constructs. The pilot study via online questionnaire was conducted on 30 respondents to evaluate the questionnaire's validity and reliability as Table 1 lists the working definitions. The respondents completed the survey of 40 questions with a five-point Likert scale from 1 ('strongly disagree') to 5 ('strongly agree') [8] [12]. In online questionnaire have Amazon Go video to introduce innovative technology that we need to research. All respondents have been using SST at supermarkets and convenience stores in Thailand and abroad. Respondents complained about knowledge of SST in Thailand, they need samples of SST which are existing and used in Thailand such as ATMs, Kiosks, Self-Check- In at airports, etc.

5. RELIABILITY AND VALIDITY

Cronbach's alpha coefficient has been used to measure reliability estimates. As shown in Table 1, the constructs and subscales are higher than the minimum desirable of 0.93 and these findings thus exceed Nunnally (1978)'s acceptable level of 0.70 [1]. Therefore, these tests show a high degree of internal consistency.

Table 1. Lists the working definition and assessment of reliability

Latent variable	Observed variable	Question	Cronbach's alpha
Customer Satisfaction (CS) Iqbal el at. (2017) [5]	Functionality / Convenience / Customization / Security	1. I can get my service done with the firm's SST in a short time. 2. The service process of the firm's SST is clear. 3.Using the firm's SST requires little effort 4. I can get service done smoothly with the firm's SSTs. 5. Each service item/function of the SST is error- free 6. The SST has operating hours convenient to customers. 7. It is easy and convenient to reach the firm's SST. 8. It is easy and convenient to use firm's SST. 9. The firm's SST understands my specific needs. 10. The firm's SST has my best interests at heart. 11. I feel safe in my transactions with the firm's SSTs. 12. A clear privacy policy is stated when I use the firm's SSTs.	0.940
	Enjoyment / Design	13. The operation of the firm's SSTs is interesting. 14. I feel good being able to use the SSTs. 15. The firm's SSTs have interesting additional functions. 16. The firm's SSTs provide me with all relevant information. 17. The layout of the firm's SST is esthetically appealing. 18. The firm's SST appears to use up-to-date technology.	
	Assurance	19. The firm providing the SST is well-known. 20. The firm providing the SST has a good reputation.	
Willingness to Use SST (WTUSST) Lin and Hsieh (2007) [1] And Lian (2018) [12]	Continue Use	21. The probability that I will use the SSTs offered by the firm again is. 22. If I had to do it over again, I would still use the SSTs offered by the firm.	0.959
	Share	23.The likelihood that I would recommend the SSTs offered by the firm to a friend	
	Use as much as I can	24. I intend to continue using the SST rather than discontinue its use. 25. My intentions are to continue using the SST as opposed to any alternative, traditional means. 26. If I could, I would like to continue my use of SST.	
Technological Innovativeness (TI) Lee and Lyu (2019) [4]	The first person to use	27. It is cool to be the first to use and own new high-tech products.	0.941
	The first person to buy	28. I get a thrill out of being the first to purchase a high technology item. 29. Being the first to buy new technological devices is very important to me. 30. I want to own the newest technological products	
	The first person to learn	31. I get a kick out of buying new high-tech items before most other people know they exist.	
Technology Anxiety (TA) Lee and Lyu (2019) [4]	Before Use	32. I have avoided technology because it is unfamiliar to me. 33. When given the opportunity to use technology, I fear I might damage it in some way. 34. Technological terminology sounds like confusing jargon to me.	0.938
	Using	35. I have difficulty understanding most technological matters. 36. I am not sure of my ability to interpret technological output. 37. I am not confident I can learn technology-related skills. 38. I hesitate to use technology for fear of making mistakes I cannot correct.	
	After Use	39. I am not able to keep up with important technological advances. 40. I feel apprehensive about using technology.	

6. CONCLUSION

This paper focusses on a conceptual framework for Self-Service Technology on TAM, Customer Satisfaction, Quality of service, Technology innovation, Technology Anxiety at the supermarket Thailand. Finally, the questionnaire that checked Cronbach's alpha for reliability and validity and will provide in-depth insights into factors that influence the willingness to use self-service technology at the supermarket in Thailand. Consequently, these tests show a high degree of internal consistency because constructions and subscales are higher than the minimum desirable of 0.93 and therefore these findings exceed the acceptable level of 0.70 of Nunnally (1978) [1]. For future work, this online questionnaire will continue to be used to examine in depth the factors that influence the willingness to use self-service technology in supermarkets in Thailand.

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The Development of Machineries and Technologies to Support Digital Transformation

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ABSTRACT

Digital technology has become an important role in organization development. Therefore, it should be aligned with the policy of Thailand Industry 4.0 which helps the country drive forward and is an implementation model for government section, state enterprises, and private section. This policy can help them work efficiently, raise their business value and increase their potential as well as their efficiency of business operation. The case study factory, Security printing business, needs to be researched and be analyzed on an operational plan preparing for Digital transformation. An essential component for the state enterprises in the manufacturing industry is the preparation of automated machinery, digital and innovation technologies with the foundation of a flexible manufacturing system, focusing on the change of working process to Smart Factory. It integrates automated machinery and operators with connected equipment through the network, which covers data collection, controllability, communication, and system operation. So, it prevents the problem of fragmented data in the factory departments when monitoring the status of devices in real-time. This study presents a development plan of machineries and technologies to support digital transformation to apply in organizations such as manufacturing information, machinery integration, security track trace and RFID system to be ready for production and inventory management systems. Furthermore, the factory will be able to support the digital system efficiently as well as to adjust changes in the market in terms of providing fast service and advanced technology to be survived in the future.

CCS Concepts

• Human-centered computing→ Accessibility technologies • Human-centered computing→ Accessibility systems and tools • Applied computing→ Business process management systems • Computing methodologies→ Machine learning • Security and privacy→ Database and storage security

Keywords

Digital Transformation; Industry 4.0; Smart Factory; Flexible Manufacturing Systems

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1. INTRODUCTION

The industrial revolution and technological developments that change the world, resulting in a change that creates both opportunities and impacts across the organization level to the national level. “Thailand 4.0” is not just a buzzword but a key to transforming our country to keep pace with the world.

Nowadays, the world is in the 4th era of industrial revolution or industry 4.0, which has become an important role in manufacturing industry [1][2]. It integrates automated machinery and operators with connected equipment through the network. The special feature is to connect customer needs directly to the production process. In worldwide, highly flexible processes that can be changed quickly enable individualized mass production. Variants are self-determined through items delivering their own production data to intelligent machines [3]. The factory will be able to produce a variety of different variations according to the specific needs of each consumer and have as many as needed by using economical and efficient production processes with the "Smart Factory", which integrates the system of production with a network connection in the form the Internet of Things (IoT), was recently developed and has been applied to the shop floor environment [4]. IoT is that advancement in connectivity among operators, machines, and infrastructure will increase intelligence, business insight, efficiency, and innovation [5]. The concept of smart factory is a manufacturing solution that has flexible and adaptive production processes that will solve problems with dynamic and rapidly changing boundary conditions in a world of increasing complexity [6].

Thailand, a country that relies on the manufacturing industry to drive the economy of the country. It is necessary for the public sector to focus on industry 4.0 by increasing the potential of new generation developers, as well as to adapt business models to meet market demands. For Thailand to go through this transition smoothly and sustainably, two concepts need to be put into practice: building strength from within and connecting domestic economy to the world economy [7].

Industry 4.0 is driven by digital transformation in vertical/horizontal value chains and product/service offerings of the companies. The required key technologies for Industry 4.0 transformation such as artificial intelligence, internet of things, machine learning, cloud systems, cybersecurity, adaptive robotics cause radical changes in the business processes of organizations [8]. The new digital technology that focuses on helping business better and more consistent with the same seamless and become workflow easier. This helps businesses maintain the capabilities to compete and push them to achieve continued growth. A digital strategy is bringing digital media and technology to deploy to link

individuals, process information and articles together to create products and the best service for consumers.

Accordingly, to respond the policy of Thailand Industry 4.0, This study presents a development plan and concept of machineries and technologies to support digital transformation to apply in organizations such as manufacturing information system, machinery integration system, security track trace and RFID system to be ready for production and inventory management of case study factory, printing business, the state enterprises in manufacturing industry. With the digital technology, it can link internal and external production systems to the organization, including customers, operators, processes, machine, materials together through the integration of the data center of production management, and can take advantage of information technology to create systems for enhance controllability of production process, reduce manual intervention in work process [9], and create business opportunities to compete with other organizations in a strong way. The concept and technologies of the smart factory are driven by the development of a factory to the digital system. The process of working in all parts of the factory is automated and become a smart factory in the future.

2. METHODOLOGY

This section presents the methods of operation to create a development plan of machineries and technologies to support digital transformation. This factory, state enterprises, classified as manufacturing industry consists of two main business is as follows:

1) Cards business (Plastic cards, Paper cards, Thai cards, Souvenir cards)
2) Printing business
- Security printing (Tobacco tax stamp, Beverage tax stamp)
- General printing (Book, Calendar, Receipt, Other government documents, etc.)

2.1 Problems/ Current Conditions Analysis

2.1.1 Production system

This factory has used less of information technology to help manage production systems, which are typically basic programs such as MS Excel and ERP system in some modules, most of which are used by operators in their operations, where the use of human in the planning process is at risk. The performance of people has a high probability of mistakes, long operating time, less flexible, data has been fragmented and some information data has not been recorded, such as the number of workpieces, the failure rate of machine operation, including no tools that will help to adjust an emergency production plan. Another important issue is the problem of not knowing the performance of both operators and machines in real-time.

In addition, assessing the capacity of the machine is crucial to contribute to the decision support system of receiving orders from customers. Capacity planning can be accomplished by using existing route resources, including where organizations can use this information to prepare for future capacity expansion. In the future, the factory plans to build a new building to install the Intaglio printing machine for supporting the security printing business, such as embossed tobacco stamps, embossed beverage stamps, the example process is shown in (see Figure 1). Therefore, new machines to be installed will need to be able to work automatically and data integration through the network.

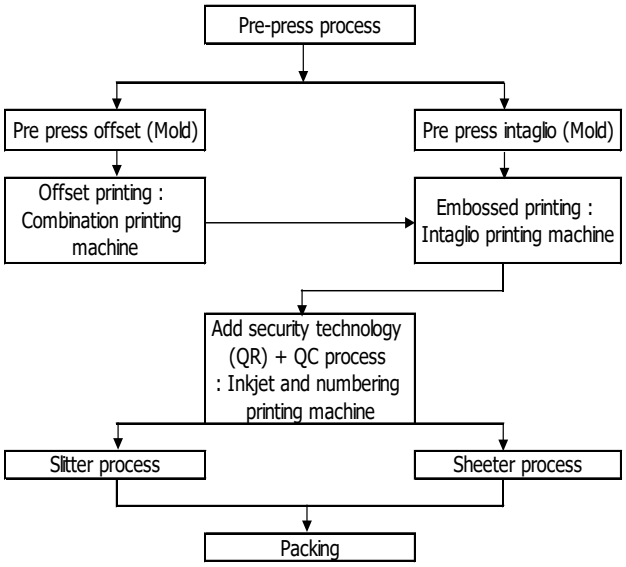

Figure 1. Embossed beverage stamps process

The capacity data of machinery usage, is backward for 1 year, while some machines were very high production load due to the backorder of the previous year because of defective machine issues, the factory must be produced overtime in the processes. This issue must be analyzed if there is another cause in addition to the above issues, such as having another task inserted without a plan, usage of machinery is not full-efficiency, and when it is known, the actual cause can be solved and controlled the capacity to meet the diversity and demand of future customers.

2.1.2 Inventory system

The factory has 2 types of warehouses 1) raw materials 2) finished goods, but no warehouse of work in process. All parts between process and finished goods pile together the production line area can have operational errors because there is not a clear storage area and indication of each product type.

Because warehouse automation is not used, it makes management inefficient, such as document handling in redundant disbursements, insufficient storage area is required to be brought outside the warehouse. It makes control difficult and risk-loss. Not control raw material or inventory stock level. Not control the first in first out system is that the raw materials/goods are pre-circulating to reduce the deterioration of the storage for a long time. At this point, the factory also encountered a problem collecting the raw materials that have expired, as a result of the distribution and storage system that does not control the use of the application in accordance with the actual use.

2.2 Study Technologies Innovations of Production and Inventory Management System

2.2.1 Smart factory

The Smart Factory is a new evolution of factory management that connects devices together through the network, which is the key point of the 4.0 industrial intelligent production system. The production system is transformed into control by the individual

parts of the machine production system, automation equipment, and robot assembly will be able to recognize data analysis and increase productivity by themselves through technology called physical cyber systems, a technology that combines the digital world into the real world, making instant communications and management of production system. The production process of a smart factory must be enabling the management of complex and flexible systems to satisfy rapid changes in production volumes and customization [10]. It provides the customers with smart products and services which will be connected to the network. Then, the smart factory will collect and analyze data coming from the smart products and related smart applications [1].

The key characteristics of Industry 4.0 are "Smart Factory" the use of highly automated and IT-driven technology for cost-efficient production. (see Figure 2) [7]

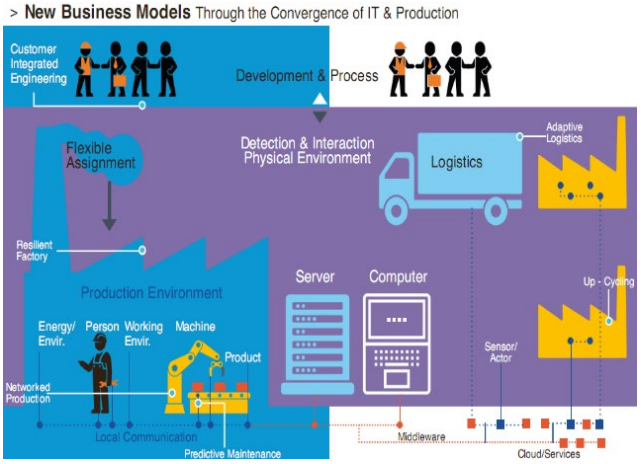

Figure 2. Characteristics of Smart factory

2.2.2 Machine integration

The Industry 4.0 Architecture model is very broad in that it aims to permit homogeneous consideration of the product to be manufactured and the production facility, with their Interdependencies [11]. Integration System signals from existing measuring instruments in the entire system, using the conversion of communication protocol to connect the device's controller and sensor, can collect the signal source and effective communication between machines. After the integration of the system, the machine can be connected to the server management system and can automate the execution and data collection. The server and the software gather all of the control systems within the entire production plant and sends information to the control computer.

2.2.3 Radio Frequency Identification (RFID)

Tracking technologies are extremely important, especially in the modern world, all tools and equipment are connected and communicated. Under the framework of the concept Internet of Things (IoT), the technology function such as Radio Frequency Identification or RFID has an important role in real-time detection and transmission of data. Material and Product have attached RFID tag written with process requirements. This information helps to follow the machines status and production route in real-time [12]. It is the operating part of the sensor system that receives information under the concept. The most essential IoT for monitoring and monitoring, which can enhance the process to be more efficient and secure.

2.3 Gap analysis and project plan

From problem issues that occur in the organization. A digital transformation is the key to improve business performance. Including the government's policy to encourage government agencies to take advantage of the application of digital technology in various activities to increase work efficiency and increase the ability to compete with the private section according to market forces in the future. Therefore, the case study factory has to adjust the work system of the department to support this policy by adopting digital technology as an important element to improve and change the current operations in order to achieve work process more conveniently and quickly. This will help businesses maintain their competitiveness and drive the factory to grow continuously.

With the strategy of digital transformation using digital technology, the factory will be able to connect all components, including people, work processes. machinery/equipment, information, materials and others for creating the best products and services for customers. As well as creating opportunities for the factory to develop their potential to become a full-service publication printing business and to provide system development services that focus on safety in order to create confidence and standards for the factory to be accepted in both public and private sections.

This study has presented the development plan and concept for the preparation of the digital transformation of 4 projects as below;

Project 1: Information technology for support production management system
Project 2: Machine integration system
Project 3: Track and trace system
Project 4: Inventory management with RFID

3. RESULTS AND DISCUSSION

This section has explained the concept and operation process for the preparation of the digital transformation of 4 projects as below;

3.1 Project 1: Information Technology System for Support Production Management

A platform of information management for supporting the production system in the production planning, production control, and material planning management (MRP), which can lead to a legitimate production cost in the future. This system can support database sharing with the ERP system (Microsoft Dynamics AX) that the factory is currently using.

Platform module properties (see Figure 3)
1) Production Planning Services
- Capacity Planning
- Schedule Planning
- Material Resource Planning

2) Production Control Services
- Lean Process
- Shop floor Control
- Production Progress Analysis

3) Outcome Services
- Product Costing
- Production Analysis
- ERP Data Interface

4) Outcome Value

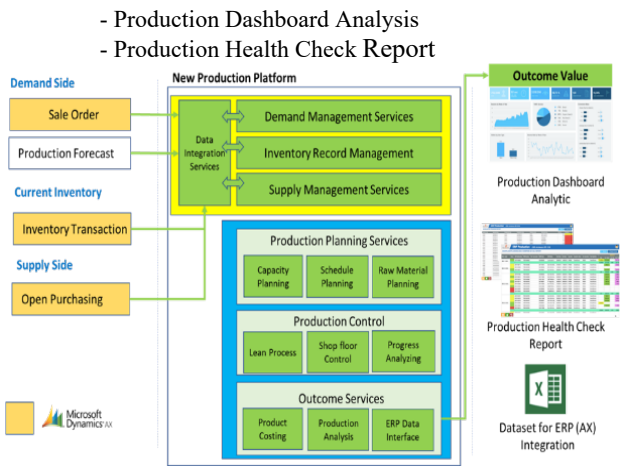

Figure 3. Production management platform

This project is tools to help when planning and adjusting the production plans in urgent cases efficiently. The machines can work fully functional without waiting for the process because the raw materials are available when producing. Operators can quickly track various statuses within the production process and order from customers. They can also increase efficiency in raw material control. As a result, the cost of storage of raw materials and inventory will be reduced, and digital import has a significant role in helping to minimize errors from human work since the human operator is considered to be risky. Moreover, Executives can follow the information of the overall production system that is important to the management of the business in real-time.

3.2 Project 2: Machine Integration System

All units of the production system are installed with a module network link (Interface System) to convert the Modbus TCP/IP protocol (Transmission Control Protocol/Internet Protocol) to a standard communication language, which will cause communication between the computer, control units and sensors of various devices to be able to collect information such as machine usage statistics, current working status, the efficiency of the manufacturing process and the failure or breakdown rate of the machine. It provides efficient communication between machines through various process simulators to display in the process through the dashboard. Moreover, the system can reduce errors from the manufacturing process as a result of human error such as saving the machine setup data, as well as to reduce operational time, such as data collection, production report, and reduce production losses. This project is the key to improving the decision-making system for executives. The operators can use the information that is real-time, including this system will be notified if abnormal situation is alerted to the control server to perform corrective action immediately before the damage is performed by the operator to remotely monitor or control the route, no need to be in the production line via a smartphone or tablet connection. (see Figure 4)

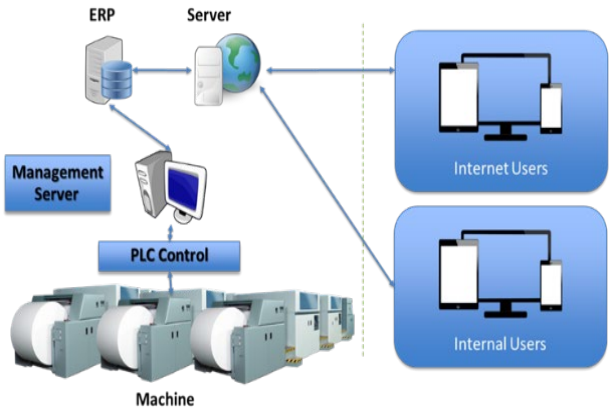

Figure 4. Machine integration concept

3.3 Project 3: Track and Trace System

Track and trace system technology allows executives and related employees to easily manage and track all the processes in the supply chain, starting from the manufacturer of the raw material, manufacturing process to the customers by installing the software and inkjet printing machine to generate and print the QR Code to store information about the entire production process of the product, such as the name, job step, Lot No. of production, date and time of production, operators ID. In addition, if the problem occurs, this information is useful in the process of traceability from raw materials to the finish goods by a systematic log of information in the process. Customers can easily follow and track the status of the product quickly, as well as to check the quality of the product, especially security products and help protect the goods from counterfeiting through the use of this code. This system can be used on both computers, apps on smartphones and tablets (see Figure 5). This technology will help strengthen our customers in the production capacity and product quality to create more interest and meet the needs of our customers.

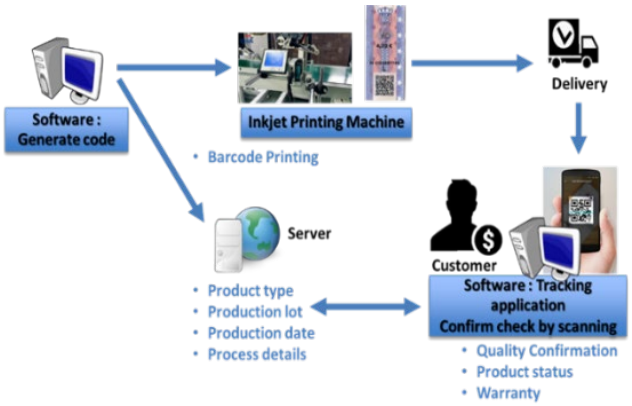

Figure 5. Track and trace concept

3.4 Project 4: Inventory Management with RFID

The warehouse is an important part of the production support, so the RFID system is used to control inventory to develop warehouses to a smart warehouse by installing software to use, manage, and track warehouse systems, as well as the provision of hardware equipment that must be used with RFID systems: RFID Tag, RFID Reader, and receiver are stored on the Tag Electronics to enhance the computing capacity and security of data. This system allows less inventory storage with minimum stock level, a high turnover ratio with real-time warehouse management data collection. Reduce functionality redundancy and reduce warehouse operation by RFID technology is a very high performance in reducing errors. It can collect information and inspect the products without the use of people counting. This can cause a lot of mistakes to be reduced, such as controlling the number of items faulty. Picking up errors and reducing product search time. Moreover, the system can link information to the centralized management server so that information can be shared, such as the production department can be filled up products at the right time.(see Figure 6) Therefore, using RFID technology will increase the efficiency and convenience of the warehouse, as well as to support the activities within the warehouse and the relevant work areas effectively.

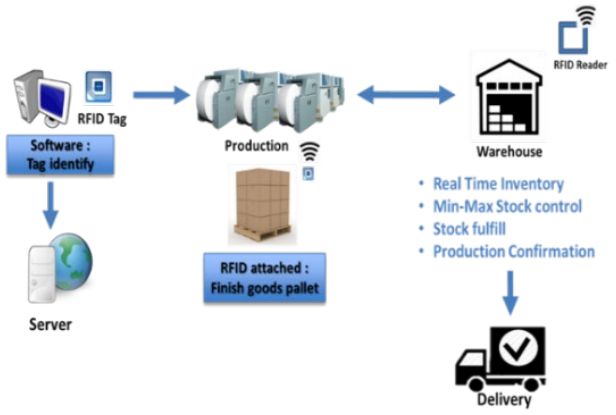

Figure 6. Inventory with RFID concept

4. CONCLUSIONS

This study has presented the development plan and concept guidelines for the preparation of the digital transformation of all four projects. This master project plan has been approved, and when this plan will be applied, it will increase the level of factory competitiveness. To make the customers confident in the technology, the potential of the product, the quality of the product which will be beneficial for the organization to be able to get the machines fully functional. Operators can quickly track various statuses within the production process and order from customers. They can also increase efficiency in raw material control. As a result, the cost of storage of raw materials and inventory will be reduced, and digital import has a significant role in helping to minimize errors from human's work This study will give a lead to the organization to be ready to adapt technology when working effectively. Therefore, the process of working in all parts of the factory will be automated, both internally and externally, to become a completely smart factory in the future.

5. ACKNOWLEDGMENTS

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Analysis of Influencing Factors of Farmers' Satisfaction with Industrial Poverty Alleviation Effect Based on Ordinal Logistic Model

-Take the three prefectures of southern Xinjiang in China as an example

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ABSTRACT

Based on a sample survey of 600 farmers in the three prefectures of southern Xinjiang, China, this paper uses questionnaire survey and ordinal Logistic model to study the influencing factors of farmers' satisfaction with the effect of industrial poverty alleviation from a microscopic perspective. The research shows that the cumulative percentage of farmers' satisfaction with the effect of industrial poverty alleviation is 90.7%, and the factors that influence the evaluation of farmers' satisfaction with industrial poverty alleviation are the educational level, the amount of household labor, the annual household income, the types of roads in front of farmers' doors, household fuel, whether rural cadres help farmers to alleviate poverty and the main poverty alleviation methods of the government. Based on this, the corresponding countermeasures are put forward: to continue to improve the embodiment of precision poverty alleviation, to strengthen the intensity of industrial precision poverty alleviation, to increase vocational skills training, to speed up infrastructure construction, based on its own advantages, to develop characteristic industries, to realize the precision poverty alleviation of industries, and to enhance the satisfaction of farmers with industrial poverty alleviation.

CCS Concepts

• **Social and professional topics → Industry statistics**

Keywords

Industrial Poverty Alleviation; Ordinal Logistic Model; Influencing Factors

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1. INTRODUCTION

Poverty has always been a major problem plaguing the social and economic development of Xinjiang in China, especially in the three prefectures of southern Xinjiang, which are one of the deep contiguous poverty-stricken areas, the task of overcoming poverty is particularly arduous in the process of building a well-off society in an all-round way. *The Outline of Poverty Alleviation and Development in Rural China (2011-2020)*, released in 2011, explicitly required that the three prefectures in southern Xinjiang in China should be taken as the key targets for poverty alleviation and should be elevated to the level of national strategy for overall poverty alleviation. The three prefectures in southern Xinjiang of China are located in the southwest of Xinjiang and are the main inhabited areas of the Uighurs. The incidence of poverty ranks first among the 14 prefectures in the country, reaching more than 55%, with the rural poor accounting for 85.15% of the whole Xinjiang. In recent years, with the strong support of the central and local governments, through measures such as consolidating agriculture, forestry, animal husbandry, improving the ability of the secondary industry to absorb the employment of poor households, and increasing the support of the tertiary industry such as finance, tourism, and e-commerce, the benefits of poverty alleviation of the industries in the three prefectures have come into being and achieved phased results. However, due to the low level of industrial structure, the lagging development of new business entities, the insufficient main role of the poor, the lack of precision in industrial selection, the imperfect mechanism of interest linkage, the lack of talents needed for industrial development and technical support, a number of factors have seriously limited the formation of the expected effect of industrial poverty alleviation, affecting the enthusiasm of the participants and their satisfaction with its effect. Therefore, it is particularly important to identify the factors that affect farmers' satisfaction with industrial poverty alleviation. On the one hand, it is conducive to the implementation of the basic principle of people-oriented poverty alleviation; on the other hand, it is conducive to the active adjustment of policies to maximize the effect of industrial poverty alleviation, improve the efficiency of poverty alleviation and realize poverty alleviation as soon as possible.

Sorting out relevant documents, the academic research on poverty alleviation in the three prefectures of southern Xinjiang in China is mainly focused on the following aspects: in terms of the current situation and existing problems of poverty alleviation in the three

prefectures of southern Xinjiang in China, Yin Weilin et al[1] found that problems such as low enthusiasm of farmers to participate in precision poverty alleviation, weak labor capacity, insufficient financial support and low utilization rate of funds, and difficulties in establishing files and cards at the grass-roots level severely limit the development of precision poverty alleviation in the three prefectures. Therefore, the efficiency and level of precision poverty alleviation should be continuously improved from the aspects of improving the labor capacity of farmers, improving the quality of poverty alleviation personnel, increasing the support of funds, ensuring the efficiency of fund use, etc. Through research, Liu Ling[2] found that the level of farmers' understanding of poverty alleviation in poverty-stricken areas in Xinjiang significantly influences their willingness to participate in poverty alleviation and the effect of poverty alleviation. At the same time, it also reflects the contradiction between farmers' willingness to participate and the relatively limited resources for poverty alleviation. In terms of poverty alleviation and development performance, Wang Baozhen et al[3] found through research that the poverty alleviation and development performance of the three prefectures of southern Xinjiang in China is increasing year by year, but the growth rate is slowing down. Among them, the average annual growth rate of social development level is the highest, followed by the production and living standards and economic development capacity, while the average annual growth rate of ecological environment improvement is the smallest. Yang Qingxu et al[4] found that the positive benefits of poverty alleviation funds are significant through empirical research, which have obvious promotion effects on the per capita income of farmers and herdsmen, industrialization rate and urbanization rate. Urbanization is the most influential factor on the per capita income of farmers and herdsmen and the per capita output value of farmers and herdsmen, followed by industrialization. Therefore, China's poverty alleviation work in the three prefectures of southern Xinjiang must attach importance to the pulling effect of urbanization and industrialization. In terms of path selection for poverty alleviation and development, Li Pingheng et al[5] believe that only by strengthening infrastructure construction, increasing financial support, optimizing industrial structure, innovating poverty alleviation and development mode and establishing multi-party poverty alleviation mechanism can the poverty problem in southern Xinjiang be fundamentally solved. Sun Qinggang et al[6] analyzed Xinjiang's open poverty alleviation path from the perspective of diversification of poverty alleviation participants, and believed that the current poverty alleviation still needs to improve the concept of poverty alleviation, build a coordination platform, strengthen the integration of resources, innovate the poverty alleviation mechanism, and enhance the overall benefit of poverty alleviation. Laiti Ju Rehemati el at[7] believe that under the concept of shared development, it is necessary continue to adhere to the "Five Batches" plan and adopt more effective measures that are conducive to improving the stock of high-quality human capital in the poor areas of the three prefectures of southern Xinjiang in China, promoting the full transfer of employment of the poor population in the three prefectures of southern Xinjiang in China, especially the poor population of ethnic minorities, increasing income and wealth through equal participation in economic and social construction, and improving the fairness of the poor population in the three prefectures of southern Xinjiang in China in sharing economic and social development. In terms of industrial poverty alleviation, Wang Wei[8] believes that there are still some problems in Xinjiang's industrial precision poverty alleviation, such as the lagging development of new business entities, the insufficient play of the main role of industrial poverty alleviation, the lack of precision in industrial selection, and the interest linkage mechanism. Li Hong[9] believes that the industrial development of the three prefectures in southern Xinjiang is lagging behind and the support for regional development is weak. It is still necessary to develop industrial poverty alleviation based on regional characteristic resources. Cai Chunmei[10] believes that in order to promote the healthy development of industrial poverty alleviation, it is still necessary to adhere to the top-level design, pay attention to market cultivation, play a good cultural card, broaden the channels of capital, and cultivate talents in the leisure agriculture industry in southern Xinjiang. Zhang Jianjun et al[11] believe that there are still problems such as lagging information construction, lack of e-commerce talents and low capital investment in poverty alleviation through rural e-commerce in southern Xinjiang. It is urgent to strengthen infrastructure construction and organize e-commerce talents training in order to promote the rapid development of rural e-commerce in southern Xinjiang and increase farmers' income and wealth. Zhou Bin[12] believes that the rich labor force in southern Xinjiang should be fully developed through education to fundamentally solve the problem of poverty alleviation.

To sum up, the current research results on poverty alleviation in southern Xinjiang are quite abundant and cover a wide range of areas, especially for industrial poverty alleviation. However, there is still little research on farmers' satisfaction with participating in industrial poverty alleviation. Therefore, on the basis of the existing research, through the investigation and arrangement of the three prefectures in southern Xinjiang of China, the author uses ordinal Logistic regression to analyze the factors that affect farmers' satisfaction with the industrial effect, in order to further improve the efficiency of industrial poverty alleviation and help southern Xinjiang get rid of poverty as soon as possible.

2. SURVEY OF RESEARCH AREAS AND DATA COLLECTION AND PROCESSING

2.1 Overview of Research Area

The three prefectures of southern Xinjiang in China refer to Hotan, Kashgar and Kizilsu Kirgiz Autonomous Prefecture (hereinafter referred to as Kirgiz), including 24 counties, of which 29 are key poverty-stricken counties, accounting for 79.2%. In 2017, the GDP of the three prefectures was 122.185 billion yuan, accounting for 11.23% of Xinjiang's GDP, and the GDP per capita was 16123.67 yuan, accounting for 35.88% of Xinjiang. It is much lower than 44941.00 yuan in Xinjiang and 59660 yuan in China. The industrial structure is unreasonable, the ratio of the three main industries is 27.61:25.61:46.78, and the development is relatively backward, and the level of infrastructure construction is lagging behind for a long time. This area has accumulated a large number of poor people for a long time, with a large base of poor people, which has brought certain difficulties to the industrial poverty alleviation. However, in recent years, with the strong support of the government, a large number of industrial projects, such as vegetables, fruits, breeding, clothing and tourism, which are suitable for the regional situation in Xinjiang, especially for the development characteristics of the three prefectures of southern Xinjiang in China, have developed gradually. In 2018, the effect of "supporting a batch of development industries" among the "Seven Batches" of precise poverty alleviation measures was especially obvious, which played a significant role

in pushing the achievement of the poverty alleviation target of 454,800 poor people throughout the year.

2.2 Data Collection and Processing of Individual and Family Characteristics of Survey Objects

In 2017, a survey was conducted on farmers' satisfaction with industrial poverty alleviation in Hotan, Kashgar and Kezhou, each of which distributed 200 samples, with a total number of 600. The return rate of the questionnaire was 91%. After all aspects of analysis and screening, the missing value option questionnaire was eliminated, and 535 valid questionnaires were finally selected to meet the requirements of statistical data. Among the respondents to the questionnaire (see Table 1), the education level is mainly in junior high school and primary school, accounting for 43.6% and 41.7% respectively.

Table 1. Table of Individual and Family Characteristics of Respondents

Characteristi-cs	Type	Frequency	Proportion	Characteristics	Type	Frequency	Proportion
Educational level	Illiteracy	36	11.5	Does the current income meet the basic living expenses of the family?	Basic satisfaction	176	56.4
	Primary school	130	41.7		Not enough to cover the expenses with the difference ranging from 3000～5000 yuan	97	31.1
	Junior high school	136	43.6		Not enough to cover the expenses with the difference ranging from 5000～10000 yuan	35	11.2
	High school or technical secondary school (vocational technical school)	10	3.2		Not enough to cover the expenses with the difference ranging from 10000～30000 yuan	3	1.0
	College or above	0	0		Not enough to cover the expenses with the difference ranging from 30000～80000 yuan	1	0.3
Marital status	Married	262	84.0		Others	0	0
	Unmarried	26	8.3	Main Causes of Poverty	Too little arable land	88	28.2
	Divorced	14	4.5		Poor farmland	24	7.7
	Others	10	3.2		Lack of water	8	2.6
Number of labor forces	1	79	25.3		Low education and no skills	29	9.3
	2	183	58.7		Less labor forces in the family	61	19.6
	3	41	13.1		Lack of development funds	30	9.6
	4	7	2.2		Inconvenient transportation and remote geographical location	19	6.1
	5	2	.6		Illness	33	10.6
Annual household income	Below 1000 yuan	81	26.0		Disability	8	2.6
	1000～3000	172	55.1		Heavy burden for children to attend school	9	2.9
	3000～5000	30	9.6		Marriage costs	3	1.0
	5000～10000	24	7.7		Less government helps	88	28.2
	10000～20000	4	1.3		More natural disasters	24	7.7
	Above 20000 yuan	1	0.3		Others	8	2.6
Migrant workers	Yes, often	75	24.0		Less government helps	29	9.3
	Yes, occasionally	142	45.5		More natural disasters	61	19.6
	Never	95	30.4		Others	0	0
Main heating equipment	Stove Electric heater Other	291	93.3				
	Earth heater	11	3.5				
	Electric heater	4	1.3				
	Others	6	1.9				

Data Sources: According to the survey questionnaire

The marital status is mainly married, accounting for 84.0%, the number of family labor force is mainly 2, accounting for 58.7%, the annual family income is mainly in the range of 1000-3000 yuan, accounting for 55.1%, followed by below 1000 yuan, accounting for 26.0%. The proportion of occasional migrant workers is 45.5%, the main heating equipment in the family is stoves, accounting for 93.3%, the basic balance of household income and expenditure accounts for 56.4%, and 31.1% of them whose income is not enough to cover the expenses, with the difference ranging from 3,000 yuan to 5,000 yuan. The main reason for poverty is due to too little arable land and too little government help, accounting for 28.2%, followed by a small labor force in the family and a large number of natural disasters, accounting for 19.6%. The personal and family profiles of these samples are in line with the basic situation of farmers in the three prefectures of southern Xinjiang in China and have certain representative significance.

3. VARIABLE SELECTION AND MEASUREMENT MODEL CONSTRUCTION

3.1 Variable Selection

The suitability test was applied to 24 variables in the questionnaire of the subject. KMO test was carried out step by step by eliminating the variables with minimum MSA value until all the variables with MSA value less than 0.55 were deleted, and finally 17 variables were determined, as shown in Table 2. In this study, farmers' satisfaction with industrial poverty alleviation is selected as dependent variable. The independent variables include four characteristic variables, namely, farmers' individual and family aspects, basic conditions, external support and industrial support. Each aspect includes several independent variables. Among them, the individual farmers and their families include 7 independent variables, such as farmers' educational level, marital status, and the number of family labor. The basic conditions include 4 independent variables, such as the installation of Internet broadband and drinking water sources. The external support includes 3 independent variables, such as whether rural cadres participate in the poverty alleviation of farmers' families and whether they have loans. The industrial poverty alleviation includes 3 independent variables, such as which poverty alleviation industries farmers mainly participate in, the main poverty alleviation methods of the government, and farmers' awareness of the poverty alleviation schedule.

Table 2 Variable Selection and Statistical Description

Variable name		Variable assignment	Minimum	Maximum	Average value	Standard deviation
Dependent variables	Farmers' Satisfaction with Evaluation of Industrial Poverty Alleviation Effect *(Y)*	Very satisfied =1; Satisfied =2; General =3; Not satisfied =4; Very dissatisfied =5	1	5	1.36	0.751
Independent variables						
Farmers' Individual and Family Characteristic Variables	Educational level *(X1)*	Illiteracy =1; Primary school =2; Junior high school =3; High school or technical secondary school (vocational technical school) =4; College or above =5	1	4	2.38	0.730
	Marital status *(X2)*	Married =1; Unmarried =2; Divorce =3; Others =4	1	4	1.27	0.693
	Number of labor forces of the family*(X3)*	Number of labor forces of the family	1	5	1.94	0.728
	Annual household income *(X4)*	Below 1000 yuan=1;1000～3000=2;3000～5000=3;5000～10000=4;10000～20000=5; Above 20000 yuan=6	1	6	2.04	0.912
	Migrant workers *(X5)*	Yes, often =1; Yes, occasional =2; No =3	1	3	2.06	0.737
	Main heating equipment *(X6)*	Stove =1; Earth heater =2; Electric heater =3; Others =4	1	4	1.12	0.496
	Main Causes of Poverty *(X7)*	Too little arable land =1; Poor farmland =2; Water shortage =3; Low education and no skills =4; Less labor forces in the family =5; Lack of development funds =6; Traffic inconvenience, remote geographical location =7; Illness =8; Disability =9; Children's Burden of School =10; Marriages cost =11; Less government helps =12; More natural disasters =13; Other reasons =14	1	13	4.36	2.837
Basic Condition Characteristic Variables	Internet broadband *(X8)*	Yes=1; No=2	1	2	1.95	0.214
	Source of drinking water *(X9)*	Purified tap water =1; Well water =2; River water =3; Rainwater collection =4; Other water sources =5	1	3	1.19	0.574
	Types of roads in front of doors *(X10)*	Soil road =1; Sand road =2; Asphalt =3; Others	1	4	2.42	0.879

		=4				
	Household fuel *(X11)*	Firewood =1; Coal =2; Canned liquefied gas =3; Others =4	1	3	1.20	0.436
Externally Supported Characteristic Variables	Have village cadres come to your home to help you out of poverty? *(X12)*	Yes=1; Never=2; Not clear=3	1	3	1.06	0.314
	Whether there is a loan *(X13)*	Yes=1; No=2	1	2	1.38	0.486
	Participate in new rural cooperative medical system *(X14)*	Yes=1; No=2	1	2	1.09	0.291
Industrial Poverty Alleviation Characteristic Variables	Which industrial poverty alleviation projects have you mainly participated in? *(X15)*	Planting =1; Aquaculture =2; Forest and fruit =3; Processing=4; Services =5; Tourism =6; Others =7	1	7	1.86	1.405
	The government's main industrial support methods *(X16)*	Financial support =1; Cooperative drive =2; Technical support =3; Others =4	1	4	1.74	0.879
	Do you know the time when your village is out of poverty? *(X17)*	Yes=1; No=2; Not clear=3	1	3	1.18	0.528

Note: According to the survey questionnaire

3.2 Model Building

Ordinal multi-classification *Logistic* regression*(Ordinal Logistic)* is a model to fit the regression relationship between multi-valued ordinal response probability and variable factors.

Ordinal Logistic model can be shown as follows:

$$Y^*=\beta X+\delta \quad (1)$$

In the formula, Y^* is an unobservable latent variable, corresponding to dependent variable; X is a set of independent variables; β is the corresponding parameters to be estimated; δ is the random error term to obey logical distribution. The relationship between Y^* and Y is:

$$\begin{cases} Y=1, \text{ if } Y^* \leqslant a1 \\ Y=2, \text{ if } a1<Y^* \leqslant a2 \\ \ldots \\ Y=j, \text{ if } Y^*>a_j-1 \end{cases} \quad (2)$$

In the formula, $a1<a2<\ldots<ai-1$ are the critical value obtained by estimation. X is given, the probability that the dependent variable Y takes each value is as follows:

$$\begin{cases} P(Y=1|X)=P(Y^* \leqslant a1|X)=P(\beta X+\delta \leqslant a1|X)=\wedge(a1-\beta X) \\ P(Y=2|X)=P(a1<Y^* \leqslant a2|X)=\wedge(a2-\beta X)-\wedge(a1-\beta X). \\ \ldots \\ P(Y=j|X)=P(Y^*>a_j-1|X)=1-\wedge(a_j-1-\beta X) \end{cases} \quad (3)$$

In the formula, $\wedge(.)$ is distribution function. The parameters of *Ordinal logistic* model are estimated by maximum likelihood method, but the marginal effect of independent variable X on the probability of each value of dependent variable is not equal to coefficient β, and the marginal effect can be expressed by the formula:

$$\begin{cases} (\partial P1/\partial xk)=-\beta k\, \phi(u1-\beta X) \\ (\partial P2/\partial xk)=-\beta k[\phi(u2-\beta X)-\phi(u1-\beta X)]. \\ \ldots \\ (\partial Pj/\partial xk)=-\beta k[\phi(uj-1-\beta X)] \end{cases} \quad (4)$$

In the formula, $k(k=1,2,\ldots)$ is the number of independent variables, $\phi(.)$ is density function. In the satisfaction evaluation model of farmers' participation in industrial poverty alleviation projects in southern Xinjiang, j is assigned 1,2,3,4,5, respectively: very satisfied =1, relatively satisfied =2, general =3, not very satisfied =4, very dissatisfied =5.

4. RESEARCH RESULTS AND ANALYSIS

The fitting information and parallelism hypothesis of the model as a whole are tested. According to the results, chi-square value is 303.746, and P value is less than 0.001, which indicates that the fitting result of the model is better. In addition, the parallelism hypothesis test result P is 0.097 greater than 0.05, which indicates that the model is suitable for analysis using the ordinal multi-classification Logistic regression model. SPSS 20.0 is used to carry out ordinal Logistic regression, and the regression results are shown in Table 3. It can be seen that farmers' satisfaction with industrial poverty alleviation is affected by many factors.

4.1 The Influence of Individual and Family Characteristic Variables of Farmers on Satisfaction Evaluation of Industrial Poverty Alleviation

The marital status of farmers, migrant workers, the main heating equipment of families and the main causes of poverty have no significant impact on the satisfaction of farmers with industrial poverty alleviation, but the educational level, the number of family labor force and the annual income of families all have significant impact on it. Specifically, the cultural level of farmers has a significant impact on their satisfaction with industrial poverty alleviation, showing a negative correlation. The higher the existing cultural level is, the lower the evaluation on the effect of industrial poverty alleviation will be. The main reason may be that most of the industries in the three prefectures of southern Xinjiang in China are labor-intensive industries, people with higher education level hope to have the more knowledge-intensive industries and the better job opportunities, which is also consistent with the unreasonable industrial structure of the three prefectures of southern Xinjiang in China. The variables of household labor force and household annual income have a significant impact on the satisfaction degree of industrial poverty alleviation, showing a positive correlation. On the one hand, the increase of effective labor force in families provides more human resources for industrial poverty alleviation projects; on the other hand, industrial development can provide more jobs, thus directly improving their income level. The increase of family's average annual income is the inevitable result of industrial development. The higher the average annual income level is, the stronger the positive feedback on the effect of industrial poverty alleviation and the higher the satisfaction will be.

Table 3 Empirical Analysis of Factors Influencing the Evaluation of Farmers' Industrial Poverty Alleviation Effect

Variable	Type	Estimate	Standard error	Significant		Variable	Type	Estimate	Standard error	Significant
Y	1	15.306	3.289	0.000		*X8*	1	-0.096	0.95	0.919
	2	16.608	3.287	0.000			2	0[a]	--	--
	3	17.843	3.295	0.000		*X9*	1	-0.951	0.682	0.163
	4	20.225	3.424	0.000			2	-1.195	1.392	0.391
X3	-	-0.051	0.253	0.019			3	0[a]	--	--
X1	1	0.423	0.264	0.016		*X10*	1	-2.095	1.738	0.028
	2	0.501	0.236	0.024			2	-1.556	1.764	0.038
	3	0.547	0.213	0.012			3	-2.515	1.716	0.043
	4	0[a]	--	--			4	0[a]	--	--
X2	1	-1.34	0.863	0.129		*X11*	1	-3.471	1.624	0.033
	2	-0.882	0.998	0.377			2	-3.285	1.637	0.045
	3	-1.627	1.145	0.155			3	0[a]	--	--
	4	0[a]	--	--		*X12*	1	-1.198	1.02	0.004
X4	1	-0.333	0.242	0.015			2	0.389	1.398	0.031
	2	-0.428	0.238	0.018			3	0[a]	--	--
	3	-0.632	0.245	0.003		*X13*	1	0.651	0.41	0.112
	4	-0.432	0.325	0.002			2	0[a]	--	--
	5	-0.645	0.241	0.001		*X14*	1	-0.401	0.568	0.481
	6	0[a]	--	--			2	0[a]	--	--
X7	1	-0.016	2.07	0.994		*X15*	1	0.496	0.985	0.153
	2	0.259	2.054	0.906			2	0.974	1.019	0. 392
	3	0.03	2.413	0.997			3	0.729	1.072	0.416
	4	0.168	2.173	0.938			4	0.888	1.569	0.712
	5	-0.243	2.103	0.908			5	1.119	1.612	0.808
	6	0.467	2.125	0.826			6	1.628	1.627	0.507
	7	-0.502	2.43	0.836			7	0[a]	--	--
	8	0.033	2.106	0.988		*X16*	1	-0.797	1.149	0.008
	9	-0.848	2.212	0.701			2	-0.705	1.178	0.019
	10	1.49	2.252	0.508			3	-0.909	1.204	0.010
	13	0[a]	--	--			4	0[a]	--	--
X5	1	-0.497	0.52	0.339		*X17*	1	-1.421	0.673	0.556
	2	0.412	0.415	0.321			2	-0.399	0.851	0.673
	3	0[a]	--	--			3	0[a]	--	--
X6	1	1.137	1.562	0.467						
	2	2.064	1.985	0.298						
	3	0.319	1.629	0.845						
	4	0[a]	--	--						

4.2 The Influence of Characteristic Variables of Basic Conditions on Satisfaction Evaluation of Industrial Poverty Alleviation

Internet broadband and drinking water sources have no significant impact on farmers' satisfaction with industrial poverty alleviation, but the types of roads in front of farmers' doors and household fuels have significant impact on them, showing a positive correlation. The types of road construction reflect the construction of public infrastructure. Judging from the investigation, the roads are mainly paved. The better road does not only reduce the transportation time of products and the inventory cost, but also attracts more investors and produces aggregation and scale benefits. The type of household fuel represents the family hardware condition to some extent. The better the condition is, the higher the satisfaction with the poverty alleviation effect will be. The main possible reason is that the relatively high quality of life that farmers can enjoy is the positive feedback result brought by participating in industrial poverty alleviation projects.

4.3 The Influence of External Support Variables on Satisfaction Evaluation of Industrial Poverty Alleviation

Whether there are loans or not and whether they participate in the new rural cooperative medical system have no significant influence on the evaluation of farmers' satisfaction with industrial poverty alleviation, but whether rural cadres help farmers to alleviate poverty has significant influence on it, showing a positive correlation.The three prefectures in southern Xinjiang of China are deep poverty-stricken areas in the country. In addition, the high proportion of ethnic minorities makes it difficult to help the poor to some extent due to communication barriers. On the one hand, the participation of rural cadres in poverty alleviation is conducive to publicizing the current poverty alleviation policies of the state, understanding the situation and problems of farmers, and helping farmers solve problems. On the other hand, rural cadres play the role of organizers and managers in industrial poverty alleviation projects to a certain extent, which is conducive to social stability and economic development, and industry is conducive to the suppression of social instability factors. Therefore, it has a positive effect for rural cadres to help farmers to help the poor out of poverty.

4.4 The Influence of Industrial Poverty Alleviation Characteristic Variables on Evaluation of Industrial Poverty Alleviation Satisfaction

The impact of which industrial poverty alleviation projects farmers have mainly participated in and whether they know about the time of poverty alleviation in their villages are not significant on their satisfaction evaluation, but the government's main poverty alleviation methods have significant impact on them, showing a positive correlation. Specifically, farmers participating in technical training have greater flexibility and higher significance in evaluating their satisfaction with poverty alleviation results. The main reason may be that through technical training, farmers' skill level has been improved, employment options are wide, and their "resources" are maximized, thus changing the poverty situation.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1 Conclusion

Based on the field survey data of 600 households in the three prefectures in the southern Xinjiang of China, this paper makes a regression analysis on the influencing factors of farmers' satisfaction with the industrial poverty alleviation effect by using a multivariate and ordinal logistic model. The empirical results show that: the individual education level in the individual and family characteristic variables of farmers have a significant negative correlation with their satisfaction with the industrial poverty alleviation effect, while the number of family labor force and the annual income of families have a significant positive correlation. In the characteristic variables of material conditions, there is a significant positive correlation between the types of roads in front of farmers' doors and the influence of household fuel on them. There is a significant positive correlation between the external support characteristic variables and whether rural cadres help farmers to help the poor out of poverty. Among the characteristic variables of industrial poverty alleviation, the government's main poverty alleviation methods have a significant positive correlation with its impact. The other variables have no significant influence on it.

5.2 Policy Recommendations

Based on the above empirical research results, in order to better mobilize farmers to participate in industrial poverty alleviation, so that industrial poverty alleviation can truly develop into a fundamental way for farmers to generate income, to avoid the occurrence of "industrialization" phenomenon of poverty alleviation, and to enhance farmers' satisfaction with the effect of industrial poverty alleviation, the following aspects should be optimized and improved:

(1) Continue to promote and improve the "Five Precision" poverty alleviation system, and especially strengthen the publicity of the "Guiding Ideology of Precision Poverty Alleviation". Adhere to the principle of advancing social and economic development together with poverty alleviation and development, combining precise poverty alleviation with district development, paying equal attention to ecological protection and production and life, fully mobilizing the enthusiasm of poverty alleviation subjects, forming an effective guarantee for effectively returning to poverty, adopting various methods in real time, and gathering social forces to resolutely win the battle against poverty.

(2) It is necessary to strengthen the investment in basic education and vocational education and transform human resources into the advantages of enterprise development. On the one hand, the government should invest funds and establish educational institutions according to local actual needs, resolutely implement the Education Law, promote the priority development of education, vigorously develop bilingual education, and reduce the dropout rate of school-age children. On the other hand, actively guide all social forces and charitable educational institutions to participate in education and poverty alleviation, and drive more social resources and teachers to support the development of education in the region. In particular, support for vocational education and skills training should be strengthened. Vocational skills training should be carried out regularly through organizations such as communities, enterprises or associations, and learning activities from more developed provinces from other areas and even from abroad should be organized regularly to bring

the latest production management methods and technical strength to the local.

(3) It is necessary to speed up infrastructure construction and create a good hardware environment for poverty alleviation. The three prefectures in southern Xinjiang of China are located at the southwest edge of the Taklimakan Desert, which is a region with serious water shortage. The construction of related water conservancy hubs and domestic and production water projects should be accelerated. Under the background of the current "the belt and road" construction, it is necessary to base on the border advantages of the three prefectures, strengthen the construction of the transportation network of railways, highways and aviation, adjust the policy of attracting foreign investment, encourage enterprises to come to Xinjiang to develop their businesses, vigorously develop the logistics industry, accelerate the economic development of ports, and provide hardware support for the development of various industries. At the same time, improve the rural medical service system, promote rural medical reform, and ensure the demand for basic medical services in rural areas.

(4) Based on the advantages of local resources, it is necessary to develop characteristic industries to achieve precise poverty alleviation. According to the specific situation of the countryside, plan suitable industrial development programs and provide enterprises with one-stop service of production and marketing. At the same time, the construction of the industrial chain should also be paid attention to, break through the upstream and downstream barriers of the industry, and form a virtuous circle of production and marketing. In particular, it is necessary to strengthen the development of e-commerce industry and provide conditions for products to be sold both at home and abroad. In addition, it is necessary to continuously form a reasonable industrial structure, gradually improve the technical level, improve productivity, especially agricultural productivity, and produce more agricultural products with local characteristics to provide a solid foundation for farmers to increase production, income and get rid of poverty.

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Session VI

Computer Science and Information Management

A Decision Making Approach under Hesitant Fuzzy Information

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ABSTRACT

For the multiple attribute decision-making problem, the decision-making approach which considers hesitant fuzzy decision information and unknown attribute weights is investigated. Primarily, the formed vectors of alternative, positive and negative ideal direction are defined. Subsequently, a bidirectional projection based on hesitant fuzzy information is established. Simultaneously, the improved closeness degree equation is proposed. Further, an attribute weight determination model which maximizes the closeness degree and entropy is constructed. In the last, an illustrative example is provided to demonstrate the validity and feasibility of the proposed approach.

CCS Concepts

• **Information systems→ Information systems applications→ Decision support systems→ Expert systems**

Keywords

Hesitant fuzzy information; Bidirectional projection; Closeness degree; Decision-making approach

1. INTRODUCTION

In recent years, the multiple attribute decision making has received extensive attention in the process of social and economic management. But along with the complexity and uncertainty in decision making, decision-makers are faced with more and more complex decision-making environment [1,2]. Thereby, they usually hesitate to make decisions in reality [3]. Accordingly, to address this problem, the hesitant fuzzy set is introduced, which is an effective tool to express the decision making information under considering the case of hesitation [4]. As a development of the fuzzy set [5], the hesitant fuzzy set was proposed by Torra [6]. He pointed out that the membership function of the hesitant fuzzy set was a set of possible values. When the decision-makers are in a hesitant state, or there is fuzzy information that reflects things, the valuable decision information can be extracted by using the fuzzy set of hesitation. This contributes to making an accurate judgment for decision-makers [7].

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Meanwhile, for the multiple attribute decision making under hesitant fuzzy information [8], the attribute weights will affect the decision making result, which is a significant factor [9-11]. a scientific and reasonable approach to solving the attribute weights maybe plays an important role in the decision-making process. Further, to discuss this problem deeply, Wang S L et al [12] developed a weighting approach according to the entropy principle. Wang Z et al [13] presented the linear programming model in order to solve the attribute weights of in decision-making. Wei [14] put forward an optimization approach for IFN ideal decision-making matrix based on the similarity point. Yuan et al [15] gave the nonlinear approach to deal with the weights, which was applied in the decision-making problems. Liao [16] investigated the problem with partially knowing the weights, and the optimization model was established to solve the weights. Rezaei [17] developed a best-worst approach of a multiple attribute decision making, as well as established a maximin model to solve the attribute weights. The literature [18-20] constructed the projection approaches to give the ranking of the alternative schemes. The above studies had achieved good results. Nevertheless, there are still some shortcomings, for instance, ignoring the hesitation degree of decision information in the method, not considering the uncertainty in the attribute weight solution, etc.

Consequently, under hesitant fuzzy information, the study of the decision-making method with unknown attribute weights needs to be further investigated. As previously noted, the decision-making approach with hesitant fuzzy information is developed in this paper. Specifically, in terms of dealing with hesitant fuzzy information, the projection technology is introduced into the decision-making method. Further, the relationships of an alternative hesitant fuzzy element, positive and negative ideal ones are considered in order to construct the bidirectional projection equations. Besides, through the attribute weights, the improved closeness degree is proposed.

Meanwhile, a determination model which maximizes the closeness degree and entropy is constructed to give the attribute weights. By applying this proposed approach, the alternative schemes are ranked to select the best one.

2. PRELIMINARIES

The definition and some characteristics of hesitation fuzzy set are described as follows.

Definition 1 [21]. X is not an empty set, $D=\{\langle x, f_D(x)\rangle, x\in X\}$ represents a hesitant fuzzy set. Where $f_D(x)$ represents a set $[0,1]$ of $x\in X$ possible membership degrees. For convenience, D is denoted as a hesitant fuzzy element $D=\{f_D(x)\}$.

Most often, the hesitant fuzzy elements should be normalized. In the set $f_D(x_i)$, When the disordered element order exists, the elements in the sets need be sorted in accordance with $f^{\delta(s)}(x)\le f^{\delta(s+1)}(x)$, where $\delta:(1,2,\cdots,m)\to(1,2,\cdots,m)$ indicates a permutation for $s=1,2,\cdots,m-1$.

Besides, the number of elements in the hesitant fuzzy sets $f_D(x_i)$ and $f_F(x_i)$ may be different. Therefore, the extension principle is adopted in order to address the sets with fewer elements. That is, under the optimistic criterion, the largest element in the set is added. Contrary, the smallest element is added.

3. DECISION MAKING APPROACH WITH HESITANT FUZZY INFORMATION

This section will describe the decision-making approach with hesitant fuzzy information. The bidirectional projection and the attribute weight determination model are proposed.

3.1. Bidirectional Projection

This section introduces the module, correlation coefficient [22] and the projection of the hesitant fuzzy element [23,24]. Simultaneously, the bidirectional projection and the closeness degree are given.

Definition 2. Suppose that a hesitant fuzzy element $f(x)$ satisfies the condition $f^{\delta(s)}(x)\le f^{\delta(s+1)}(x)$, where δ is a permutation, and then the module of the hesitant fuzzy element is defined by:

$$|f(x)|=\sqrt{\left(f^{\delta(1)}(x)\right)^2+\left(f^{\delta(2)}(x)\right)^2+\cdots+\left(f^{\delta(s+1)}(x)\right)^2} \quad (1)$$

Definition 3. Two hesitant fuzzy elements $f_1(x)=\{f_1^{\delta(1)}(x), f_1^{\delta(2)}(x),\cdots,f_1^{\delta(m)}(x)\}$ and $f_2(x)=\{f_2^{\delta(1)}(x), f_2^{\delta(2)}(x),\cdots,f_2^{\delta(m)}(x)\}$, and the correlation coefficient between $f_1(x)$ and $f_2(x)$ is expressed by:

$$\rho\left(f_1(x),f_2(x)\right)=\cos\left(f_1(x),f_2(x)\right)=\frac{\sum_{i=1}^{m} f_1^{\delta(i)}(x)\cdot f_2^{\delta(i)}(x)}{|f_1(x)||f_2(x)|} \quad (2)$$

According to Definitions 2 and 3, the projection equation is provided. Specifically, suppose that there are two hesitant fuzzy elements $f_1(x)$ and $f_2(x)$, further, the projection of $f_1(x)$ on $f_2(x)$ is expressed as:

$$Pr_{f_2(x)}^{f_1(x)}=|f_1(x)|\rho\left(f_1(x),f_2(x)\right)=\frac{\sum_{i=1}^{m} f_1^{\delta(i)}(x)\cdot f_2^{\delta(i)}(x)}{|f_2(x)|} \quad (3)$$

Where $Pr_{f_2(x)}^{f_1(x)}$ indicates the projection value. The higher the value $Pr_{f_2(x)}^{f_1(x)}$, which illustrates that $f_1(x)$ is closer to $f_2(x)$.

In order to construct the bidirectional projection, the formed vector between two hesitant fuzzy elements is introduced.

Definition 4. $f_1(x)=\{f_1^{\delta(1)}(x), f_1^{\delta(2)}(x),\cdots,f_1^{\delta(n)}(x)\}$ and $f_2(x)=\{f_2^{\delta(1)}(x), f_2^{\delta(2)}(x),\cdots,f_2^{\delta(n)}(x)\}$ are two hesitant fuzzy elements, and then $f_1(x)f_2(x)=\{f_2^{\delta(1)}(x)-f_1^{\delta(1)}(x), f_2^{\delta(2)}(x)-f_1^{\delta(2)}(x),\cdots,f_2^{\delta(n)}(x)-f_1^{\delta(n)}(x)\}$ is the formed vector of $f_1(x)$ and $f_2(x)$.

Additionally, in normalized hesitant fuzzy decision-making matrix $F=[f_{ij}]_{m\times n}$, where, $i\in\{1,2\cdots,m\}$, $j\in\{1,2\cdots,n\}$. Further, the positive ideal hesitant fuzzy element of F is denoted by $F^+=(f_1^+,f_2^+,\cdots,f_n^+)$, $F^-=(f_1^-,f_2^-,\cdots,f_n^-)$ indicates the negative ideal hesitant fuzzy element, where, $f_j^+=\max_{1\le i\le m}\left(f_{ij}^{\delta(S)}\right)$ and $f_j^-=\min_{1\le i\le m}\left(f_{ij}^{\delta(S)}\right)$. Meanwhile, the alternative hesitant fuzzy element $F_i=(f_{i1},f_{i2},\cdots,f_{in})$ is given, Subsequently, the formed vectors of them can be expressed by respectively:

$$F^-F^+=\left(f_1^+-f_1^-,f_2^+-f_2^-,\cdots,f_n^+-f_n^-\right) \quad (4)$$

$$F^-F_i=\left(f_{i1}-f_1^-,f_{i2}-f_2^-,\cdots,f_{in}-f_n^-\right) \quad (5)$$

In accordance with the above analysis, the bidirectional projection relationships of the formed vectors between F^+, F^- and F_i are provided as follows respectively:

1) The projection of the formed vectors between F^- and F_i on the formed vectors between F^+ and F^- is described by:

$$Pr_{F^-F^+}^{F^-F_i} = \left|F^-F_i\right| \rho\left(F^-F_i, F^-F^+\right) = \frac{\sum_{j=1}^{n}(f_j^+ - f_j^-)\cdot(f_{ij} - f_j^-)}{\left|F^-F^+\right|} \tag{6}$$

2) The projection of the formed vectors between F^+ and F^- on the formed vectors between F_i and F^+ is described by:

$$Pr_{F_iF^+}^{F^-F^+} = \left|F^-F_i\right| \rho\left(F^-F^+, F_iF^+\right) = \frac{\sum_{j=1}^{n}(f_j^+ - f_j^-)\cdot(f_j^+ - f_{ij})}{\left|F_iF^+\right|} \tag{7}$$

As aforementioned, the bidirectional projection is given. Further, based on the TOPSIS method [25,26], the closeness degree is established as follows:

$$D\left(F_i\right) = \frac{Pr_{F^-F^+}^{F^-F_i}}{Pr_{F^-F^+}^{F^-F_i} + Pr_{F_iF^+}^{F^-F^+}} \tag{8}$$

In addition, the problem with hesitant fuzzy multiple attributes will be introduced and considered, the closeness degree equation can be further improved through the attribute weights.

Therefore, suppose that $S_i = \left\{S_1, S_2, \cdots S_m\right\}$ is the set of alternative schemes, $G_j = \left\{G_1, G_2, \cdots G_n\right\}$ represents the set of attributes. Moreover, in normalized hesitant fuzzy decision-making matrix $F = \left[f_{ij}\right]_{m\times n}$, f_{ij} indicates the evaluation information of the alternative scheme S_i under the attribute G_j. Meanwhile, $\alpha_j = \left\{\alpha_1, \alpha_2, \cdots \alpha_n\right\}$ denotes the projection attribute weights of the formed vectors between F^- and F_i on the formed vectors between F^+ and F^-. $\beta_j = \left\{\beta_1, \beta_2, \cdots \beta_n\right\}$ denotes the projection attribute weights of the formed vectors between F^+ and F^- on the formed vectors between F_i and F^+. Where, $\alpha_j \in [0,1]$, $\sum_{j=1}^{n}\alpha_j = 1$, $\beta_j \in [0,1]$, $\sum_{j=1}^{n}\beta_j = 1$. The projection matrixes based on hesitant fuzzy information are aggregated with the attribute weights, and the weighted projection of schemes S_i under the attribute G_j can be given.

1) The weighted projection of alternative schemes S_i under the attributes G_j on the positive ideal direction is expressed by:

$$Pr^+ = \alpha_j \times Pr_{F^-F^+}^{F^-F_i} \tag{9}$$

2) The weighted projection of alternative schemes S under the attributes G on the negative ideal direction is expressed by:

$$Pr^- = \beta_j \times Pr_{F_iF^+}^{F^-F^+} \tag{10}$$

Accordingly, the improved closeness degree equation under the attribute weights is developed as follows:

$$D\left(S_i\right) = \frac{Pr^+}{Pr^+ + Pr^-} \tag{11}$$

Consequently, based on the values $D\left(S_i\right)$, alternative schemes can be ranked. The higher the value $D\left(S_i\right)$, the better the alternative scheme S_i is.

Nevertheless, in decision making, it is difficult to determine the attribute weights. Therefore, in the next section, the method of determining the attribute weights is proposed.

3.2. Attribute Weight Determination Model

In some cases, due to the influence of external uncertainties, it is difficult to determine the attribute weight in decision-making. When the attribute weight is unknown, the fair competition between candidate schemes is considered. The higher the value $D\left(S_i\right)$, the better the ranking of alternative schemes. Accordingly, the model can be established as follows:

$$maxD\left(S_i\right) = \frac{Pr^+}{Pr^+ + Pr^-} \tag{12}$$

Due to the uncertainty of attribute weight, the maximum entropy theory [12] is introduced. The maximum entropy represents the minimum information and it is reasonable in the case of incomplete data [27]. Therefore, the maximum entropy model of attribute weight α_j and β_j can be constructed respectively

$$maxG = -\sum_{i=1}^{n}\alpha_j \ln \alpha_j \quad S.T.\begin{cases}\sum_{j=1}^{n}\alpha_j = 1 \\ 0 \le \alpha_j^L \le \alpha_j \le \alpha_j^U \le 1\end{cases} \tag{13}$$

$$maxG = -\sum_{i=1}^{n}\beta_j \ln \beta_j \quad S.T.\begin{cases}\sum_{j=1}^{n}\beta_j = 1 \\ 0 \le \beta_j^L \le \beta_j \le \beta_j^U \le 1\end{cases} \tag{14}$$

Based on the models (12) - (14), the model (15) of solving attribute weight α_j and β_j can be obtained as follows:

$$maxZ = \lambda \frac{Pr^{+}}{Pr^{+}+Pr^{-}}$$

$$-(1-\lambda)(\sum_{i=1}^{n}\alpha_j \ln \alpha_j + \sum_{i=1}^{n}\beta_j \ln \beta_j) \qquad (15)$$

$$S.T.\begin{cases} \sum_{j=1}^{n}\alpha_j = 1 \\ \sum_{j=1}^{n}\beta_j = 1 \\ 0 \le \alpha_j^L \le \alpha_j \le \alpha_j^U \le 1 \\ 0 \le \beta_j^L \le \beta_j \le \beta_j^U \le 1 \end{cases}$$

Where $\lambda \in [0,1]$ represents the balance coefficient, whose value can be determined by the decision-maker according to the actual situation. The model (15) can be solved by LINGO and other software. Thus, α_j and β_j are obtained.

4. ILLUSTRATIVE EXAMPLE

To illustrate this decision-making approach, the case of supplier selection is introduced in this paper. Suppose that $S_i = \{S_1, S_2, S_3, S_4, S_5\}$ is the set of alternative schemes and $G_j = \{G_1, G_2, G_3, G_4\}$ is the set of attributes. Simultaneously, G_1 denotes the enterprise reputation; G_2 indicates the product quality; G_3 represents the technical ability; G_4 stands for the service level; according to the above four attribute indexes, the alternative scheme S_i can be evaluated. The hesitant fuzzy set is adopted to evaluate alternative schemes, and the hesitant fuzzy decision-making matrix is shown in Table 1.

Table.1 Hesitant fuzzy decision-making matrix

	S_1	S_2	S_3	S_4	S_5
G_1	{0.2,0.3,0.7}	{0.2,0.4,0.5}	{0.4,0.5,0.6}	{0.3,0.4}	{0.3,0.8}
G_2	{0.6,0.7}	{0.3,0.7}	{0.3,0.6}	{0.6}	{0.4,0.5,0.8}
G_3	{0.4,0.6}	{0.3,0.7}	{0.4,0.5}	{0.2,0.8}	{0.6}
G_4	{0.4,0.4,0.7}	{0.4,0.4}	{0.3,0.7}	{0.2,0.6}	{0.1,0.4,0.6}

Primarily, according to the optimistic criterion, the largest element is added to the sets. Through the normalized processing, the normalized hesitant fuzzy decision-making matrix $F = \left[f_{ij}\right]_{m\times n}$ is given as shown in Table 2.

Table.2 Normalized hesitant fuzzy decision-making matrix

	S_1	S_2	S_3	S_4	S_5
G_1	{0.2,0.3,0.7}	{0.2,0.4,0.5}	{0.4,0.5,0.6}	{0.3,0.4,0.4}	{0.3,0.8,0.8}
G_2	{0.6,0.7,0.7}	{0.3,0.7,0.7}	{0.3,0.6,0.6}	{0.6,0.6,0.6}	{0.4,0.5,0.8}
G_3	{0.4,0.6}	{0.3,0.7}	{0.4,0.5}	{0.2,0.8}	{0.6,0.6}
G_4	{0.4,0.4,0.7}	{0.4,0.4,0.4}	{0.3,0.7,0.7}	{0.2,0.6,0.6}	{0.1,0.4,0.6}

Sequentially, the positive and negative ideal hesitate fuzzy element F^{+} and F^{-} can be are listed as follows:

$$F^{+} = \begin{pmatrix} \{0.4,0.8,0.8\},\{0.6,0.7,0.8\} \\ \{0.6,0.8\},\{0.4,0.7,0.7\} \end{pmatrix}$$

$$F^{-} = \begin{pmatrix} \{0.2,0.3,0.4\},\{0.3,0.5,0.6\} \\ \{0.2,0.5\},\{0.1,0.4,0.4\} \end{pmatrix}$$

Further, based on equations (4) - (7), and the bidirectional projection value matrix is calculated and given as follows:

$$Pr_{F^{-}F^{+}}^{F^{-}F_i} = \begin{bmatrix} 0.18 & 0.13 & 0.33 & 0.10 & 0.64 \\ 0.36 & 0.15 & 0.05 & 0.27 & 0.17 \\ 0.22 & 0.20 & 0.16 & 0.16 & 0.38 \\ 0.35 & 0.17 & 0.46 & 0.29 & 0.12 \end{bmatrix}$$

$$Pr_{F_iF^{+}}^{F^{-}F^{+}} = \begin{bmatrix} 0.60 & 0.67 & 0.64 & 0.66 & 0.20 \\ 0.20 & 0.35 & 0.40 & 0.27 & 0.35 \\ 0.49 & 0.47 & 0.47 & 0.40 & 0.30 \\ 0.30 & 0.42 & 0.30 & 0.49 & 0.48 \end{bmatrix}$$

Later, suppose that the balance coefficient $\lambda = 0.5$ and the weight information is: $\Omega = (\alpha_1 \geq 0.2, \alpha_2 \geq 0.15, \alpha_3 \geq 0.2,$ $\alpha_4 \geq 0.15;\ \beta_1 \geq 0.2, \beta_2 \geq 0.15, \beta_3 \geq 0.2, \beta_4 \geq 0.1\}$. By using the equation (15), the attribute weights α_j and β_j are calculated as follows.

$$\alpha_j = \{0.26, 0.21, 0.23, 0.30\}$$

$$\beta_j = \{0.20, 0.32, 0.23, 0.25\}$$

Then, according to the equations (9) and (10), the weighted projection is provided as follows respectively:

1) The weighted projection of schemes S under the attributes G on the positive ideal direction is:

$$Pr^{+} = \{0.28, 0.16, 0.27, 0.21, 0.33\}$$

2) The weighted projection of schemes S under the attributes G on the negative ideal direction is:

$$Pr^{-} = \{0.37, 0.46, 0.44, 0.43, 0.34\}$$

Further, based on equation (11), the value $D(S_i)$ is calculated.

$$D(S_1) = 0.43,\ D(S_2) = 0.26,\ D(S_3) = 0.38,$$

$$D(S_4) = 0.32,\ D(S_5) = 0.49$$

From the above values, it is shown that:

$$D(S_5) > D(S_1) > D(S_3) > D(S_4) > D(S_2)$$

Meanwhile, the ranking of alternative schemes can be obtained as follows:

$$S_5 \succ S_1 \succ S_3 \succ S_4 \succ S_2$$

In conclusion, S_5 is the best scheme.

5. CONCLUSION

This paper investigates the multiple attribute decision-making problem with hesitant fuzzy under unknown attribute weights, and the decision-making approach with hesitant fuzzy information is proposed. Firstly, the formed vector equations are defined and given. Subsequently, the hesitant fuzzy bidirectional projection equations are established. Further, the attribute weights are introduced, and the weighted projection of the alternative schemes under the attribute is calculated and obtained. Meanwhile, the improved closeness degree equation is constructed. Moreover, an attribute weight determination model which maximizes the closeness degree and entropy is developed to give the values of the attribute weight. Later, this proposed decision-making approach is applied to solve the problem of supplier selection, and the ranking of alternative schemes is provided for selecting the best one.

Nevertheless, along with the complexity and uncertainty in decision making, the multiple attribute decision-making problems under heterogeneous information has become one of the important studies. Consequently, the future focus discussion will be the decision-making methods with heterogeneous information.

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The Promotion Mechanism Development for User's Information Need Understanding Based on Knowledge Structure Precise Matching

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ABSTRACT
Understanding user's information needs is the premise and basis to improve the quality of information services and systems. When engaging in various activities, people have run into problems that are followed by the realization of insufficient knowledge structure to resolve these problems, and the need for information has arisen. After information needs are generated, they have experienced an expression process from the internal to the external and from the abstract to the concrete. The process of information need expression is influenced by the users themselves and their surrounding environment. Ambiguities will appear during this process. The current systems mainly promote understanding through (1) information extraction and knowledge acquisition, (2) ontology, semantic web, and knowledge graphs, (3) semantic disambiguation, and (4) topic modeling. This research proposes a new promotion mechanism for the understanding of user information needs. Based on collaborative filtering and folksonomy, the mechanism can precisely match the user with other most related users and get the user's knowledge structure.

CCS Concepts
• Information systems→ Collaborative filtering • Information systems→ Social tagging • Information systems→ Information retrieval query processing.

Keywords
Information need; folksonomy; ontology

1. INTRODUCTION
Information need is one of the key concepts about human information behavior. Information behavior is generated by information needs and terminated due to the satisfaction or disappearance of information needs. Information service and information systems are usually designed and developed according to information needs. The lack of understanding of information need restrict further improvement of information systems' results.

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If researchers can better understand how users express their information needs, how problems possibly occur in understanding those needs, and what are current techniques and methods used to solve these problems, they can improve the system's understanding of users' information needs, so as to further improve the retrieval effect.

This paper will try to (1) define and determine the causes of information needs,(2) discuss how to express and understand information needs,(3) evaluate the ambiguities during information need expression (4) explore how the current information systems understand users' information needs and deal with their problems, and (5) suggest a method that could probably improve the system's understanding of the users' information needs based on their problems.

2. INFORMATION NEEDS AND THE CAUSES
Basic human needs are divided by psychologists into three categories: physiological needs, affective needs, and cognitive needs. Wilson[1] argues that these three kinds of needs are interrelated, and people seek information in order to meet these needs.

Discussion on information needs started from the 1960s. As a basic concept in the field of information behavior, the concept of information need has been discussed by many scholars in the field of information behavior. Taylor[2][3] points out that information needs are related to uncertainty and have a process of development and change, and she proposes four kinds of information needs according to the degree of uncertainty. Dervin[4] argues that people's actions are hindered by encountering incomprehensible situations or contexts, and there is a gap between what they know and what they want to know. This gap, which can be interpreted as information need, can be eliminated by seeking information. Belkin[5] puts forward anomalous states of knowledge hypothesis (ASK), and he points out that the anomalous state of knowledge is the consciousness of lack in the existing knowledge structure. When a user is unable to solve the problems in a specific field because of the anomalous state of knowledge, an information need arises. And because of the anomalous state of knowledge, the user cannot clearly express what is needed. According to Ford[6], information need is "the state in which people are aware that they don't know, or that there are conceptual inconsistencies in the cognitive structure that are insufficient to accomplish the task." Hosono and Zou[7] summarizes it as follow: "the cognitive view of information science research regards information need as the insufficient, abnormal and other defects of knowledge structure". Zhong[8] defines information need based on its social reasons: people's needs for information are generated to solve different problems in the process of social activities. It should be noted that

an information need is not an inherent need, but is generated by people to solve problems in a specific situation, so it is a secondary need.

Dervin, Belkin, Ford, and Hosono consider information need as the anomalies of knowledge structure. When problems are encountered in real life and cannot be solved by existing knowledge, information need is realized. The anomaly of the knowledge structure is what Taylor calls the visceral need. These scholars have emphasized the anomalies of the user's existing knowledge structure. The definition of user's information need by Zhong emphasizes that it is the goal to solve their problems that causes information need, and the external environment of information need should not be neglected.

These definitions of information need are generally based on the reasons for information need, and the causes of information need are divided into internal and external causes. The external cause of information need arises when people engage in various social activities, complete tasks, and they have to solve different problem. The internal cause is the deficiency in people's knowledge structure. Generally, people recognize the lack of knowledge structure that affects decision making in the activities. The deficiency in people's knowledge structure has always existed. When they encounter various problems in their activities, the lack of knowledge structure becomes apparent, and information needs emerge.

3. INFORMATION NEED EXPRESSION

3.1 Levels of Information Need Expression

There is a difference between the user's inherent information needs and the information needs they express. Researchers have studied the levels of user's information need expression.

Taylor[2] assumes that the user's information needs are different and traceable. From the process of problem formation, the user's information needs are studied, and the information needs are divided into the following four levels: the visceral needs, the conscious needs, the formalized needs, the compromised needs. The first three are the intrinsic needs of the user, and the compromised needs are the information needs that user finally expresses. Such divisions clearly distinguish the levels of information need expression from the internal state to the external state. However, in the actual process of expressing information needs, these four levels do not necessarily have to be experienced in order, and some of them may be skipped. For example, when a user generates some kind of information need and recognizes it, he will not formally form a query but consults a librarian instead. The librarian will then form a query submitted to the information system based on the discussion with the user. In the communication process, the user's conscious need is directly translated into the compromised need, while the formal need is skipped in the process.

In analyzing the process of information retrieval, Ingwersen[9] pointed out that the first stage is the formation of information needs from the user's problem situation, and the second stage is the user's formal expression of those needs. When there is a difference between the internal and the expressed, the user's problem becomes ambiguous.

To sum up, the process of the formation and the expression of user's information need is a process from the internal to the external and from the abstract to the concrete. It should be noted that although this is a gradual process, some of the steps may be skipped.

3.2 Determinants of Information Need Expression

It can be inferred from the above that the user's information needs require a process from formation to expression. In this process, both the user and the surrounding environment will affect the expression.

Many researchers think that users themselves make significant influence on the expression of their information needs. Ingwersen[9] states that the recall, recognition, and cognition of different concepts and knowledge will affect the process of information retrieval , and the expression of information needs, a critical step in information retrieval, are also affected. Hu[10] states that internal factors, such as user's information awareness, cognitive ability, knowledge structure, knowledge level, and experience, will affect the expression of user's information needs. Xu[11] argues that internal factors, such as the user's cognitive ability, articulation skills, and user's trust in the information service system, will affect the expression of user's information needs. In particular, she points out that it is the internal causes that determine the user's information needs. On the other hand, social factors and natural factors are external causes that can make an influence on the internal causes.

At the same time, the user's external environment also affects the expression of information needs. The channels through which users express their needs, the symbols used, and the social and natural conditions will have an important impact on the expression of user's information needs. The monetary cost, ease of use, speed, efficiency, capability to meet users' needs, and quality of information services will also affect the expression of information needs. For example, if the price of a single information service is high and the speed is slow, users will think twice before they express their information needs, so that the queries they submit to the information system can be expectedly more accurate, in order to reduce the frequency of information services and the costs.

In response to the above factors, Kim[12] argues that there are three things that information systems and information services need to do :

(1) Increase user input to make the initial query clearer. The key is to encourage users to express as much as possible, to provide more information about their information needs, so that the system can more accurately understand the user's information needs.

(2) Reduce the search scope through the system's question and answer. Enhance the interaction between man and machine, and help the user to ambiguous input through effective response from the system.

(3) Cluster the features of search results based on expected answers. Use K-means and other algorithms to cluster the search results, narrow the choice of answers, and then match the user's needs to get more accurate results.

Besides, in the field of information seeking, "search as learning" is a topic of current interest. As Vakkari[13] has stated, it focuses on evaluating how the interactions between search engines and users lead to the reconstruction of user's knowledge structures and queries in the search process. In the search process, users express the topic vaguely due to insufficient knowledge structures. After receiving the information provided by the search engines, they reconstruct their knowledge structures and clarify their queries step by step. The knowledge structures play an important role in the expression of information needs. Furthermore, the proper feedbacks from search engines assist users on reconstructing their knowledge structures and clarifying their information needs.

4. THE UNDERSTANDING OF INFORMATION NEEDS

4.1 Problems in Information Need Understanding

Ambiguities appear in the whole process when user expressed information needs. First of all, according to the ASK hypothesis, since the user does not understand the information he wants to obtain, there is an anomality in the knowledge structure, so it is difficult for the user to have a comprehensive, clear and accurate understanding of the information needs of himself. Secondly, even if the user has a more comprehensive, clear and accurate understanding of his information needs, he needs to express the concepts in mind in words, and the words usage will cause the problems of synonyms, homonyms, polysemous, and confusing words. Therefore, the text could be unclear, vague, and misleading.[14] Even if there is no ambiguity in the expression of user's information needs, there may be ambiguities due to context. In the person-to-person information service, because of the gaps and differences in the knowledge structure between users and information experts, the user's expression of information needs and the understanding of experts will be different.

From the perspective of linguistics, ambiguity is divided into oral ambiguity and written ambiguity. The former refers to the ambiguity in the speech level, and the latter refers to the ambiguity in the written material. From the perspective of the constituent elements of the language system, ambiguity in Chinese can be divided into phonetic ambiguity, lexical ambiguity and grammatical ambiguity: phonetic ambiguity is caused by homonyms, lexical ambiguity is caused by polysemous words, and grammatical ambiguity is caused by structural hierarchy, structural relationship or semantic relationship.[15] In the expression of information needs, these kinds of ambiguities are very common. In the information service of people facing people, there will be oral ambiguity, since voice, vocabulary and grammatical ambiguity may occur. While users use information systems, there will be written ambiguity. Because the current queries are basically composed of vocabulary, vocabulary ambiguity appears more often.

4.2 Techniques Used in Information Systems to Understand Information Needs

With the development of computers and the Internet, the technology of computer processing and understanding has also been developing, and the trend from data processing to information processing to knowledge processing has emerged. In general, the current methods and techniques for understanding the expression of information needs can be divided into the following aspects:

(1) Information extraction and knowledge acquisition

Information extraction is the basis of the data preparation work that the system needs to perform before understanding the user's needs. The main function of information extraction is to extract specific fact information from the information. Usually, the extracted information is described in a structured form and can be directly stored in the database for the search and further utilization. Named entity recognition, syntactic analysis, text analysis and reasoning, and knowledge acquisition are key techniques for information extraction.[16] Through information extraction, a large amount of fact information can be obtained from comparatively large sample corpora (such as news, Wikipedia, etc.) to build a knowledge base or ontology, etc., in order to help the system better understand the user's knowledge structure. That is to say, in the aspect of helping the system understand the expression of user's information needs, the purpose of information extraction technology is mainly knowledge acquisition. Current knowledge acquisition is mainly carried out in three aspects: direct acquisition of knowledge from structured, semi-structured and unstructured data; knowledge fusion of acquired knowledge; and knowledge calculation of implicit knowledge.[17]

(2) Ontology, Semantic Web, and Knowledge Graph

In order to better understand the user's information needs, it is necessary to know the relationship between the entities or concepts expressed by the users. Ontology is first developed in the field of philosophy, and it is a set of concepts and categories in a subject area or domain that shows their properties and the relations between them. It is mainly used to describe and represent a domain knowledge and to share information between people, databases, and applications, often expressed as a set of objects (concepts), relationships, functions, theorems, and examples.[18] Berners-Lee[19] proposed the concept of Semantic Web at the end of the twentieth century. The Semantic Web is an operational information network—interpreted symbolic information derived from data through semantic theory.[20] In May 2012, Google officially released the Knowledge Graph to public, followed by the release of many other large-scale knowledge graphs such as Freebase, DBPedia, NELL and YAGO. The knowledge graph is essentially a semantic web, with nodes representing entities or concepts, and edges that represent various semantic relationships between entities or concepts. Many knowledge graphs use the unified resource description framework as the data format and contain many SPO (Subject, Predicate, Object, respectively, subject, attribute and object) triples.

Using ontology, semantic web, and knowledge graph, people can establish the connection between concepts to enable the systems to construct a certain knowledge base by itself and for it to better understand the information needs of users. In it, a certain parsing analysis is needed to help form a match between the information need expression and the knowledge base, such as semantic web, knowledge graphs, and so on. For example, when the user asks: "Which team is Michael Jordan in?" and, in the system's knowledge base, there are former US professional basketball player and a professor of computer science at the University of California at Berkeley, both named Michael Jordon, the system need to obtain more information from the context, such as "team", to find the relevant concepts required by the user in the constructed ontology and understand that Michael Jordan is the basketball player. The system then retrieves the basketball player Michael Jordan and returns the results the user really needs.

(3) Semantic disambiguation

As mentioned above, ambiguities appear in the whole process when users express their information needs. These ambiguities have become a major obstacle for the system to understand the expression of user's information needs. The task of semantic disambiguation is to determine the semantics of an ambiguous word through its usage context.[21] The main direction of semantic disambiguation is based on statistical methods. The methods of statistical learning mainly include dictionary-based, naive Bayesian classification, SVM (Support Vector Machine) classification, and information theory-based classification. By performing semantic disambiguation, the range of references can be effectively reduced, and the accuracy of understanding can be improved.

(4) Topic modeling

In natural language processing, a topic can be regarded as a probability distribution of terms. The topic model is usually used to simulate the document generation process, and then various topics are obtained through parameter estimation. When a document is represented in the form of a bag of words, its dimensions may be tens of thousands. If the number of topics in the specified topic model is K, and through the training of the topic model, K topics are finally formed, then the documents in the term space can be transformed into the topic space to obtain a new expression of the document. Since the number K of the usual topics is much smaller than the number of terms, the topic model is often used for dimensionality reduction. In the area where the text is the object of processing, the new dimensions after dimensionality reduction (i.e. components on K topics) tend to have semantic features.[22] By using the topic model, the text data input by the user can be dimensioned to better understand the user's information needs expression.

5. A METHOD TO IMPROVE USER'S INFORMATION NEED UNDERSTANDINGS BASED ON USER'S KNOWLEDGE STRUCTURE

As mentioned above, the user's knowledge structure is insufficient when his information need arises. User's cognitive ability and knowledge structure will affect the information need expression. Different people have different knowledge structures, and their understanding of the concepts, the expression of concepts, and the relationships between concepts are also different. The problem with the current knowledge base is that even if the system constructs a certain knowledge base through ontology and semantic web, the entities and concepts in such knowledge bases are mainly formulated by experts, and the expression of concepts also follows certain standards. Experts are not necessarily identical to the user's knowledge structure, and their understanding of different concepts is also different. Therefore, how to accurately match the user's knowledge structure, so that information systems and information services can more accurately understand the needs expressed by users becomes the key.

The concept of collaborative filtering was first proposed by Goldberg et al.[23] in 1992 and is commonly used in recommendation systems. It is mainly divided into user-based collaborative filtering and item-based collaborative filtering. Among them, the user-based collaborative filtering algorithm has the assumption that if users score similarly on one item, they will score similarly to other items, and the algorithm will calculate the target user's score based on the nearest neighbors of the target users (the most similar users).

Vander[24], the concept proponent of the folksonomy, defined the folksonomy as the result of the free tagging on information or objects by individual users for their search needs. This kind of tagging is done in a social environment, and this environment is open and shared. Tagging is done by consumers of information. Celine et al.[25] propose the approach named folksOntology which is a structured method on how to use folksonomy to construct an ontology. Nowadays, many studies[26-27] are based on the folksonomy to construct domain ontology, which is marked by the public, automatically enriches and builds, but they rarely consider the similarity of the user who is the subject of ontology construction.

In this study, we use collaborative filtering as a supplement to this method, so that the knowledge structure with the highest matching degree can be obtained, and the current user's needs can be better understood and processed. The returned search suggestions can also help users to further clarify their own information need. Here is the conceptual framework(figure1):

(1) Tags generation. Users browse and use information resources, and tag the resources (R1, R2, R3, ...). Each resource gets several tags (T1, T2, T3, ...), and the system invalidates the tags (such as "to be read") and stores valid tags in the database.

(2) Query submission. A specific user (U0) generates and submits a preliminary search query(T1) to the system based on his information needs.

(3) Collaborative filtering. The user's interest vector is constructed based on the search log data and the interest areas of the specific user (U0), and the similarity is calculated with the interest vectors of other users, and the users whose ranking is ranked higher or greater than a certain threshold (U1, U2, ... Un) are selected. The user's tags, generated by similar users around a specific user (U0), are integrated in a specific way to form an ontology.

(4) Query expansion. Based on the generated ontology for a specific user (U0), the user's search query(T1) can be located, and returns the relevant terms (T2, T3) in the ontology and their relationship with the original search query. The user can adjust or expand the search query accordingly, or automatically accept the recommendations made by the system.

It is worth noting that this method can work in two ways. When the user chooses to automatically accept the suggestions made by the system, or the system does not feedback this process to the user, the user does not need to process the feedback. This process is a deeper understanding of the user's information needs.

When the system returns the results to the user and allows the user to adjust the search query, the process is to help the user to express the information need more accurately. The user can acquire certain knowledge in this process, but correspondingly, the user needs to bear additional cognitive load. Nevertheless, the collaborative filtering is useless and even negative for the user to acquire knowledge because it will choose the most similar users to form the ontology which could be hardly new to the user. So, this way of using the method is not recommended.

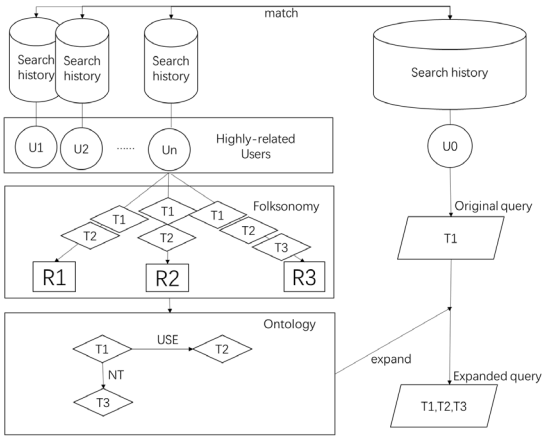

Figure 1. The mechanism of the method (U refers to User, R refers to Resource, T refers to Term)

6. CONCLUSIONS AND DISCUSSIONS

With the development of computers and the Internet, human beings are about to enter the era of web 3.0. Web 3.0 offers users intelligent filters based on user needs and a diversified need satisfaction

platform. This paper summarizes the definitions and causes of information need, and analyzes the levels of information need expression and the determinants in this process. Because ambiguities appear in the whole process when expressing the information needs, there will be certain difficulties for the systems to understand user's information needs.

At present, some techniques have focused on understanding the user's information needs. This paper introduces the collaborative filtering into the construction of the ontology. By accurately matching the user's knowledge structure, it provides a new way to improve the user's information expression and understanding.

This method is currently only in the concept stage and has not been empirically tested. Here are some of its potential problems.

(1) Performing large-scale collaborative filtering requires a large amount of calculation, and the reaction time is long. The solutions include: a. Reduce the time required for calculation by adopting an optimization method, for example, grouping users first, and performing local collaborative filtering; b. Periodically calculate and store the corresponding knowledge structure of the users, and directly call them when the user submits the query.

(2) The problem of obtaining the annotation. For some online communities, such as del.icio.us, it has become a good habit for users to label resources. Considering that the precise expression of user requirements may be used in the knowledge management system, we have reason to expect a corresponding user tag generation mechanism in the system. If you consider a search engine whose application scenario is a massive web resource, designers can set up a mechanism to allow users to add tags and select from the most frequently selected tags. By reducing user work and setting appropriate reward mechanisms, users are encouraged to do the tagging.

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Theory and Applications of Graph Neural Networks in Knowledge Acquisition

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ABSTRACT

Knowledge acquisition is a process in which an artificial intelligence system acquires relevant knowledge from datasets. Knowledge acquisition extracts and forms knowledge from data of different structures. One type of data used to acquire knowledge is structured data, such as physics models, chemical structures, social network information, and traffic network information. Many structured data can be represented as graph structures with dependencies and attributes. In recent years, deep learning methods are applied to knowledge acquisition tasks. As a deep connection model, graph neural network (GNN) is suitable for processing data represented as graph structure since it can use nodes and edges to realize information interaction and obtain graph dependencies. In this review, we discuss GNN model and its variants. Experiments show that the variants of GNNs outperform traditional methods in many knowledge acquisition tasks.

CCS Concepts

• **Computing methodologies → Knowledge representation and reasoning**

Keywords

Knowledge Acquisition; Graph Neural Network; Graph Convolutional Network; Graph Attention Network

1. INTRODUCTION

Knowledge acquisition play an important part of knowledge systems. Its task is to extract the content from abundant sample data and organize it for knowledge modeling. Knowledge acquisition needs to adopt various data structures (structured data, semi-structured data, unstructured data). For structured data, tools such as Extract-Transform-Load (ETL) [1][2] are widely used. ETL simply extracts, cleans, transforms sample data, and then loads the results into the data warehouse. The method only realizes the simple integration of different data, but doesn't acquire new knowledge. [3] describes a knowledge-based framework which utilizes an external knowledge base to encode the background knowledge and semantic information of text into representation. [4] investigates the issue of measuring knowledge diffusion efficiency and identify the important members with great influence on knowledge diffusion. The essence of [3][4] is to express and diffuse the original knowledge, which is not used to learn new knowledge.

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Many structured data in life can be naturally converted into graph structure data, such as physics models, chemical structures, social network information, and traffic network information. For example, Fig. 1 shows that daily food intake can be modeled through graph structure. Each node represents different food, each edge represents the relationship between the food. The graph can evaluate whether the food cause adverse reactions in the body. In recent years, deep learning [5] methods are applied to analyze graph data. Knowledge acquisition is not a unified representation of the original knowledge, but a new knowledge obtained through neural networks training.

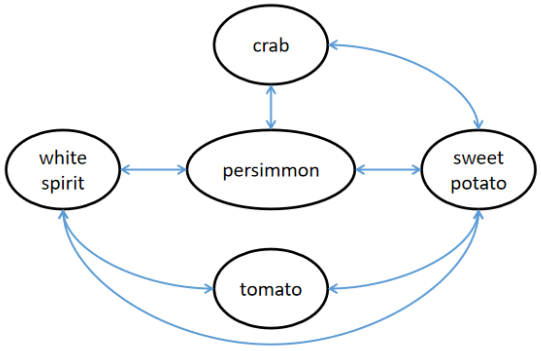

Figure 1. Graph structure of the relationship between the food

[6] proposed a graph neural network model for graph data processing. Circulatory nerve structure is used to propagate the information of the surrounding nodes, so as to reach a stable fixed point and then realize the representation of the target node. [7] and [8] considered the general question of how to construct deep architectures with small learning complexity on general non-Euclidean domains and proposed two constructions, one based

upon a hierarchical clustering of the domain, and another based on the spectrum of the graph Laplacian. [9] presented a formulation of convolutional neural networks in the context of spectral graph theory, which provides the necessary mathematical background and efficient numerical schemes to design fast localized convolutional filters on graphs. It offers the same linear computational complexity and constant learning complexity as classical CNNs, while being universal to any graph structure. [10] reduced the computation amount of graph convolution, and proposed graph convolutional network (GCN). It motivates the choice of convolutional architecture via a localized first-order approximation of spectral graph convolutions. The model scales linearly in the number of graph edges and learns hidden layer representations that encode both local graph structure and features of nodes. [11] proposed a novel graph neural network that removes all the intermediate fully-connected layers, and replaces the propagation layers with [12] attention mechanisms that respect the structure of the graph. [13] presented graph attention networks (GATs), novel neural network architectures that operate on graph-structured data, leveraging masked self-attentional layers to address the shortcomings of prior methods based on graph convolutions or their approximations. [14] presented diffusion-convolutional neural networks (DCNNs) and showed how diffusion-based representations can be learned from graph structured data. It has several attractive qualities, including a latent representation for graphical data that is invariant under isomorphism, as well as polynomial-time prediction and learning that can be represented as tensor operations and efficiently implemented on the GPU. [15], [16] and [17] provided comprehensive reviews of GNNs in machine learning fields , further discussed the applications of GNNs across various domains, and proposed potential research directions in this rapidly growing field.

The rest of this paper is organized as follows. In section 2, we introduced the basic model of GNN and its two variants. In section 3, we introduce applications of GNNs to knowledge acquisition. In section 4, we summarize this paper and future research directions of knowledge acquisition.

2. MODELS

GNN is an effective tool for processing structured data. Several methods have been proposed in previous papers to improve original GNN. This paper introduces two important variant GCN and GAT. In section 2.1, we introduced some background knowledge about graphs. In section 2.2, we describe the GNN model. In Section 2.3, we describe the GCN model. In Section 2.4, we describe the GAT model.

2.1 Graph

A graph is one of the most important data structures in computer science. It is composed of nodes and connections between them. The connections represent the relationship between two nodes. Edges can be directional or nondirectional, and the direction of edges depends on the dependence between nodes.

A graph G can be described by the set of nodes V and edges E in the graph and the global attribute u, $G = (V, E, u)$. Nodes set is defined as $V = \{ v_i \}$ $i = 1 : N^v$, where N^v represents the number of nodes *and* v_i represents the attributes of node i. Edges set is defined as $E = \{(e_k, r_k, s_k)\}$ $k = 1 : N^e$, where N^e represents the number of edges, e_k represents the attributes of edge k, r_k is the receiving node, s_k is the sending node.

2.2 Graph Neural Network

GNN learns the vector representation of entities, relationships in the graph and rules that constitute them. It preserves the topological relationship between structured input data, and tracks the graph structure in the nodes by processing the input data nodes. [6] designed a supervised learning model, which was divided into two parts: local transformation function f_w and local output function g_w. The functions were realized by multi-layer feedforward neural network. The transformation function f_w extracts information from adjacent nodes and generates the state by a vector x_n. The output function g_w maps the state to an equal dimensional vector o_n. The equations for x_n and o_n are as follows:

$$x_n = f_w(l_n, l_{co[n]}, x_{ne[n]}, l_{ne[n]})$$

$$o_n = g_w(x_n, l_n) \tag{1}$$

where, l_n represents the attributes of node n, $l_{co[n]}$ represents the attributes of the associated edges of node n, $x_{ne[n]}$ represents the state vectors of adjacent nodes of node n, $l_{ne[n]}$ represents the attributes of adjacent nodes of node n. According to eq.1, all the attributes and states of graph data are integrated together to obtain the global transformation function F_w and the global output function G_w. The equations for x and o are as follows:

$$x = F_w(x, l)$$

$$o = G_w(x, l_N) \tag{2}$$

Eq.2 actually defines a map φ_w, with one graph structure data as input, and outputs a vector o_n for each node in the graph. Banach's theorem is used to calculate the state value of each node. With the mapping relationship φ_w and state value of each node, the learning task turns into minimizing loss function. The graph structure dataset is as follows:

$$L = \{(G_i, n_{i,j}, t_{i,j}) \mid G_i = (N_i, E_i) \in \mathrm{G}; n_{i,j} \in N_i; t_{i,j} \in R^m, 1 \le i \le p, 1 \le j \le q_i\}$$

where, G_i is a subset of G, $n_{i,j}$ refers to the jth node in the graph G_i, $t_{i,j}$ refers to the expected target value of node $n_{i,j}$, p is less than or equal to the number of subsets of G, and q_i is less than or equal to the number of internal nodes in G_i. The loss function based on dataset L is:

$$e_w = \sum_{i=1}^{p} \sum_{j=1}^{q_i} (t_{i,j} - \varphi(G_i, n_{i,j}))^2 \tag{3}$$

Gradient descent strategy is used to minimize the loss function, by taking the partial derivative of the parameter w with the loss function, and then updating the value of the weight w.

2.3 Graph Convolutional Network

Graph data is irregular, so the graph data has no translation invariance. This feature makes convolutional neural network (CNN) and recurrent neural network (RNN) unable to effectively

process graph data. GCN and CNN have similar functions. They are both feature extractors, but GCN extracts features from graph data.

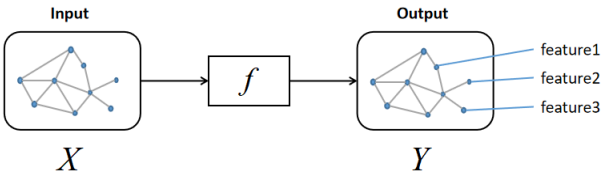

Figure 2. Input and output of convolutional neural network

The main task of GCN is to obtain the features of each node and use features to achieve various tasks such as node classification, graph classification, and link prediction, by feeding input nodes and edges into a function *f*.

Suppose a graph of N nodes, each node has its own feature x_i. We combine the features into a matrix X of $N \times D$ dimensions, the edges between the nodes into an $N \times N$ dimensional matrix A. Here X is the feature matrix and A is the adjacency matrix. Taking X and A as the input, the propagation equation of GCN between layers is:

$$H^{(l+1)} = \sigma(\tilde{D}^{-\frac{1}{2}}\tilde{A}\tilde{D}^{-\frac{1}{2}}H^{(l)}W^{(l)}) \tag{4}$$

$\tilde{A} = A + I$, where I is the identity matrix of the graph. A contains the connection information between each node in the graph and its adjacent nodes. After adding I, the information used in the operation includes both the node itself and its adjacent nodes. $\tilde{D}$ is the degree matrix of the nodes, the diagonal elements are the degrees of each node, and the value of the elements outside the diagonal is 0. W is the weight matrix to be trained. H is feature of each layer, and for the input layer H is X. σ is a nonlinear activation function.

Input a graph that changes the features of each node from X to Z through several layers of GCN. No matter how many hidden layers, the edges between nodes are shared. Suppose we construct a two-layer GCN, and the activation functions adopt ReLU and SoftMax respectively. The equation of forward propagation is as follows:

$$A = f(X, A) = soft\max(\hat{A}\operatorname{Re}LU(\hat{A}XW^{(0)})W^{(1)}) \tag{5}$$

Finally, we calculate the cross entropy loss function for all tagged nodes (represented by S_L) :

$$L = -\sum_{l \in S_L}\sum_{f=1}^{F} Y_{lf} \ln Z_{lf} \tag{6}$$

2.4 Graph Attention Network

GAT uses attention mechanism to sum the features of neighboring nodes. In GAT, each node is assigned with different weights according to the features of its neighbors. By including the attention mechanism, the information only relates to the adjacent nodes and not affected by the whole graph.

The core concept of GAT is graph attention layer. The input node feature vectors are processed by the attention layer to form new outputs. In short, GAT is similar to GCN, and it is also a feature extractor. GAT uses the original features of input to predict the new features of output. In order to obtain the corresponding input-output transformation, it is necessary to perform at least one linear transformation according to the input to obtain the output. Therefore, a weight matrix W needs to be trained for all nodes. The attention mechanism of self-attention is implemented for each node. The attention coefficients are as follows:

$$e_{ij} = a(W\vec{h}_i, W\vec{h}_j) \tag{7}$$

where, $\vec{h}_i$ and $\vec{h}_j$ are the feature vectors, and a is attentional mechanism for computing attention coeffificients. The above equation actually shows the importance of node j to node i.

Masked attention is introduced into the graph structure. It ensures that only attention is assigned to the neighbor node set N_i of node i. SoftMax regularization of all adjacent nodes j of node i is include to make the attention coefficients easier to calculate and easy to compare. The equation of masked attention is as follows:

$$\alpha_{ij} = soft\max_j(e_{ij}) = \frac{\exp(e_{ij})}{\sum_{k \in N_i}\exp(e_{ik})} \tag{8}$$

by integrating the above equations (7) and (8), the complete attention mechanism is as follows:

$$\alpha_{ij} = \frac{\exp(Leaky\operatorname{Re}Lu(\vec{a}^T[W\vec{h}_i \,\|\, W\vec{h}_j]))}{\sum_{k \in N_i}\exp(Leaky\operatorname{Re}Lu(\vec{a}^T[W\vec{h}_i \,\|\, W\vec{h}_k]))} \tag{9}$$

where, $\vec{a}$ is the weight matrix between the connecting layers in the neural network, and LeakyReLU function is added to the output layer. T represents the transpose of the matrix, and || means concatenation operation.

The attention coefficient α_{ij} between different regularized nodes is obtained, which can be used to predict the output features of each node:

$$\vec{h}_i^{'} = \sigma(\sum_{j \in N_i}\alpha_{ij}W\vec{h}_j) \tag{10}$$

in the equation, $\vec{h}_i^{'}$ represents the feature vector output by the ith node, W represents the weight matrix multiplied by the feature, α represents the attention coefficient, and σ represents the nonlinear activation function. Eq.10 calculates the output features of each node based on linear and nonlinear activation of all adjacent nodes. In order to stabilize the learning process of self-attention, multi-head attention was added, and the final equation was obtained:

$$\vec{h}_i^{'} = \sigma(\frac{1}{K}\sum_{k=1}^{K}\sum_{j \in N_i}\alpha_{ij}^k W^k \vec{h}_j) \tag{11}$$

in the equation, there are K attention mechanisms to consider; The Kth attention mechanism is a^k; The weight matrix of linear transformation of input features under the Kth attention mechanism is expressed as W^k.

3. APPLICATIONS

Social network and traffic network are two important applications in knowledge acquisition. They share several common features. Firstly, a large number of entities participate in the formation of the network. Secondly, there exist at least one relationship between network entities, and the relationship can be expressed as the degree of discrete value and real value. Thirdly, there is non-random or local hypothesis for social network and traffic network, and the intuitive meaning is that the relationship tends to cluster. For example, if A is correlated with B and C, the probability of B and C being correlated is higher than the average.

We regard social network and traffic network as graphs. If there is a strong or weak relationship, each edge needs to identify the strength (weight) of the relationship. It is also important to note that social and traffic maps can be either nondirectional or directional.

3.1 Social Network

In this section, we focus on user-level social influence prediction and take it as an example to show that GNNs can acquire knowledge from social networks. [18] proposed a deep learning framework DeepInf which represented the influence dynamics and network structure as potential space. The main task of DeepInf uses GCN and GAT to predict user-level social influence .

Let $G = (V, E)$ be a static social network, where V represents user set and E represents relationship set. For user v, its r-neighbors are defined as Γ_v^r, indicating the shortest distance between nodes u and v in the graph G. The r-ego network of user v is a sub-network derived from Γ_v^r and is defined as G_v^r. When a user in a social network performs a social activity, there is a $s_u^t \in \{0, 1\}$ for each timestamp t, where $s_u^t = 1$ indicates that the user u performed an action before or after the timestamp t, $s_u^t = 0$ indicates that the user has not performed the action.

The probability of the user v's action state depends on its r-ego network and the action of r-neighbors. The social influence locality is intended to quantify the activation probability of v after a given time interval Δt :

$$P(s_v^{t+\Delta t} \mid G_v^r, S_v^t)$$

the influence prediction can be expressed as a binary graph classification problem and can be achieved by minimizing the following loss function on the model parameters θ, the equation is as follows:

$$l(\Theta) = -\sum_{i=1}^{N} \log(P_\Theta(s_{v_i}^{t_i+\Delta t} \mid G_{v_i}^r, S_{v_i}^{t_i})) \qquad (12)$$

where, Δt should be large enough so that the action state of user v can be predicted at the end of the observation window.

A fixed-size subnet is sampled from the user v's r-ego network using the random walk with restart (RWR). People are more susceptible to active neighbors, so random walks start with ego user v or one of the active neighbors. Next, the random walk iteratively travels to its neighborhood with a probability proportional to the weight of each edge. RWR runs until it successfully collects a fixed number of nodes, denoted by $\bar{\Gamma}_v^r$. The subnet caused by $\bar{\Gamma}_v^r$ is denoted as $\bar{G}_v^r$. The action state of the sampling neighbor of v is denoted by $\bar{S}_v^t$. The loss function can be redefined as:

$$l(\Theta) = -\sum_{i=1}^{N} \log(P_\Theta(s_{v_i}^{t_i+\Delta t} \mid \bar{G}_{v_i}^r, \bar{S}_{v_i}^{t_i})) \qquad (13)$$

The DeepInf consists of a network embedding layer, an instance normalization layer, an input layer, several graph convolution or graph attention layers, and an output layer.

In the embedding layer, the pre-trained embedding layer maps user u to his D-dimensional representation $x_u \in R^D$. In the instance normalization layer, using the image style transfer technique, for each user u belonged to $\bar{\Gamma}_v^r$, after retrieving his representation x_u from the embedding layer, the normalized y_u is given by the following equation:

$$y_{ud} = \frac{x_{ud} - \mu_d}{\sqrt{\sigma_d^2 + \varepsilon}} \qquad (14)$$

for each embedded dimension d, there is

$$\mu_d = \frac{1}{n} \sum_{u \in \bar{\Gamma}_v^r} x_{ud}, \sigma_d^2 = \frac{1}{n} \sum_{u \in \bar{\Gamma}_v^r} (x_{ud} - \mu_d)^2 \qquad (15)$$

where, μ_d and σ_d are the mean and variance, ε is a small number used to keep the value stable. This normalization removes instance-specific means and variances, which forces downstream models to focus on the user's relative position in the potential embedded space rather than his absolute position. This part can avoid over-fitting during data training.

The input layer constructs an feature vector for each user. The vector contains the normalized low-dimensional embedded information, user's action state, and whether the user is an ego user. The input layer covers all other custom nodes' elements .

In the graph convolution layer, the GCN model is constructed by stacking multiple GCN layers. The input of each GCN layer is node feature matrix H, then the equation of output H' is:

$$H' = GCN(H) = g(A(G)HW^T + b) \qquad (16)$$

where W and b are model parameters, g is nonlinear activation function, and $A(G)$ is the matrix that captures the structural information of graph G. GCN instantiates $A(G)$ into the following Laplace normalization form:

$$A_{GCN}(G) = D^{-\frac{1}{2}} A D^{-\frac{1}{2}} \qquad (17)$$

where A is the adjacency matrix of G, $D = diag(A1)$ is the degree matrix.

Based on GCN, GAT is introduced and the attention coefficient is normalized. Redefined attention coefficient is as follows:

$$a_{i,j} = \frac{\exp(Leaky\,\mathrm{Re}\,LU(c^T[Wh_i \,||\, Wh_j]))}{\sum_{k\in\overline{\Gamma}_i^1}\exp(Leaky\,\mathrm{Re}\,LU(c^T[Wh_i \,||\, Wh_k]))} \quad (18)$$

After obtaining the normalized attention coefficient $a_{i,j}$, we insert $A_{GAT}(G)$ into eq.16. This completes the single-head diagram and notes the definition of the mechanism. On this basis, multi-head attention aggregates the output of K single attention together through an aggregation function can be expressed as follows:

$$H' = g(Aggregate(A_1(G)HW_1^T, \cdots, A_K(G)HW_K^T) + b) \quad (19)$$

In the output layer, output a two-dimensional representation for each user, compare the difference between the predict value and the actual value, and then optimize the logarithmic loss function.

DeepInf was significantly better at predicting locality of social influence than a baseline [18] with rich manual features. Experimental results in table 1 show that the DeepInf model can significantly improve the prediction performance and acquire new knowledge of predicting social influence [18]. The model shows that GNNs are feasible and effective to acquire knowledge from social network data.

Table 1. Prediction performance of different methods on the four datasets (%).

DATA	MODEL	AUC	PREC.	REC.	F1
OAG	LR	65.55	32.26	**69.97**	44.16
	SVM	65.48	32.17	69.82	44.04
	PSCN	69.16	36.45	64.64	46.61
	DeepInf-GAT	**71.79**	**40.77**	60.97	**48.86**
DIGG	LR	84.72	56.78	73.12	63.92
	SVM	86.01	63.42	67.34	65.32
	PSCN	87.37	64.75	68.15	66.40
	DeepInf-GAT	**90.65**	**66.82**	**78.49**	**72.19**
TWITTER	LR	78.07	45.86	**69.81**	55.36
	SVM	79.42	**49.12**	67.31	56.79
	PSCN	78.74	47.36	67.29	55.59
	DeepInf-GAT	**80.22**	48.41	69.08	**56.93**
WEIBO	LR	77.10	42.34	72.88	53.56
	SVM	77.11	43.27	70.79	53.71
	PSCN	81.31	47.72	71.53	57.24
	DeepInf-GAT	**82.72**	**48.53**	**48.53**	**59.27**

3.2 Traffic Network

Forecasting traffic flow in traffic network is a hot topic in knowledge acquisition. It is still challenging because traffic flow is non-linear and highly complex. [19] proposed the Attention based Spatial-Temporal Graph Convolutional Networks (ASTGCN) for traffic flow forecasting and realize the knowledge acquisition from traffic networks. ASTGCN uses the data of all traffic network nodes in the past time T to forecast the traffic flow Y at P time points in the future. It is also important to note that the ASTGCN framework contains three parts of the same structure, which are used to extract the recently, daily and weekly dependency features respectively as shown in fig. 3.

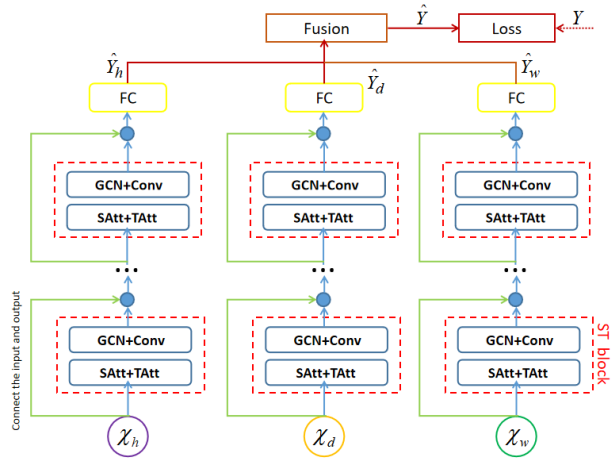

Figure 3. The framework of ASTGCN.

In spatial dimension, the traffic conditions of different locations are dynamic. We introduce an attention mechanism to adaptively capture the dynamic correlation between nodes in the spatial dimension, simplifying the equation as follows:

$$S = V_s \cdot \sigma((XW_1)W_2(W_3X)^T + b_s)$$
$$S'_{i,j} = \frac{\exp(S_{i,j})}{\sum_{j=1}^{N}\exp(S_{i,j})} \quad (20)$$

where, V_s, b_s, W_1, W_2, W_3 are learnable parameters, sigmoid σ is the activation function, and S is the spatial attention matrix, indicating the dependence of nodes i and j. Eq.20 uses the SoftMax function to normalize S.

In temporal dimension, ASTGCN introduces an attention mechanism to adaptively model the correlation between traffic conditions at different time periods by assigning different weights to the data, the equations are as follows:

$$E = V_e \cdot \sigma((X^T \cdot U_1)U_2(U_3X) + b_e)$$
$$E'_{i,j} = \frac{\exp(E_{i,j})}{\sum_{j=1}^{T}\exp(E_{i,j})} \quad (21)$$

where, V_e, b_e, U_1, U_2, U_3 are learnable parameters, E represents the time attention matrix, $E'_{i,j}$ represents the dependence of node i and j. Eq.21 uses SoftMax function to normalize the attention matrix E.

For the space-time convolution module, we respectively use the method of graph convolution in the space dimension and the method of standard convolution in temporal dimension. The convolution equation of the graph on the spatial dimension is:

$$g_{\theta * G} x = g_\theta(L)x = \sum_{k=0}^{K-1} \theta_k T_k(\widetilde{L})x \tag{22}$$

$$\widetilde{L} = \frac{2}{\lambda_{\max}} L - I_N \tag{23}$$

where θ is a vector of polynomial coefficients, λ_{max} is the maximum eigenvalue of the Laplace matrix, and L is the standard form of the Laplace matrix. The iterative relation of Chebyshev polynomial is $T_{k(x)} = 2xT_{k-1(x)} - T_{k-2(x)}$. In equation $T_{0(x)} = 1$, $T_{1(x)} = x$. The above equation is equivalent to using convolution kernel g_θ to extract the information of the neighbors of order 0 to (K−1). Applying the spatial attention mechanism to the convolution process, and the equation is as follows:

$$g_{\theta * G} x = g_\theta(L)x = \sum_{k=0}^{K-1} \theta_k (T_k(\tilde{L}) \odot S') x \tag{24}$$

where, $\odot$ represents Hadamard product.

In temporal dimension, standard convolution is used to update signals of nodes by merging information on adjacent time slices. The equation is as follows:

$$X = \mathrm{Re}LU(\Phi * (\mathrm{Re}LU(g_{\theta * G} X))) \tag{25}$$

where * represents the standard convolution operation, Φ is the parameter of the time dimension convolution kernel, and ReLU is the activation function .

By combining the above features, the equation is as follows:

$$\hat{Y} = W_h \odot \hat{Y}_h + W_d \odot \hat{Y}_d + W_w \odot \hat{Y}_w \tag{26}$$

where, h, d and w represent recently, daily and weekly. W represents the learning parameters, reflecting the degree of influence of the three-dimensional components on the prediction target.

ASTGCN was tested on two datasets of the Traffic Volume Performance Measurement System (PeMS). It can be seen from the experimental results in table 2 that ASTGCN outperformed most advanced models. This also proves that the GNNs can realize knowledge acquisition of traffic network data [19].

Table 2: Average performance comparison of different approaches on PeMSD4 and PeMSD8

Model	PeMSD4		PeMSD8	
	RMSE	MAE	RMSE	MAE
HA	54.14	36.76	44.03	29.52
ARIMA	68.13	32.11	43.3	24.04
VAR	51.73	33.76	31.21	21.41
LSTM	45.82	29.45	36.96	23.18
GRU	45.11	28.65	35.95	22.2
STGCN	38.29	25.15	27.87	18.88
GLU-STGCN	38.41	27.28	30.78	20.99
GeoMAN	37.84	23.64	28.91	17.84
MSTGCN(ours)	**35.64**	**22.73**	**26.47**	**17.47**
ASTGCN(ours)	**32.82**	**21.8**	**25.27**	**16.63**

4. CONCLUSION

In this paper, we proposed the development of GNNs and analyzed its efficiency and feasibility to acquire knowledge on structured data. In the applications of knowledge acquisition, the variants of GNNs show the excellent performance.

However, the knowledge acquisition is not limited to structured data. New knowledge can be acquired from various data. More attention should be paid to unstructured data and semi-structured data. For instance, [20] proposed a joint reasoning method to exploit relationships between objects for image and video captioning. It incorporates 1) common sense reasoning for embedding image or video regions into semantic space to build semantic graph and 2) relational reasoning for encoding semantic graph to generate sentences.

Ultimately, major progress in GNNs will be realized by the systems that combine representation learning with complex reasoning. Although deep learning and simple reasoning have been used in computer vision and natural language processing for a long time, new methods are needed to learn, reason and deduce in various data to achieve data-based knowledge acquisition.

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A Deep Learning-based Approach for Human Posture Classification

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ABSTRACT

Lifting posture is considered as a leading factor in low back injuries in the workplace. Hence, it is necessary to evaluate the risk of various lifting tasks. Classifying postures is important before performing an ergonomic task assessment. Recently, many studies have revealed that the deep learning method has a high accuracy in identifying human postures. However, few studies have explored how the deep learning method can be applied to classify different postures during a lifting task. The objective of this study was to develop a deep learning technique-based model for classifying three states of postures (squatting, standing and stooping) during a lifting task.

A dataset comprising 2,600 various static images (squatting, standing and stooping) taken from 0° and 90° camera view angles and their corresponding 3D joint coordinate data recorded by the marker-based motion tracking system was used in this study. The images were randomly divided into training (1,300 images), validation (650 images) and testing (650 images) datasets. After all of the images were cropped to a fixed size, the training dataset was processed in the neural network as the input, and the validation dataset was used to revise the weight of the model while training to build the classifying model. Finally, the testing dataset was processed as input for classifying three static postures using the proposed model. A classification based on the 3D coordinate data captured by the marker-based motion tracking system was used as the reference to validate the accuracy of this classifying model.

Overall, the model developed in this study reached 91.23% accuracy. The accuracy of correctly classifying the squatting, standing and stooping postures is 94.35%, 98.33% and 75.86%, respectively. In addition, this model showed a nearly equivalent accuracy for identifying the images taken from 0° (91.64%) and 90° (90.86%) cameras. The results of this preliminary test showed that the deep learning method has the potential to classify different static postures within a lifting pattern.

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CCS Concepts

•Computing methodologies → Machine learning → Machine learning approaches → Neural networks •Applied computing → Physical sciences and engineering → Engineering → Computer-aided design •Computer systems organization → Embedded and cyber-physical systems → Sensors and actuators

Keywords

Deep learning method; Lifting; Posture classification.

1. INTRODUCTION

Lifting is a common working posture in manual material handling task, which is composed of standing, stooping and squatting posture states. Lifting posture is considered a leading factor in low back injuries in a workplace. Hence, it is necessary to evaluate the risk of various lifting tasks. By identifying the posture of a lifting task, it is possible to determine the lifting pattern and frequency of a lifting task. Accordingly, classifying posture is important for performing an ergonomic task assessment.

Marker-based motion tracking systems are common tool for tracking human movement. Such systems are setup with several synchronized cameras and use reflective markers attached on a subject's joints to capture joint locations with 3D coordinates. While a marker-based motion tracking system has high accuracy, and is considered a reliable tool, it is not practical to implement in a real workplace. Placing cameras is also challenging in an actual workplace, and attaching reflective markers to joints is time-consuming and may interfere with the subject's activity. Hence, there are several studies applying marker-less methods such as a depth camera to compare the accuracy with marker-based motion tracking system. Although many studies have shown adequate accuracy in some situations, a depth camera may have higher errors due to performing complicated motions or self-occlusion.

Recently, computer vision and deep learning methods have become popular. A variety of studies have explored deep learning approaches to analyze human posture and activities, such as estimating joint position, joint angle, L5/S1 joint moment and constructing 3D human skeletal model. The results have revealed that deep learning methods are highly accurate in identifying human motion. However, while most studies used a deep learning approach to estimate and calculate the errors of the parameters mentioned above, few studies have explored how a deep learning method can be applied to classify different postures during a lifting task.

This study applies a deep learning approach to the lifting task. The objective of this study is to develop a deep learning technique-

based model for classifying three lifting posture states: squatting, standing and stooping. Future applications of the results from this study can be applied to develop a system to automatically classify a lifting posture at a real workplace and for identifying employee lifting frequency in order to supervise and discover potential hazards from excessive lifting.

2. LITERATURE REVIEW

There are many manual material handling tasks in the workplace, including lifting, twisting, bending, maintaining static posture and so on [1]. Lifting is one of the common posture in manual material handling and is considered as a leading factor in low back injuries. According to previous study, lifting posture is composed of squatting, stooping and standing posture. Each state of lifting posture can be classified based on the measurement of torso and knee angle [2].

Analyzing human posture and movement is important to evaluate the risk of musculoskeletal injury in the workplace. Many researches have considered three-dimensional motion tracking system as typical assessment tool with high accuracy. However, both active and passive 3D motion tracking system are limited to performing ergonomic assessments in the field [3], due to complexity, time-consuming and space requirement.

Compared with motion tracking system, depth camera is portable, low cost and without attaching markers. A variety of studies have used depth camera to perform ergonomic assessment. Previous research evaluated the error of joint location in different daily static postures with the depth camera located in front of the sagittal plane of the subject [4]. Another research assessed the error of joint angle recorded by the depth camera located in the front and the lateral side of the subject [5]. The results of these researches show that although depth camera isn't as accurate as marker-based motion tracking system, it has good agreement with motion tracking system. However, depth camera is constrained and obtains higher error when performing complicated motion or being obstructed [6].

Deep learning has become popular for the previous years. Many studies explore deep learning-based method for analyzing human posture and activities, including constructing a 3D human skeletal model with two RBG images from different angle of view [7], estimating cyclist's joints from a single RGB image using machine learning approach [8] and estimating 3D L5/S1 joint moment during symmetrical lifting [9]. The results indicate that deep learning has high accuracy in assessing the motion of human. Therefore, deep learning method is potential to perform human posture classification.

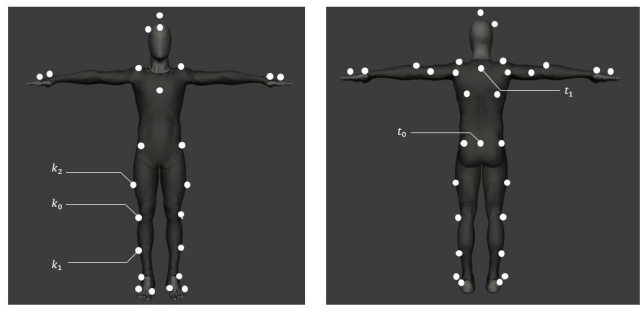
3. METHODS

3.1 Apparatus

The experiment setup included six infrared cameras and two depth cameras (Microsoft Corp., Kinect V2). This study used a motion tracking system (NaturalPoint Inc., OptiTrack) as a gold standard. The frame rate of the motion tracking system is 120 Hz. Furthermore, one of the depth cameras was set in front of the sagittal plane of the subject and the other depth camera was set up at the perpendicular view of a subject's sagittal plane. Both depth cameras were placed at a height of 0.75 m from the ground. The distance between depth cameras and the subject is 2m. The depth cameras were used to capture RGB images during a lifting task at a 30 Hz frame rate. All of the apparatus including infrared cameras and depth cameras were calibrated and synchronized.

3.2 Participant

This study conducted a preliminary test for classifying three different states of human postures during a lifting task with a deep learning technique-based model. The dataset consisted of one male and one female subject performing a symmetrical lifting task at a self-selected speed. The lifting range was from the ground to the height of subject's shoulder. All of the participants had no musculoskeletal disorders or surgical history. The participants were asked to wear properly-fitted clothing and 37 reflective markers were placed on their joints (Figure 1). The lifting trial started when the participant was prepared and stood still, and ended when the participant lifted an object to shoulder height. The participant repeated the lifting task four times and had a break between each trial of the lifting tasks.



Front **Behind**

Figure 1. The placement of 37 reflective markers

3.3 Experiment Procedure

After the experimental environment was set up, the experimenter would explain the procedure to the participant. The participant was asked to practice the lifting task before the formal experiment. The subject performed repetitive lifting task from the ground to the shoulder height four times with self-selected speed (Figure 2). The data of joint locations and RGB images were recorded by marker-based motion tracking system and depth cameras simultaneously.

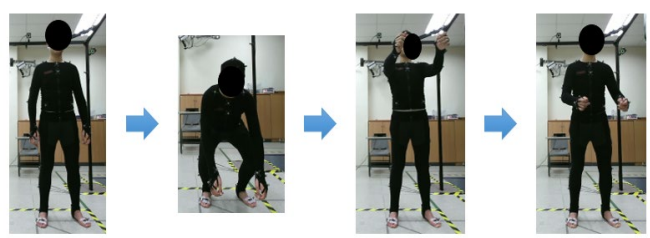


Figure 2. The movement of the lifting trial in this experiment

3.4 Data Processing

The experiment acquired various static RGB images taken from 0° and 90° camera view angles, and the corresponding 3D coordinate joint data of the images were recorded by the marker-based motion tracking system.

According to previous research, the RGB images were classified to three human posture states based on torso angle and knee angle (Figure 3). Figure 4 had shown the definitions of torso angle (θ_t) and knee angle (θ_k) in this study. The calculation of torso angle is $\overrightarrow{t_0t_1} \cdot \overrightarrow{t_0t_2} = \left|\overrightarrow{t_0t_1}\right| \times \left|\overrightarrow{t_0t_2}\right| \times \cos\theta_t$, and the calculation of the

knee angle is $\overrightarrow{k_0k_1} \cdot \overrightarrow{k_0k_2} = |\overrightarrow{k_0k_1}| \times |\overrightarrow{k_0k_2}| \times \cos\theta_k$. Squatting was identified when the knee angle was smaller than 130°. Stooping was identified when the knee angle was larger than 130° and the torso angle was larger than 40° flexion from vertical. Standing was identified when knee angle was larger than 130° and the torso angle was smaller than 40°. We used the classification mentioned above to annotate the images.

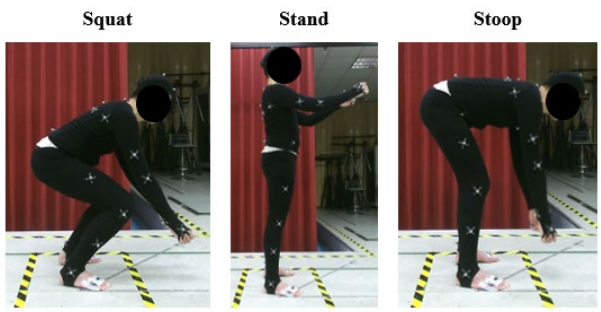


Figure 3. Three states of the lifting task

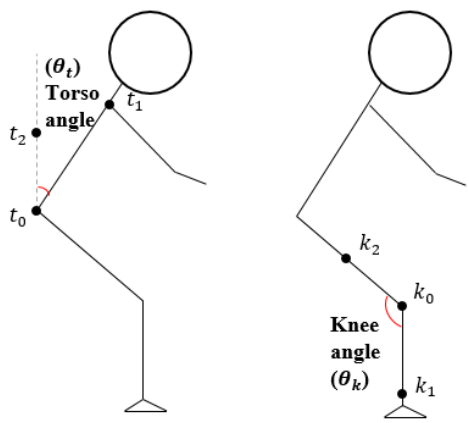


Figure 4. The definitions of torso and knee angle (t_0 represents the joint of hip, t_1 represents the joint of spine and t_2 represents the point vertical from the ground; k_0 represents the joint of knee, k_1 represents the joint of shin and k_2 represents the joint of thigh)

To classify the images captured from depth cameras, the deep neural network was used. A total of 2,600 RGB images were randomly divided into training (1,300 images), validation (650 images) and testing datasets (650 images). After all images were cropped to a fixed size, the training dataset was processed in the neural network as the input, and the validation dataset was used to revise the weights of the model while training to build the classification model. Finally, a testing dataset was processed as input to classify three static postures using the proposed model. A classification based on the 3D coordinate data captured by the marker-based motion tracking system was used as a reference to validate the accuracy of this classification model. The deep learning platform used in this study was Keras, and the training and testing process were implemented on an i5-7400 computer with NVIDIA GTX1070 and 16GB RAM. Figure 5 showed the network architecture of deep learning model in this study. The training dataset was processed in the convolutional neural network as input. After the model was built, the testing dataset, which was distinguished from the training and validation datasets, was processed as input to identify the postures by the proposed model.

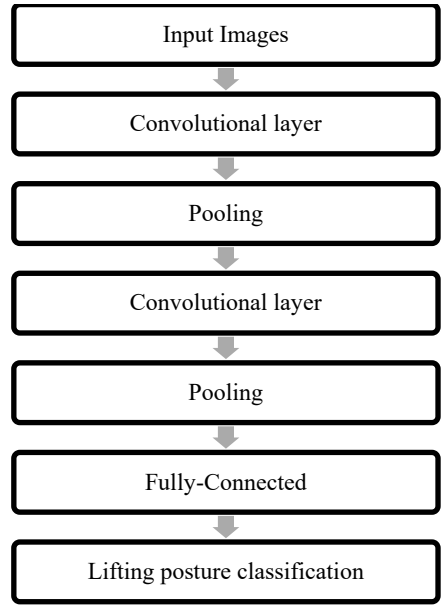


Figure 5. Network architecture of deep learning model in this study

Additionally, the classification results from the testing dataset were compared with the annotation results based on the marker-based motion tracking system. The accuracy was calculated as followed:

$$\text{Accuracy}(\%) = \frac{\text{Number of misclassified images}}{\text{Total number of tested images}} \times 100\%$$

4. RESULTS

The model developed in this study reached 91.23% accuracy. Table 1 showed classification accuracy for the three posture states. Stooping had the lowest classification accuracy (75.86%), while the accuracy in classifying squatting (94.35%) and standing (98.33%) was relatively higher. In addition, this model showed a nearly equivalent accuracy for identifying images taken from the 0° (91.64%) and 90° (90.86%) cameras (Table 2).

Table 1. The classifying accuracy of three states of posture

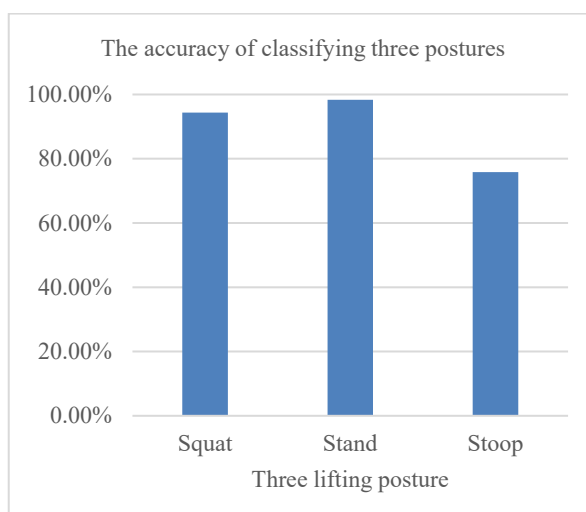


Table 2. The classifying accuracy of two camera view

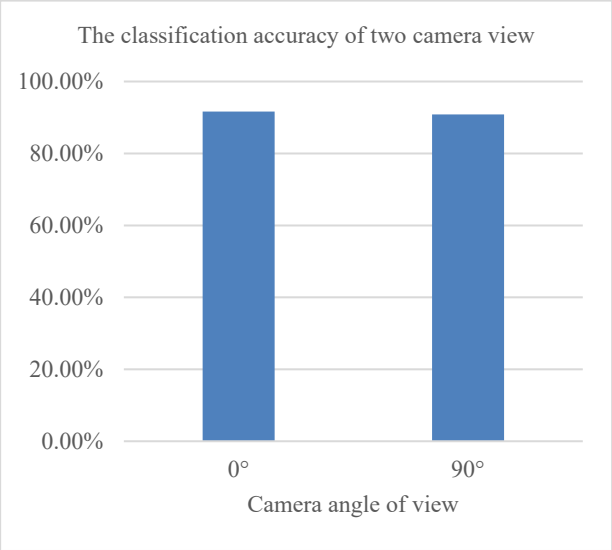
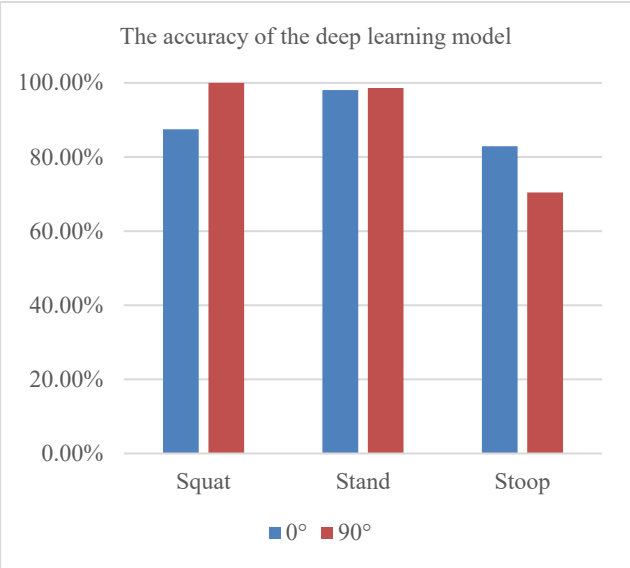


Table 3 showed a comparison of the accuracy in identifying three different postures from two camera views. We found that standing posture had a similar identifying accuracy from different camera views. Squatting had better accuracy from a 90° camera view, while stooping had better accuracy from a 0° camera view. Overall, the 0° camera view had the best performance in classifying a standing posture (98.06%) and the worst performance in classifying a stooping posture (82.89%). The 90° camera view had the best performance in classifying a squatting posture (100%) and the worst performance in classifying a stooping posture (70.41%). Furthermore, identifying squatting from a 90° camera view had the highest accuracy (100%), while identifying stooping from a 90° camera view had the lowest accuracy (70.41%).

Table 3. The classifying accuracy of the deep learning model



Overall, the stooping posture had the highest misclassifying possibilities. The results indicated that stooping postures had been misclassified as squatting. On the other hand, 9 squatting postures had been misclassified as stooping. (Table 4)

Table 4. The classification of three postures

Reference classification (based on motion tracking system)	Deep learning model classification		
	Squat	Stand	Stoop
Squat	167	1	9
Stand	2	294	3
Stoop	42	0	132

5. DISCUSSION AND CONCLUSION

This study provides a preliminary test to classify three lifting posture states with a deep learning-based approach. The results indicate potential for utilizing a deep learning approach to classify posture during a lifting task. Moreover, the deep learning model has relatively higher accuracy in classifying standing and squatting posture. Stooping has the most classifying errors. There are 42 errors misclassifying stooping posture as squatting, and the 90° camera view has twice as many errors as a 0° camera view. Thus, the 0° camera performs better in classifying a stooping posture. In the testing dataset, the knee angle of the participants are close to 130° in some stooping images (the threshold of classifying stooping and squatting posture), which is likely to be the reason of misclassifying stooping posture as squatting. Overall, there are only few errors for misclassifying standing posture. Squatting posture has better classifying performance in 90° camera view while stooping has better classifying performance in 0° camera view.

Previous research proposed a classifying algorithm using image bounding box dimensions as input to classify three states of lifting postures. The results showed high accuracy in classifying three lifting posture states, and had better performance in classifying standing posture [2]. Our study has revealed that the deep learning method has better performance in correctly classifying standing posture. In addition, 0° and 90° camera views have nearly equivalent accuracy in classifying lifting postures. This experiment demonstrates that it is possible to classify lifting postures based on deep learning method. Furthermore, deep learning-based approach is capable of identifying lifting postures in different camera view angles.

There are some limitations to this study. First, the study didn't consider the effect of holding the load while performing a lifting task. Therefore, we couldn't determine how occlusion affected classification accuracy. Second, there were only two subjects in this experiment. The results of classification accuracy may be different if the number of subjects is increased. Last, this experiment only asked the subject to perform one lifting range (from floor to shoulder height). Future studies can investigate more lifting tasks and add more cameras to compare accuracy from different view angles. In conclusion, we developed a deep learning-based approach to classify lifting posture with potential for implementation in an actual workplace.

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Agile Scrum Adoption of the Application Development Projects of Company C

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ABSTRACT
Company C has incurred 31 percent of delayed projects for more than three months due to the method of applying the Agile practices. The study assesses which among the Agile practices should Company C improve on to meet its project timeliness. Company C was evaluated against other IT companies, namely Company A, B and D based on how in-depth the Agile practices were applied in the company using one-way ANOVA to test the difference of means of the companies on each Agile practice. The Agile practices that Company C excels and needs improvement were obtained. A binary logistic bootstrap regression is performed to determine which Agile practices positively affect in improving the project timeliness of Company C. Based on the identified best implementation of the Agile Scrum practice in Company C from one-way ANOVA, and the positive and negative coefficients in regression, the practices that should be maintained and improved were obtained for the formulation of the Agile framework of Company C. To improve project completion rate, Company C should improve on the following practices: increasing frequency of evaluating backlog items at least every other sprint, limiting stand-up meeting to 15 minutes, creating separate implementation task, conducting sprint planning with key persons, consistent iteration length, more frequent iteration demos, performance of unit testing, understanding architectural design and implemented by the team, performing pair-programming on key portions, collaborating more frequently of team members and using of formal written document as supplement for informal communication should be implemented.

CCS Concepts
• Social and professional topics→ Management of computing and information systems • Social and professional topics→ Project and people management • Social and professional topics→ Project management techniques • Social and professional topics

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Keywords
Agile Scrum; One-way ANOVA; Binary Logistic Bootstrap Regression

1. INTRODUCTION
Agile Scrum is a relatively young concept to the Filipino IT Companies. There have been studies that agile is agreed to be working but the trend has not been explored most especially in the Filipino IT companies. With Agile now entrenched and customized by solutions development teams, it is questioned which variant of any one Agile Scrum practice was most effective, and if Scrum was in fact contributing to the success. The Agile outcomes and practices survey will explore the trend even further. The study aims to answer the following questions: Are there results one group is seeing that may be representative problems of others? Are there results that are positive that can be modeled? Since the Agile mindset and flow is dynamic and changing, how are teams adapting and creatively applying the manifesto?

The Agile Scrum activity starts with gathering the demand, listing the features to be developed in the project. A regular quick meeting is conducted called Daily Scrum wherein team members update each other with their daily tasks and the result of previous day's task. In a Sprint, the tasks identified in the Product Backlog are implemented which lasts from one to four weeks. The tasks chosen to be developed in Sprint are chosen during Sprint Planning meeting and placed in a Sprint Backlog. At the end of each sprint, the Sprint Review Meeting is conducted to inspect the output of the sprint. The Scrum Master makes sure that the Scrum activities happens and clears the barrier of the team members. Another role is the Product Owner who defines the requirements and rank each by importance and priority.

The concept of Agile Scrum is relatively new given that it has only been founded in the early 2000s thus having limited literature. In addition, most of the studies related to Agile were mostly case studies. The study compiles the best practices from top companies in the Philippines and provide benchmark on Company C.

2. RELATED LITERATURE
According to Carvalho and Mello [3], the literature on Agile is still scarce but expanding. There is a demand of sharing scientific knowledge on the topic. One of the challenges of software development is the constant change on the requirements to address demands. Scrum is lean product development developed by Jeff Sutherland inspired by lean manufacturing principles. Agile focuses on development and participants' relationships. Development is split into short cycles of a few weeks long such that

each version adds value to the business. With this setup, there is a continuous client feedback and project risk is minimized. Less emphasis is placed on documentation but focus is placed on the iteration. Scrum is inspired from a rugby formation where the players have a meeting when they start a move. Some of the Scrum management practices identified in the paper are the following: product backlog, daily scrum, sprint, sprint planning meeting, sprint backlog and sprint review meeting.

The paper conducted a thorough literature review with Agile Scrum as subject. The works were classified as Conceptual Research and Empirical Research. Conceptual Research were classified as Theoretical/ Conceptual, Literature Review, Simulation and Theoretical Modeling. Empirical Research were subdivided into Survey, Case Study, Action Research and Experimental Research. The benefits of Agile Scrum are documented from the research study. There is an increase in 2007 and 2008 because there is a gradual implementation of the method by companies who are the scholars of the subject. The most common types of studies are Case Study and Theoretical/Conceptual methods. There are a few references for Literature Review. In the study, most of the literature came from software companies not from university and research centers. The benefits of Agile Scrum were increase in collaboration among the people involved, improved quality of the product, increase in team productivity and increase in client satisfaction among others.

In a study conducted by Salinas et. al,[12] the authors investigate the adoption, barriers and limitations in the application of Agile methods in Paraguay. The study identified the difficulties in adopting agile methods: organizational culture in disagreement with agile values and lack of skills or experience with agile methods. The study cited studies from Sao Paulo, Brazil which pointed out the main concerns in adopting the method were the lack of documentation and the ability to change organizational culture. The study probed the difficulties in agile adoption, such as coaching others in adopting the agile culture. Other studies focused on team management, agility in distributed teams, prioritization of requirements, documentation, change requirement, organizational culture, process and monitoring and feedback. The study conducted a survey addressing the main issues of adoption, concerns and barriers. The following concerns were identified: inability to scale, reduced software quality, development team opposed to change, lack of early planning and internal company regulations. 44.44% of the concerns originate from reduced software quality. The barriers identified to further adoption in the enterprise: company's internal rules or standards, budget constraints, project complexity, customer collaboration, confidence in the ability to scale and lack of experience. Majority of the companies (55.56%) lack experience with only 1 to 2 years. The software development companies in Paraguay experience the following concerns: reduced software quality, change resistant development team and inability to scale. For the barriers reported are little experience, confidence in the ability to scale agile methods, little or no customer collaboration and complexity or size of the project. In addition, the paper pointed out that the development community is unfamiliar with the requirements gathering practice in agile method. The paper investigated the maturity level of the practices and defined the maturity in agile software development. Cluster analysis was used to analyze quantitative data and content analysis for the qualitative data. The output of the study was the proposed new definition for agile software development maturity. The study investigated literatures that aim to develop framework for Agile which was described as iterative, gradual, continuous and value-based that would be useful for companies and organization, regardless of scale. The paper also probed if the traditional project management approach and Agile can be combined which was performed using a literature review. The paper concluded that the study of the Agile methodology is growing in popularity and is very effective and suitable for many situations.

Hossain et. Al. [10] have reviewed the literatures written about Agile. There has been an increasing interest from project managers considering in introducing agile projects. It would be very useful to have references on how to effectively use Agile in projects. There has been a question whether agile practices can be used in a distributed setting.

According to Sletholt et. al, [14] in a survey conducted by the authors, requirements activities are perceived as problematic in software projects especially when the teams are large. In addition, test cases for validation and verification is perceived as challenging. In the study, the authors probed how scientist develop their software. The paper provided literature review to propose best practices for scientific software development. The extent to which agile practices have been used in software projects was investigated. The impact on testing and requirements activities in projects with agile projects are observed. The project analyzed the literatures with respect to the 35 agile practices originating from the Scrum methodology and XP practices. From the literatures reviewed, there is high emphasis on verification and validation activities. Requirements gathering was handled in a semi-agile manner. One of the challenges identified is the verification of scientific terms which requires consultation with the experts. The presence of agile practices was reviewed. XP Practices are effective in the development of a computational biology software such that code quality is improved, robust bug detection, more focused developed, maintenance was easier and productivity is increased. It was observed that XP projects more often succeed on small projects. One of the challenges are most scientific software projects development span for several years. The effect of Agile was discussed on the paper. Agile is responsive to changing requirement. Assignment of task are easier and more focused. Testing was performed extensively, approaches on adding test of new modules improved. Previous studies pertain to experience reports. With personal experience papers there may be researcher bias. Furthermore, there is also a limit to which the conclusion in the literature review.

3. METHODOLOGY

With 31% of Company C's Agile application development projects experiencing critical delay from expected end date of more than three months (90 days), the study aims to identify the factors which lead to the failure of project developments. The use of regression in the study aims to identify the factors that lead to the success of selected IT companies in the adoption of Agile methodology. The study is divided into three phases. Phase 1 refers to the assessment of Company C on its adoption of Agile Scrum practices. To assess Company C's performance an initial interview was conducted to some of the application development managers of Company. Based

on the interviews, there were 34 Agile best practices identified in the questionnaire. Purposive sampling was utilized with the respondents fulfilling the following criteria: (1) the respondent should be Agile Scrum practitioner (2) should belong to the IT software development industry and (3) willing and able to answer the survey. The adoption of Agile practices was gauged as favorable, neutral, or less favorable from an agile adoption point of view. Phase 2 determines the significant positive and negative practices among the best practices initially defined in the questionnaire; and Phase 3 generates the customized Agile Scrum framework of Company C which can be used by Filipino IT companies new in adopting Agile. The bootstrap regression is run for each Agile Scrum category with the odds of the project being on time as the dependent variable and the Agile Scrum practices under the major category as the independent variable. The B coefficient will be interpreted whether the practice is properly observed. If the B coefficient is negative for the said practice, the Agile Scrum practice concerned contributes to the delay of the project. These practices should be addressed for the improvement of the on-time completion rate of the application development projects of Company C.

On the practices information, SAS has initially defined 34 best Agile practices, grouped into eight major sections, addressing major facets in Agile Scrum. Setup refers to the preparation of scheduling of the delivery of the features. It also defines the exit criteria for a feature to be considered as done. Daily standup meetings pertain to the regular mode of communication in an Agile Scrum team. It is a brief, informal meeting to address if there are concerns in the tasks. Story management refers to the way the feature is documented, broken down and distributed within the team. Iteration pertains to the adherence of the team in the planning and execution of the project schedule. Product Quality refers to the way the teams address deviations from the expected behavior through prevention and mitigation. Technical Practices pertains to the tools that are specific to Agile such as pair programming and automated tests. Teamwork refers to the synergy of the project team and how they interact with the client or Product Owner. Retrospective is the post-evaluation of the team on each project milestone, assessing good and bad points of finished milestone and implement improvements based on the lessons learned.

Beyond each question response, the comment field allowed the respondent to provide information relevant to the analysis. This qualitative feedback proved to be valuable in validating the quantitative questions data.

Table 1. Project Methodology

Input	Process	Output
Phase 1: Assess the level of Agile Scrum adoption of Company C's application development projects.		
Interview Questions Research from related literature Agile Scrum Adoption Survey	Interview Data Collection One-way ANOVA Tukey's Test on Comparison of Means	Project Focus Assessment of the state of Agile application development projects
Phase 2: Identify which Agile Scrum practices would contribute to the success of application development projects in Company C.		
Survey Responses Minitab and SPSS 22.0	Binary Logistic Bootstrapping Regression	Agile Practices with positive and negative contribution on the success of the project.
Phase 3: Develop a customized Agile Scrum framework for Company C.		
Best practices identified in one-way ANOVA Agile Practices that have positive and negative contribution in on-time project completion.	Gap Analysis	An Agile Scrum Framework will be generated.

To assess the level of Agile Scrum adoption of Company Cs application development projects, one-way Analysis of Variance was utilized. One-Way ANOVA (Analysis of Variance) is used to determine if the mean values of each agile practice differ across different groups (Company A, B, C and Others). This test is used to determine which company will be used as a benchmark that company C should emulate for each Agile best practice. The p-value for the mean values of each Agile Practice is 0.05. Tukeys' comparison results are used to formally test whether the difference between a pair of groups is statistically significant. For the hypothesis:

H_0: All means of practice i across all groups are equal.

Ha: At least one mean of practice i from the group is different.

If the p-value is less than or equal to the assigned significance level, $\alpha = 0.05$, the difference between some of the mean values for each practice are statistically significant.

To determine which groups are statistically significant between any pair of groups, the grouping information table as well as the test for difference of means is used in Minitab. Confidence intervals that do not contain zero indicate that the mean difference is statistically significant.

The expected results of one-way ANOVA are the benchmarked best practices from the 3 major companies that were respondents of the survey.

3.1 Phase 1: Comparison of Means Across Companies that use Agile Scrum

The level of Agile Scrum adoption of Company C's application development projects is assessed. One-Way ANOVA was used to determine which of the practices does Company C is superior compared to other companies and what practices it needs to improve on.

3.2 Phase 2: Identify which Agile Scrum practices would contribute to the success of

application development projects in Company C.

Logistic Regression can be used when the response takes only one of the two possible values representing absence and presence of the attribute of interest. The simplest idea would be to let πi be a linear function of the covariates, say

$$\pi_i = x_i'\beta \quad (1)$$

where β is a vector of regression coefficients.

The linear probability model is often estimated from individual data using ordinary least squares (OLS). One problem with this model is that the probability πi on the left-hand-side must be between zero and one, but the linear predictor x'iβ on the right-hand-side can take any real value.

A simple solution to this problem is to transform the probability to remove the range restrictions and model the transformation as a linear function of the covariates which is performed in two steps.

The probability πi is moved to the odds defined as the ratio of the probability to its complement, or the ratio of favorable to unfavorable cases.

$$odds_i = \frac{\pi_i}{1-\pi_i} \quad (2)$$

The logit or log-odds is calculated which has the effect of removing the floor restrictions. Logits may also be defined in terms of the binomial mean μi = niπi as the log of the ratio of expected successes μi to expected failures ni-μi.

The inverse transformation is called the anti-logit which gives the probabilities

$$\pi_i = logit(n_i) = \frac{e^{n_i}}{1+e^{n_i}} \quad (3)$$

Suppose further that the logit of the underlying probability πi is a linear function of the predictors.

$$logit(\pi_i) = x_i'\beta \quad (4)$$

where xi is a vector of covariates and β is a vector of regression coefficients.

This defines the systematic structure of the model. The left-hand-side is a logit rather than a mean. Thus, βj represents the change in the logit of the probability associated with a unit change in the j-th predictor holding all other predictors constant. The logit identified in the study is the indicator of the project of the corresponding respondent is completed on-time or not, with πi for on-time and 1-πi for delayed projects. Occurrences of on-time project completion are observed only on samples coming from Company C as indicated in the scope of the study. The odds and logits are then computed which serves as the input values for regression. Bootstrapping is used for regression which will be discussed in the succeeding paragraphs.

Bootstrapping is a nonparametric approach to statistical inference that substitutes computation for a more traditional distributional assumptions and asymptotic results. Its advantages are applicable with the study such as it does not require distributional assumptions (such as normally distributed errors) because it provides accurate assumptions when data is not well behaved, or the sample size is small. Moreover, bootstrap can be applied to complex data-collection plans such as stratified and clustered samples.

The bootstrapping procedure can be generalized by the following steps:

1. Using the observed sample data as "stand-in" for the population, replicate the data collection procedure, thus producing r bootstrap samples:
2. For each bootstrap sample, the estimate θ∗b = s(Bootstrap sample b) is calculated.
3. Use the distribution of the θ∗b s to estimate properties of the sampling distribution of θ .

$$SE^*(\widehat{\theta^*}) = \sqrt{\frac{\sum_{b=1}^{r}(\widehat{\theta}_b^* - \overline{\theta^*})^2}{r-1}} \quad (8)$$

where

$$\bar{\theta}^* = \frac{\sum_{b=1}^{r}\widehat{\theta}_b^*}{r} \quad (9)$$

Bootstrapping can be extended to regression models. A response-variable value and regressors for each observation is collected.

$$z_i' = [Y_i, X_{i1,\cdots,}X_{ik}] \quad (10)$$

The observations z' can be resampled and the regression estimate computed for each bootstrap samples producing r sets of bootstrap regression coefficients. In case of linear regression, the bootstrapping procedure is followed:

1. Estimate the regression coefficients A,B1, . . . ,Bk for the original sample, the fitted value is calculated and residual for each observation:

$$\hat{Y}i = A + B1xi1 + \cdots + \beta kxik \quad (11)$$

$$Ei = Yi - \hat{Y}i \quad (12)$$

2. Select the bootstrap samples of the residuals and the bootstrapped Y values are calculated.

3. Regress the bootstrapped Y values on fixed X values to obtain bootstrap regression coefficient such as for example, estimates are calculated by least-squares regression, then

b∗b=(X_X)−1X_y∗b for b = 1, . . . , r.

4. The resampled b∗b= [A∗b,B∗b1, . . . ,B∗bk]' can be used in the usual manner to construct bootstrap standard errors and confidence intervals for the regression coefficients.

In the study, the regression coefficients of the major categories of the Agile Scrum practices are estimated, and the fitted value of the odds of the project timeliness is obtained. The bootstrap samples are indicated using the Agile Scrum practices of each of the 8 major Agile Scrum categories and the bootstrapped Y values are calculated. Regression on the bootstrapped Y odds values on fixed X Agile Scrum practices on each category is performed 1000 replications using the SPSS Software (Version 22) wherein estimates are calculated using least-squares regression. Regression is run for each eight major categories (Setup, Daily Stand-up Meeting, Story Management, Iterations, Product Quality, Technical Practices, Teamwork and Retrospective), with the practices under each category as the dependent variables and the odds of the on-time or delayed projects as the dependent variable so that the

degrees of freedom will not be violated by the small sample size. The replications are used to eliminate the bias from the samples. The regression coefficients of the Agile Scrum practices, βk will be used as a basis to describe its behavior. The dependent variable, project timeliness considers the response to the independent variables (setup, daily standup meeting, story management, iteration, product quality, technical practices, teamwork and retrospective). The Agile practices are processed through Binary Logistic Bootstrap Regression, marking the on-time and delayed projects from the respondents of the survey. The probability of occurrence of on-time and delayed projects is obtained and served as a dependent variable of the regression model.

3.3 Phase 3: Generate a customized Agile Scrum framework for Company C

Gap Analysis which involves the comparison of the actual performance of object of interest, in this case company C with the potential or desired performance, that is the best practice identified from benchmarking of Addagada [1]. It addresses the questions "where are we?" and "where do we want to be?" in a clear way.

4. RESULTS AND DISCUSSION

The current performance of company C was obtained from the interviews and surveys and the desired performance is obtained from benchmarking through Tukey's Comparison of Means.

Table 2. Summary of comparison of means of practices where Company C should improve on

Company A	Company B	Company C	Company D	Tukeys with Significant Difference
Setup: There is a clear and commonly understood definition of "Done" for completed features				
2.8214	2.8750	2.5500	2.7188	B vs. C, A vs. C
Standup Meeting: How are roadblocks or impediments resolved?				
2.8571	2.4688	2.4250	2.4063	A vs. B, A vs. C, A vs. D
Iterations: End-of-iteration demos occur.				
2.9286	2.9375	2.4250	2.7969	B vs. C, A vs. C, D vs. C
Product Quality: Code reviews occur.				
2.9286	2.6250	2.5000	2.8906	A vs. B, A vs. C, D vs. B, D vs. C
Product Quality: Architectural design for the product(s) is understood by the team.				
2.6071	2.7500	2.3500	2.5313	B vs. C
Technical Practices: Automated unit and/or acceptance tests are run as part of each automated build.				
2.8930	2.9688	1.6750	2.4840	B vs. D, B vs. C, A vs. C, D vs. C
Technical Practices: Team members pair-program at appropriate times.				
2.6786	2.8438	2.1500	2.2970	B vs. D, B vs. C, A vs. C
Teamwork: Formal written documents are used to supplement rather than replace faster, more informal communication				
2.4643	2.4060	2.1000	2.5000	D vs. C, A vs. C
Teamwork: Coaching is utilized to help adopt agile practices.				
2.9286	2.8750	2.3000	2.5310	A vs. C, B vs. C
Retrospective: An appropriate level of action is taken based on retrospective feedback				
2.6429	2.7813	2.1750	2.4844	B vs. C, A vs. C

The positive coefficients contribute to the success of the Agile projects. 22 practices are identified as such with the higher coefficient having a greater contribution.

Table 3. Agile Practices that contribute to the project success

Category	Statement	B
Setup	There is a clear and commonly understood definition of "Done" for completed features.	1.099
Setup	The release is planned at a high-level.	20.168
Stand-up meeting	Regular stand-up meetings occur.	16.987
Stand-up meeting	Resolution of roadblocks or impediments.	1.253
Story Management	Developers and testers work together in story implementation and acceptance criteria.	16.932
Story Management	Technical and user documentation is included in determining if a story is complete.	56.112
Story Management	Handling of incomplete stories.	1.223
Iterations	Manner of loading the iteration	20.513
Iterations	Team members attend the sprint /iteration planning meetings.	19.598
Iterations	If used, stabilization iterations are scheduled in advance.	0.618

Iterations	Product is potentially shippable at the end of each iteration.	18.511
Iterations	QA Testing is performed alongside development.	37.565
Product Quality	Bugs/defects are continuously monitored.	0.858
Product Quality	Code reviews occur.	1.15
Technical Practice	Automated unit and/or acceptance tests are run as part of each automated build.	0.676
Teamwork	Everyone that's needed for this project is assigned, engaged and available as needed.	36.168
Teamwork	The client sets goals and gives the team freedom to deliver successfully.	35.185
Teamwork	Product Owner or someone that assumes the role of having the product vision is highly involved	36.202
Teamwork	The team responds to change in a swift, non-bureaucratic way.	36.203
Teamwork	Coaching is utilized to help adopt agile practices.	35.478
Retrospective	Retrospectives occur periodically.	18.529
Retrospective	An appropriate level of action is taken based on retrospective feedback.	0.588

Table 3 specifies the practices that the Agile Projects need to improve on as improper implementation of the practices contribute to the delay of the project

Table 4. Agile Practices that contribute to the project delay

Category	Statement	B
Setup	Frequency of evaluating the priorities of Backlog items.	-2.260
Stand-up meeting	Length of typical stand-up meeting	-0.560
Story Management	Stories are broken down and small enough to be done in one iteration.	-20.323
Story Management	Each team member creates a record of their tasks to help break down their assignments.	-1.682
Iterations	Sprint/Iteration planning meetings occur.	-19.575
Iterations	Iterations do not change length.	-9.427
Iterations	End-of-iteration demos occur.	-39.306
Product Quality	Performance of unit testing	-1.404
Product Quality	Architectural design for the product(s) is understood by the team.	-0.278
Technical Practice	Team members pair-program at appropriate times.	-2.151
Teamwork	Team members work on finishing each iteration as a team, helping each other along the way as needed.	-106.393
Teamwork	Formal written documents are used to supplement rather than replace faster, more informal communication.	-35.384

5. RECOMMENDATION

Based on the outcome of the one-way ANOVA and Regression analysis, the objectives on the beginning of the study will be answered.

5.1 Research Objective 1

The first objective of the study was: Assess the level of Agile Scrum adoption of Company C's application development projects. From the findings from the one-way ANOVA Test and Tukey's Post Hoc Test, the answers of Company A, B, C and D on their observance of the Agile practices. Among the 34 Agile Practices, 10 of the Agile Practices are the gaps to be addressed by Company C. The following are the Agile Scrum practices that should be addressed: Setup Practice 2: There is a clear and commonly understood definition of "Done" for completed features. Standup Meeting Practice 3: Roadblocks or impediments are resolved quickly. Iterations Practice 6: End-of-iteration demos occur. Product quality Practice 3: Code reviews occur. Product quality Practice 4: Architectural design for the product(s) is understood by the team. Technical practices Practice 1: Automated unit and/or acceptance tests are run as part of each automated build. Technical practices Practice 2: Team members pair-program at appropriate times. Teamwork Practice 4: Formal written documents are used to supplement rather than replace faster, more informal communication. Teamwork Practice 7: Coaching is utilized to help adopt agile practices. Retrospective Practice 2: An appropriate level of action is taken based on retrospective feedback.

5.2 Research Objective 2

The second objective of the study is to identify which Agile Scrum practices would contribute to the success of application development projects in Company C. The objective was obtained by performing a regression analysis on the 34 Agile practices as independent variables and project timeliness as the dependent variable. Only of 22 out of the 34 Agile practices are the have positive impact on project timeliness. The following practices have positive impact on the completion of the project and should be maintained by company C: Clear and commonly understood definition of "Done" for completed features. The release is planned at a high-level. Regular stand-up meetings occur. Resolution of roadblocks or impediments is performed by the team. Developers and testers work together in story implementation and acceptance criteria. Technical and user documentation is included in determining if a story is complete. Handling of incomplete stories is done on the next iteration. Loading of iteration is based on historical velocity. Team members attend the sprint /iteration planning meetings. Hardening (or stabilization) iterations are scheduled in advance. Product is potentially shippable at the end of each iteration. QA Testing is performed alongside development. Bugs/defects are continuously monitored (low technical debt). Code reviews occur. Automated unit and/or acceptance tests are run as part of each automated build. Everyone that's needed for this

project is assigned, engaged and available as needed. Formal written documents are used to supplement rather than replace faster, more informal communication. Product Owner or someone that assumes the role of having the product vision is highly involved. The team responds to change in a swift, non-bureaucratic way. Coaching is utilized to help adopt agile practices. Retrospectives occur periodically. An appropriate level of action is taken based on retrospective feedback.

Take note that the following Agile practices have negative coefficients on the regression equation. Negative coefficient in the regression equation means that these practices should be addressed to achieve project timeliness. These are the following 12 Agile Scrum practices that should be addressed: Frequency of evaluating the priorities of Backlog items, length of typical stand-up meeting. Stories are broken down and small enough to be done in one iteration. Each team member creates a record of their tasks to help break down their assignments. Sprint/Iteration planning meetings occur. Iterations do not change length. End-of-iteration demos occur. The team is responsible for unit testing. Architectural design for the product(s) is understood by the team. Team members pair-program at appropriate times. Team members work on finishing each iteration as a team, helping each other along the way as needed. The client sets goals and gives the team freedom to deliver successfully.

5.3 Research Objective 3

Positive coefficients on the regression are the practices that should be maintained. In terms of setup, Ewler [5] presented having well written story definition of done contributes to the success of the project in terms of the performance to schedule. The developers and the product owner or client sit together and agree on the schedule of the features. In Gil-Santamaria [7], a feature is considered as done when it is fully developed, tested and accepted by the product owner. It is stated in Rising and Janoff [11] that successful projects have their requirements documented in high-level and open to interpretation. Based on the study conducted by Flora et. al [6], the most widely used practiced by the company that develops mobile applications is the daily standup meeting. In a study conducted by Cho [4] and Sison and Yang [13], daily standup meetings contribute to the success of the project because the developers are on the same page and the team is informed with the progress of each team members. Furthermore, in a study by Hansen and Baggesen [9] the team members are much more engaged to collaborate and actively work on the problems raised during stand-up meetings. In terms of Story Management, Gil-Santamaria [7] related testing goes hand in hand with the development of the feature. Cho [4] stresses that technical documentation should be accomplished so that it would be less difficult for new developers or developers who work on a feature of the system that they haven't been previously involved. In handling of incomplete sprints, it is stated in Rising and Janoff [11] that tasks for a sprint must be well quantified and achievable within the sprint time period. In terms of Iteration, goals are set related to future product releases in addition to current development activity for loading iteration. Sprint planning meetings are held by only those who had a need attended based on Rising and Janoff [11]. Teams should be represented to relay the discussion to the other members. Another best practice observed by on Rising and Janoff [11] is that the first piece of code is done and re-estimated is practiced by projects to solidify the design of the project. It is also noted in their study that there are sprint tasks might include all-design cycle phases. Instead of executing at the end of the cycle, it is mentioned in Gil-Santamaria [7] testing should be integrated throughout the iteration cycle.

In terms of Product Quality, bugs or defect are treated as entries in the product/sprint backlog for planning or tracking purposes stated in Gil-Santamaria [7]. Hansen and Baggesen [9], code reviews can be done manually or automatically. In some projects, developer box is setup for code review. In terms of technical practice of automated unit/ acceptance test, Gil-Santamaria [7] mentioned that optimized testing efforts are done through automated testing.

In terms of teamwork, Rising and Janoff [11] noted in their study that the team members look after each other's tasks and volunteer to help each other to attain project success. The product owner of the successful project in a study conducted in Rising and Janoff [11] always meets with the team whenever help is needed. In a study by Cho [4], the project responds to change through incremental development, customer collaboration and frequent delivery of iteration. Coaching and adequate training is effective in overcoming Agile practices as concluded in the study conducted in Benefield [2]. Coaching is used to correct misguided implementation of Agile Scrum.

In the study in Hansen and Baggesen [9], doing regular retrospectives contributed to the success of Agile projects by creating more trust and understanding between and among the distributed teams. Moreover, Vijay and Ganapathy [15] recommended that teams should implement action points on the retrospective meeting. The teams should start working on the action points to provide right solution.

The following practices that have negative coefficients in regression that should be improved:

One of the practices identified in Vijay and Ganapathy [15] was the lack of understanding of a done feature. Cho [4] identified that too much time spent on daily standup meeting can reduce productivity of the members. In story management, Vijay and Ganapathy[15] mentioned that not freezing the agreed features to be delivered in the iteration should be addressed. In terms of iteration, Cho [4] mentioned that the Sprint Plannings are inefficient as well as Vijay and Ganapathy [15] mentioned that sprint planning is conducted by the onsite members only, thus citing not practicing Sprint planning contributes to the failure of the project. Having an inconsistent length of iteration because of not reducing the scope to fit the deadline instead of extending the sprint contributes on the delay in the completion of the project. Furthermore, Vijay and Ganapathy [15] stated that lack of obtaining feedback from demo contributes to the delay of the project.

For product quality, lacking documentation results to project delay due to clarification. There must be a proper knowledge transfer for the new members of the team. The finding of lack of performance of unit testing is consistent with the result of the study conducted in Sison and Yang [13] which sites that lack of familiarity of the developers on test driven environment poses as a challenge in the success of the project. In terms of technical practices, the finding found that the lack of practice of pair programming contributes on the challenges on attaining project success is consistent with the results of Sison and Yang [13]. Under teamwork, lack of

coordination results to duplication of task between the team members according to Vijay and Ganapathy [15]. Furthermore, lack of formal written documents as found in the study is consistent regarding factors that contribute on the delay of the project. Finally, the finding on the lack of appropriate level of action is taken after retrospective is consistent with the results of the study of Vijay and Ganapathy [15] which is the output of retrospective not utilized thus contributing to the failure of the project.

6. CONCLUSION

The research study uses the survey data to explore the relevant practices of Agile Scrum software development using quantitative methods. Previous studies have presented factors that contribute to success of Agile Scrum projects in the form of case studies. A generalized approach in the form of a statistical study evaluating the Agile Scrum practices that contribute to the success has not been conducted in a Philippine setting. Only few literatures used survey as a medium to evaluate the success factors in Agile Scrum and have used the practices as determinants in contributing Agile Scrum factors affecting project timeliness of Company C.

The research paper used interview and survey to the members of selected Filipino IT Companies for data gathering. The use of one-way ANOVA and regression in the study aims to set direction for Company C on improving project timeliness.

The data was collected from 164 respondents from three major IT companies based in the Philippines and other companies. Company C can improve on the practices that have negative coefficient on the regression.

The key contribution of this research is to give Company C focus on formulating strategies for the improvement of the company's project timeliness. Similar study can be done to other software development companies to improve their project timeliness.

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Lens Quality Inspection using Image Processing and Machine Learning

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ABSTRACT
This research proposes a system to inspect defective lenses with a polarization technique by using image processing and machine learning. Currently, a skilled operator checks the lens quality with the polarization method by eye and decides whether or not a lens is good (OK) or not good (NG). A 'not good' lens has a circle or a line appearing in the stress pattern of the lens. This research designs and develops a lens quality checking system with machine learning by simulating and prototyping a machine to experiment and collect persistent data, using the camera to capture and analyze images with image processing and machine learning techniques to decide on the lens quality in the computer. The experimental results show that the proposed system with a trained model with data augmentation and image preprocessing can achieve performance testing with 97.75% accuracy.

CCS Concepts
• **Computing methodologies → Artificial intelligence → Computer vision → Computer vision problems → Interest point and salient region detections**

Keywords
lens quality inspection; polarization; image processing; machine learning

1. INTRODUCTION
In lens manufacturing, the plastic lens production process involves the use of casting or injection. In the casting process, the space between two glass molds is filled with a liquid monomer such as CR-39, or allyl diglycol carbonate (ADC), and the polymerization to cure plastic is completed in the oven at a specific temperature and time [16]. The lens defects that occur in the casting process can be classified into 2 types: type A - circle defects and type B - line defects. Normally, the operators check the lens defect by using a polarization technique by placing the lens between two crossed polarizers. The skill of operators is needed to guarantee that all defective lenses are rejected. An automated process to check lens quality is proposed by designing and developing a system to inspect lens defects by using image processing and machine learning to help in decision making and to increase the efficiency of the production process by replacing workers.

This paper is organized as follows. Section 2 presents the review of literature related to this research. Section 3 describes the proposed system consisting of an overview of the system and software development. The experiment and results are presented in Section 4, and finally Section 5 concludes our proposed system.

2. RELATED WORKS
The polarization technique is used to show the stress distribution patterns or refractive index variations inside the lens by placing the lens between crossed polarizers (see Figure 1) because the stress of the lens changes the angle of polarization and results in a different stress distribution pattern inside the lens. Lens defects can be classified into 2 types: circle defects (type A) and line defects (type B). The circle or line appears in the stress pattern of the lens as shown in Figure 2. The image processing technique can be used to identify the defect instead of humans. Huang, Chang and Wu proposed a new image polarization method to measure the tilting and decentering of the lens by placing a sample lens between two linear polarizers and observing the change of shape, patterns and colors of the polarization image and the degree of error in the lens shape can be calculated using an image processing technique [5]. Lin, Lin and Tsai proposed a method to inspect the LED lens using image processing to identify the defective area in the frequency domain using discrete cosine transform blocks, Hotelling's t-squared statistic and the grey clustering method. The experimental results showed that the technique can detect the defective area better than the technique used in the factory [7]. Yao et al. proposed a method to identify three types of lens defect by using image processing: point impurities, scratches and feathers. The experimental results revealed that the thinning algorithm plays an important role in improving the accuracy of the classification of scratches and feathers [17]. Labati et al. inspected an quality of wood particles in oriented strand board using image processing technique in frequency domain to calculate an energy histogram and related features for neural network to estimate the quality of the wood particles [6]. Thavorakul proposed and compared a few methods to check a lens quality using polarization technique and image processing. The experimental result shown that the combination of two methods, the finding object method and the finding similar shapes method, delivered the good result but the operator is required to inspect the good lens from the rejected lenses therefore it cannot use in the production line [13].

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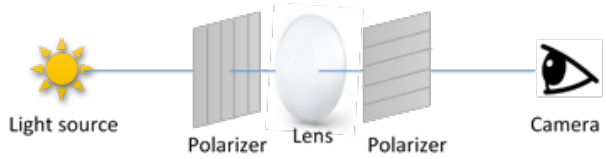

Figure 1. Polarization technique used in the system

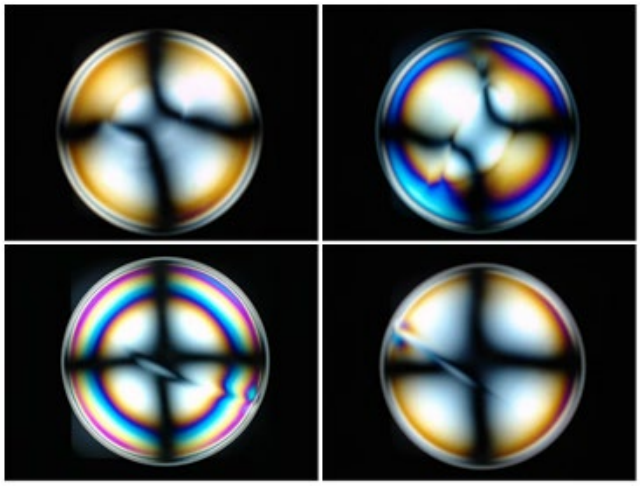

Figure 2. Lens defection of type A (above) and type B (below)

Machine learning is a method by which a specific task is learned from known (training) data and then unknown (test) data can be subsequently identified. An artificial neural network (ANN) is a type of machine learning that is widely used in many researches. The ANN is commonly used in supervised learning which all nodes are fully connected. There are many researches using neural network approach for object recognition and classification [6, 12, 14]. A convolutional neural network (CNN) is a neural network model that is appropriate for computer vision applications particularly in image detection and classification. The CNN contains many layers: convolutional layer to filter and extract features in small area of image, pooling layer to compress volume to reduce overfitting and computation, and fully connected layer to categorize results in the final layer. Data partition for testing can be divided into three groups: the self-consistency test, the split test, and the cross-validation test [9]. The self-consistency test uses the training data as test data without partition. The split test divides the data into two sets: training data and testing data. The cross-validation test divides the data into N sets: training data N-1 sets and testing data 1 set and rotates the testing data from set 1 to set 2 to obtain set N. Wang et al. proposed a defect detection method using image processing combined with a convolutional neural network and the experimental result showed that the proposed method achieved a fast detection with high accuracy [15]. Sahla proposed object identification from the size, shape and with a barcode location using the deep convolutional neural network in MATLAB to implement smart picking in industry [11]. Pike developed an autonomous drone-attached camera to detect a group of ground robots by using computer vision and deep learning to train the neural network model. The result of this system can be run in real-time in a drone [10]. Lin, Gua and Yang proposed a method to detect texture defects based on feature fusion using Faster-RCNN to inspect the product texture in industrial production [8]. Chen, Wang and Wang used Faster-RCNN to detect wood surface defects by enhancing the image and extracting the edge feature points of the wood defects. The experimental results showed that the proposed algorithm can detect wood defects better [2].

3. PROPOSED SYSTEM

3.1 System Overview

The system consists of an LED lamp as the light source at the bottom, two polarizers, for which the polarization axis is oriented orthogonally, a lens placed between the two polarizers, and the UI-3240LE-NIR camera for capturing the stress distribution pattern on the other side, connected with a NUVO-5501 industrial computer as shown in Figure 3. The system is designed to fit in the production line to replace the current station which uses an operator to check for lens defects. The structure of the system is an aluminum profile attached to black acrylic sheets to control the light environment, a bearing is placed at the lens base to enable the lens to be rotated to increase the performance of the input image in any direction. The polarization box is shown in Figure 4.

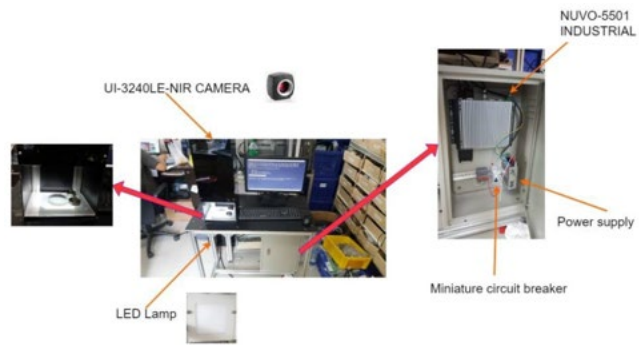

Figure 3. System overview

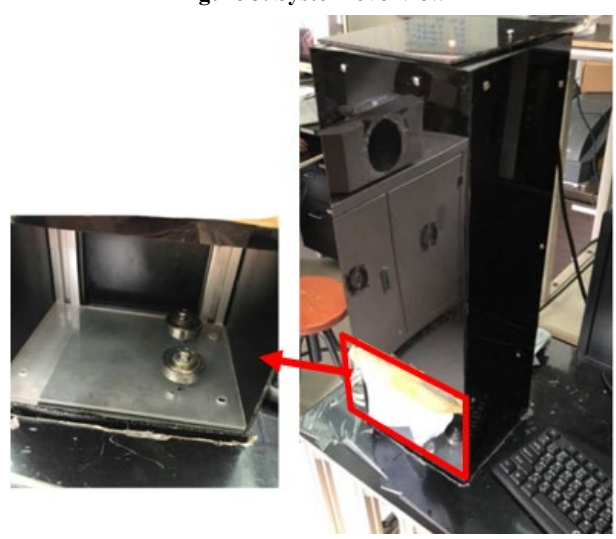

Figure 4. The polarization box

3.2 Software Development

The software of the proposed system consists of two sections: image preprocessing and machine learning. The first section is the image preprocessing part to enhance the image and extract data from the image which is suitable for machine learning using the Python and OpenCV library [4] for image processing. The resulting image is suitable for training and testing in the next section.

The steps of image preprocessing are as follows (see Figure 5):

1. Find lens boundary and crop: a lens image is segmented by using the threshold to find the height and width of the lens, and the original lens image is segmented by using Canny filter to detect a circle which is a lens boundary and crop the

original lens image with this circle. Then, the new image is created with the size of the height and width values and copy the cropped image. The result of this step is the lens image enclosing in bounding box.

2. Blur image with Gaussian filter: the result image from step 1 is blurred by using the Gaussian filter with kernel size of 5x5. The result of this step reduces the detail of lens image.
3. Find edge with Laplace filter: the result image from step 2 is sharpen by using the Laplace filter with kernel size of 9x9. The result of this step gives the edge of lens image.
4. Blur image with Gaussian filter: the result image from step 3 is blurred by using the Gaussian filter with kernel size of 9x9. The result of this step reduces the detail of edge image.
5. Segment and blur image: the result image from step 4 is segmented by using threshold and then blur image using the Gaussian filter with kernel size of 5x5. The result of this step enhances the detail of the edge image.
6. Erode image: the result image from step 5 is eroded by using a box structuring element size of 5x5. The result of this step reduces the noise in the image.

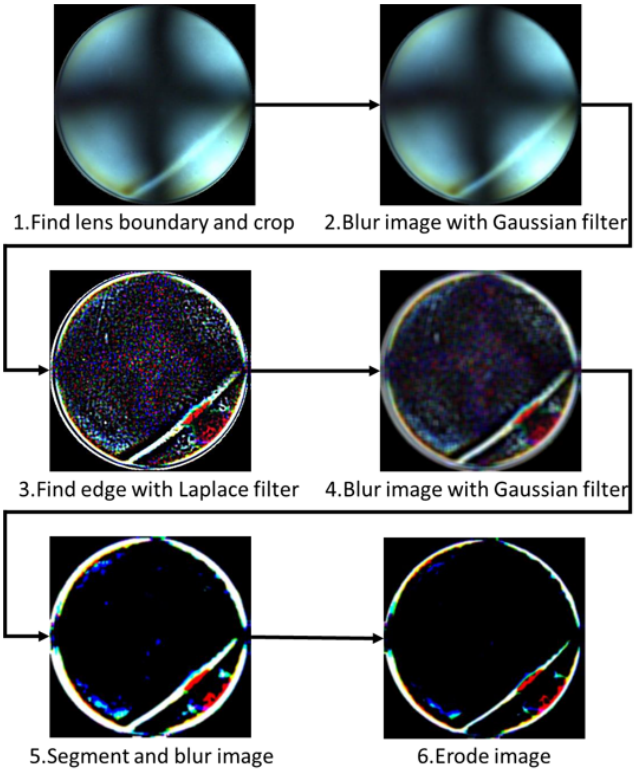

Figure 5. Steps of image preprocessing

The second section is the machine learning part to analyze all preprocessed images and to determine whether the lens is good or not good by identifying the defect type using Python, Scikit-Learn and Keras libraries [1][3] for the convolution neural network (CNN).

4. EXPERIMENT AND RESULTS

The experiment consisted of two parts: the training set and the testing set. The training set used 5,200 images, of which 800 images were good lens images; 1,400 images were defective lens images with a circle (type A) and 3,000 images were defective lens images with a line (type B) The model was trained by partition data using the split test technique. Each epoch in the training process had 42 iterations. Each iteration of the images was randomized and split into training data of 3,900 images (75% of 5,200 images) and testing data of 1,300 images (25% of 5,200 images) to guarantee model overfitting. Moreover, data augmentation was used to generate more training data from the original images, which increased the model performance by rotating with 45 degrees, zooming in and out by 30%, and moving left and right by 30%. Finally, the performance of the model with four parameters: training accuracy, training loss, validation accuracy, and validation loss was calculated and each epoch was averaged. The training process was run until 40 epochs. The three training models were investigated to compare model performance; model 1 with no data augmentation and no image preprocessing; model 2 with data augmentation and no image preprocessing, and model 3 with data augmentation and image preprocessing as shown in Table 1. The comparisons of model performance with no data augmentation and no image preprocessing, and with data augmentation and no image preprocessing are shown in Figures 6 and 7. It is evident that the data augmentation increased the performance of the model, which can learn better than with no variation of image. The data augmentation and image preprocessing had the best performance with accuracy at about 97% as shown in Figure 8. It shows that the image preprocessing process can help the model to classify the quality of lens better than the original image.

Table 1. The configuration of training models

	No Image Preprocessing	Image Preprocessing
No Data Augmentation	Model 1	-
Data Augmentation	Model 2	Model 3

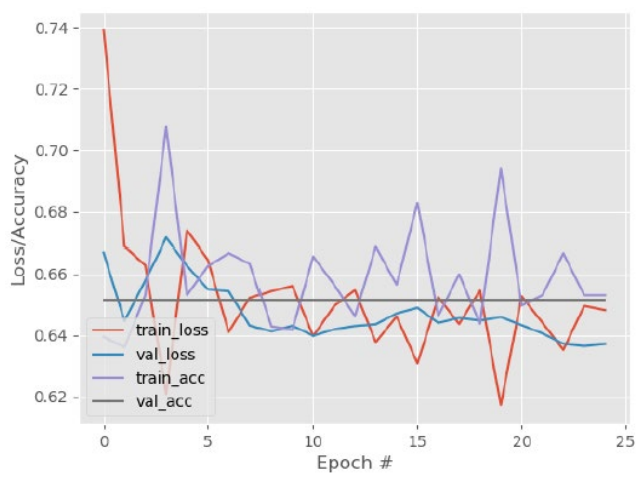

Figure 6. Performance of model with original model and no image preprocessing

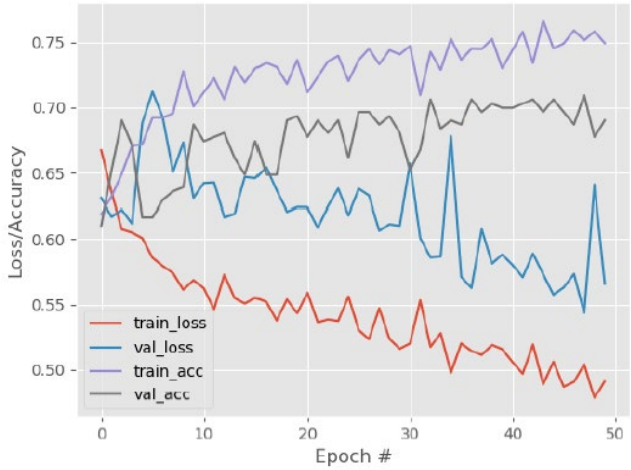

Figure 7. Performance of model with modified model and no image preprocessing

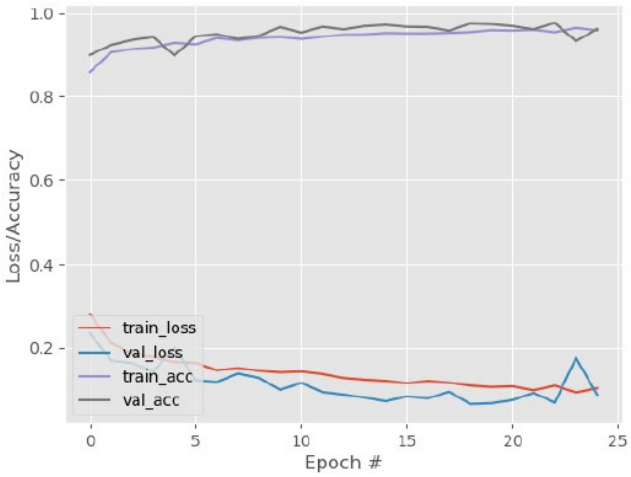

Figure 8. Performance of model with modified model and image preprocessing

The testing set used 1,200 images, of which 200 images were good lens images, 500 images were defective lens images with a circle (type A), and 500 images defective lens images with a line (type B). This data set was unknown and not in the training set to test the system in the real situation by using the modified model and image preprocessing. The experiment results are presented in Table 2. The proposed system can identify good lens images, not good lens images (type A), and not good lens images (type B) correctly with accuracy of 88.00%, 99.60%, and 99.80%, respectively. The overall accuracy of the system was 97.75%. The system states that good lenses are not good lenses of 3 images and undefined lenses of 21 images. The polarization image of good lens looks very similar with not good lens and can hardly be classified by human. The examples of good lens and not good lens images are shown in Figure 9. The undefined lenses shown in Figure 10 are hard to identify as they are not good lens images (type A) on the left and good lens images on the right.

Table 2. Accuracy of the model

Lens	Correct	Incorrect	Undefined	% Accuracy
Good	176	3	21	88.00
Not Good (type A)	498	0	2	99.60
Not Good (type B)	499	0	1	99.80
Total	1173	3	24	97.75

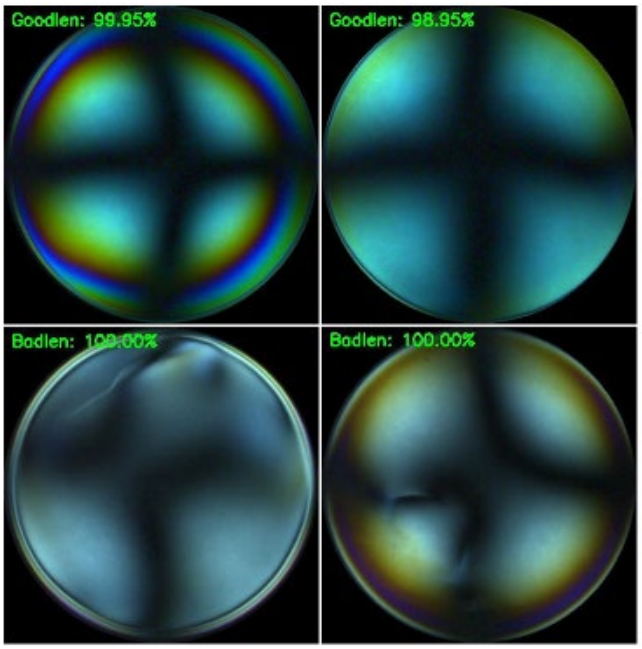

Figure 9. Examples of good lens (above) and not good lens (below)

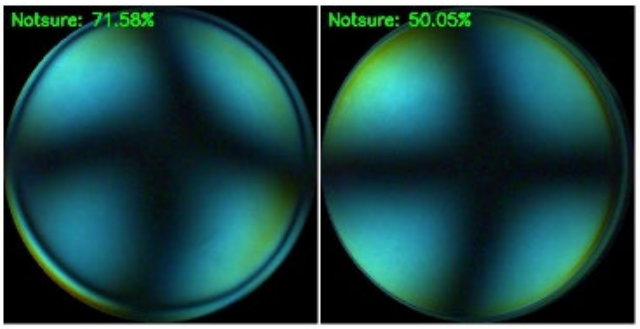

Figure 10. Examples of undefined lenses

5. CONCLUSION

This paper proposed lens quality inspection with the light polarization technique using image processing and machine learning to detect lens defects, which can be classified into two types: circle (type A) and line (type B). Before employing this technique, skilled workers checked for lens defects in the production line using only their eyes. Human error can occur

because of the limitations of humans. Using the proposed system to verify the human decision will reduce human error and increase productivity. All 5,200 images were used to train the model and to compare the efficiency values for training accuracy, training loss, validation accuracy, and validation loss in three training models: model 1 with no data augmentation and no image preprocessing; model 2 with data augmentation and no image preprocessing, and model 3 with data augmentation and image preprocessing. We noticed that the validation accuracy is an important parameter to adjust the model over fit. The accuracy of machine learning in the training model with image preprocessing and data augmentation to extract feature and increase variation of the input image has 97%. Accuracy. The proposed system was tested in the production line with 1,200 images and achieved overall average accuracy of 97.75%.

6. ACKNOWLEDGMENTS

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Influence of Generation Gap in Distinguishing Philippine Currency Coins

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ABSTRACT

The preliminary study assesses the design of new coins produced by the Bangko Sentral ng Pilipinas. Two sets of coins are currently in circulation: The Bangko Sentral ng Pilipinas and the New Generation Currency Coin (NGC) Series. The researchers conducted the study to address the public confusion on the NGC coins that are being released in the circulation. The major priority of this study is to identify the influence of generation gap in distinguishing the NGC coins. The researchers conducted a time study on respondents from different age groups while identifying the values of the currency. Based on the study, the respondents rely on their visual sense more than their other senses when recognizing the newly released coins. The researchers used Ishikawa diagram to determine the factors that causes the coin confusion. Analysis of Variance and Tukey's Comparison of Means were utilized to identify which generation from the Baby-boomers to Generation Z were able to recognize the currency immediately. The researchers recommended aids on helping user easily recognize the difference between the new generation coins.

The birth of the Philippine Peso isn't complex. Starting from the known history of the Philippine wherein our forefather learned how to exchange goods and the concept of trade started to be known. In early centuries, Filipinos started trading with our neighboring countries. They use gold, silver and any precious stones as coinage. This is a way for them to buy goods. After the barter system, the Spanish introduced "teston" a silver coin that served as the main currency in the Philippines. When the economy bloomed, other currencies such as the Alfonsino peso and Mexican peso circulated in the country, ultimately giving more meaning to money and its importance. After gaining its independence from Spain in 1898, the Philippines started producing its own currency in coin and paper. The "sentimo" was introduced to differentiate coins from bills and to give more value to money when trading with locals and foreigners. The Philippines coin design keeps changing and adapting as time passed by. The colonization of different nation like Spaniards Americans and the Japanese resulted in different form of coins in size, color, shape and value in the country. The current coinage is far different from before.

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CCS Concepts

•Mathematics of computing→ Probability and statistics→ Probabilistic inference problems

Keywords

Time Study; Analysis of Variance; Tukey's Comparison of Means

1. INTRODUCTION

1.1 Background of the Study

Money can be a metal coin, or a piece of paper with a historic image on it, but the value that people place on it has nothing to do with the physical value of the money. Money is a unit of measurement and a storehouse for wealth. Long ago, according to Bangko Sentral ng Pilipinas, barter was a system of trading commonly practiced throughout the world and adopted by the Philippines, then cowrie shells and cobs and macuquinas were the earliest coins. There were also released banknotes and when the

1.2 Statement of the Problem

As the Bangko Sentral ng Pilipinas (BSP) releases new coins in the circulation, the general public are all confused with the values of the coins because of its design that is almost identical in terms of color and size which sometimes lead to loss of money or deception.

1.3 Research Questions

In this study, the following research questions are to be answered:

1. What factors are considered upon redesigning the coins?
2. Does generation gap influence in distinguishing the currency value of Philippine coin?

1.4 Significance of the Study

This paper aims to contribute in further investigation on the confusion of the participants of every age bracket on distinguishing

the New Generation Currency Coins in the Philippines. In addition, the study would be helpful on Bangko Sentral ng Pilipinas to broaden their horizon on the public's view regarding the New Generation Currency Coin.

1.5 Scope and Limitations

This study focused about the influence of Generation Gap in Distinguishing Philippine Coin Currency. The Philippine coin design keeps changing and adapting as time passed by and resulted in different form of coins in size, color, shape and value in the country. The current coinage is far different from before.

The data was gathered from August to November 2019 from 80 participants which are grouped by corresponding age bracket from youngest to oldest to assess their own view on recognizing the newly released coins in the Philippines.

1.6 Problems and Limitations

There were several problems and challenges which the researchers encountered while conducting the research for this study.
The first challenge was recruiting enough participants for each age bracket. Since the researchers are conducting surveys by approaching pedestrians in public but was performed to ensure that the respondents fit to the target users of the coin currencies. The study was mainly focused on the city of Manila, which were the residence of the proponents of the study.

2. REVIEW OF RELATED LITERATURE

According to Lucas (2018) [9], the Bangko Sentral ng Pilipinas introduced a new series of coins was meant to deter foreign entities from stealing large quantities of the local specie to extract their nickel content. Nickel is highly resistant to corrosion and, as such, is a key element for making stainless steel alloys. The new series design features enhanced the aesthetics and security of the coins. In particular, the micro-printed details using laser-engraving technology were included in the two highest denominated coins, the 10-Piso and 5-Piso, which makes it difficult for these coins to be duplicated using traditional coin counterfeiting methods. The coins, which appear as "metallic silver," addressed concerns on discoloration predominantly observed for copper-based metals. The new generation coins featured the new BSP logo, three national heroes (Apolinario Mabini in the 10-Piso, Andres Bonifacio in the 5-Piso and Jose Rizal in the 1-Piso), a stylized three stars and a sun in the 25-, 5- and 1-Sentimo, and endemic flora consistent with the design of the new banknote series that highlights Philippine fauna.

2.1 Material

According to Gulle (2018) [6], Philippines was used to be known for its gold, silver, and copper, but a new element has taken the throne as the country's top mineral product: nickel. As the world's second-biggest supplier of nickel ore, the country exported 577,000 metric tons of it in 2016 and 2017 combined. Last year's nickel ore exports came in at 230,000 metric tons — a third less than the 2016 figure—but still raked in $455.21 million (P24.533 billion) for the country in 2017, according to the United Nations Comtrade database on international trade. That dollar figure shows the bright potential of the versatile element for the Philippine economy, perhaps even more than the precious metals mined elsewhere in the country. In fact, the Philippines was the world's top nickel producer in decades past, but the shifting local political landscape combined with environmental concerns forced it to lose ground to Indonesia. Our Southeast Asian neighbor has capitalized on our country's current situation and kicked its production into high gear to feed the mineral-hungry economy of China. It doesn't mean that local nickel miners aren't standing their ground, though. Thirty of the country's 50 mining firms dig for nickel, and seven of them have formed a group — the Philippine Nickel Industry Association (PNIA) — to help champion the sector as well as the broader concept of responsible and sustainable mining that gives back to its partner communities.

2.2 Problems

According to Gonzales (2018) [5], the Bangko Sentral ng Pilipinas (BSP) announced a new design for the 5-peso coin. It features Filipino revolutionary leader Andres Bonifacio as to commemorate his 154th birthday. The newly designed coin is under the New Generation Currency (NGC) Coin Series, a project launched by the BSP in 2010. Weighing 7.5 grams, the obverse of the coin bears the inscription "Republika ng Pilipinas" and the name and profile of Andres Bonifacio. The reverse features a Philippine plant called "Tayabak" and the BSP logo. It boasts of "corrosion resistance" abilities to prevent forgery. Compared to the old 5-peso coin, the new coin looks simpler and more updated. From the past, the old "singko" features General Emilio Aguinaldo on the obverse and the BSP logo on the reverse. It is primarily made of nickel-brass, a compound that contributes to its yellow-gold hue. When the new 5-peso coin circulated this year, it garnered different-yet-mostly-negative reactions from netizens. People found it extremely similar with the 1-peso coin due to its silver color and medium size.

Malasig (2018) [10] cited that the change has been hard to swallow for many Filipinos who feel the new designs were too similar with each other making them hard to tell apart. When the BSP first announced the new design of the five-peso coin in December of 2017, the public quickly aired their concerns that it might be confused with the current one-peso coin. The recent release of the new designs of ten-peso, one-peso, 25-centavo, and one-centavo coins prompted Filipinos to debate on the two sides of the new coin designs.

According to Ala (2018) [2], BSP downplayed the public's dissatisfaction over the confusing New Generation coins, saying the coins can be easily distinguished by simply looking at the coins or running a finger on their edges when giving or receiving them. The BSP issued these new coins to increase its security features and to prevent metal extraction. The BSP Branch Deputy Director Tomas Cariño Jr. told a media forum that by adding the coins' different edges were designed to aid the blind or those with poor eyesight in distinguishing one from the other. The old Philippine coins were replaced after 23 years in circulation last March 26 when BSP completed the release of the new P10, P5, and P1 together with the 25-centavo, 5-centavo and 1 -centavo denominations. In accordance with RA 7653 or the New Central Bank Act which provides for the replacement of currency unfit for circulation and retirement of old notes and coins. To enhance security features using the latest technology to prevent our coins from being counterfeited. Adding that the new coins, all silver in colors, have new edges from plain, reed to intermittent reeds, aside from their mint mark and micro prints. The new metal composition of the new coins which are made of nickel. Recalled that in the past when the metal value of the P1 coin was worth more than its face value, enterprising foreigners would take them to their country where these were melted down and the metal extracted at a profit. The new coins will remedy that problem explaining that the new series would be made mainly of steel, with only a double plating of nickel for protection. The metallic composition of the new coins also improved their resistance to wear and corrosion.

Ornedo (2019) [12] had been critical in the plan to release P20 coins, saying that it would signal the devaluation of the Philippine peso

and negatively impact the Abaca industry from which material for the paper bills are sourced. Columnist and editor Manuel Quezon III, a descendant of the late President Manuel Quezon whose face appears on the twenty-peso bill, Quezon said the family agreed that twenty-peso coins would be inconvenient, considering that the bill is widely used. Very heavy, cumbersome and thus this public aspect should be considered particularly are aware there was perhaps less testing of the new series of coinage leading to confusion and outright irritation. Psychologically, as citizens, it would send a signal of devaluation: abolition of one denomination of paper currency sends an overall signal of the shrinking value of our currency; symbolically it also serves, unintentionally to be sure but will still be interpreted as such, as the demotion of the personality of the bill to be withdrawn from circulation.

According to Acosta III (2018) [1], with the BSP's release of the first of the six coins, the five-peso coin, to coincide with last year's Bonifacio Day, has brought on a lot of negative reactions from the public, many of whom claim that it gives unnecessary confusion, as it is easily mistaken for a lower denomination, the one- peso, if held together. Coins are made of metallic planchet, a blank metallic disc, which are pressed to bear the denomination and design of a specific coin. It is made up of metals ranging from plain to (usually) alloys of different metals. The world market of metal prices has been erratically changing in response to global economy. To date, the cost of the metals used to make our coins are as follows: $1.46/lb. for zinc, $5.93/lb. for nickel, and $3.02/lb. for copper. While the new generation series uses steel coated in nickel, which costs $1.18/lb. for steel (cast). Unknown to most people, hoarding of specific currencies is a common issue. During the recent spike in nickel prices, some people would exploit the coin to extract the metal. To address the growing issue of currency and medium imbalance, the BSP has resorted to another choice as the base of coin currencies — steel. It is durable, readily available, and more importantly, cheaper to mint compared to the old series. Our advances in plating technology also address concerns on susceptibility to rust and resistance to the daily abuses of commerce. There are other metals that can technically be used to mint our coins, such as aluminum. But most cheap metals are friable and cannot withstand day-to-day use. The other issue is counterfeiters — as more counterfeit money dilutes the market, the economy suffers. BSP is mandated to safeguard the integrity of our currency against possible counterfeiters, and the longer a country maintains the same set of currencies, the easier it is to be copied and perfected by counterfeiters. To prevent this from happening, mints redesign currency features ranging from mere alterations to a total revamp of the currency. One of the biggest concerns people have with the new coins is their similarities and how difficult it will be for many to distinguish them. Whether through natural wear and tear or efforts done by those attempting to exploit the coins, metal plating can eventually peel off and expose the base metal and coating. Discoloration or rusting will eventually be enough to be consider the coin mutilated, which the BSP must then recoat or remint to restore it. This process is costly and a waste of resources. Discoloration of the surface of the coins or worse, rusting, will eventually be enough to be considered mutilated. Hence, BSP will either facilitate its recoating or reminting just to restore. A process that occurs more than it should will cost money, therefore, impractical waste thereof. To address the matter, the BSP enhanced some of the old features of the coins. They have put more emphasis on our heroes' portraits by increasing their size ratio and contrasting denomination against micro-printed scripts. The coins likewise feature an array of local flora on the reverse side to replace the previously uniform rising sun image. Irregularly shaped coins are very difficult to make, and with increasing difficulty, comes a costlier production. Initial confusion is not at all surprising, hence proper information must be released for the general public to educate them of the new features to further avoid misconception. The confusion about the coins likely stems from the early release of the five-peso coin, as it bears a strikingly similar diameter with the current one-peso coin. The public has to keep in mind that the New Generation Coins were designed to circulate exclusively. As a set, they work to complement each other such that, even in a pool of coins, one person would be able to easily differentiate one coin from another based on their face or the markings on the sides. However, monetary replacement takes time, and coexistence with the present set is inevitable. Until such time that the market has completely converted, extra caution must be exercised.

According to Lopez, (2019) [8] Consumers who are still confused with the all-silver coins released by the Bangko Sentral ng Pilipinas (BSP) will soon have a respite, with a distinct look for the five-peso denomination being planned. In a statement, the central bank announced that it will be releasing an "enhanced" version of the 5-peso coin, which will make it more distinct from other denominations. The changes were based on studies on the design, security features, and specifications of the new coins. The new nickel-plated steel coins are said to be more durable than the 1995 design but are relatively smaller and lighter. Many Filipinos have complained about getting confused between the 1-peso and 5-peso coins. This forced the BSP to issue guidelines on how to set them apart by feeling the ridges of the one-peso and the smooth edges of the five-peso coin.

Martin (2018) [11] clamored for the series of newly issued peso coins should be withdrawn because are causing confusion among the public. The BSP claims that the design of the coins was the result of more than two years of design study. Rep. Nograles said that the new coinage could even have a negative economic impact on the economy. Aside from the unintended overpayments and underpayments, the vending machine industry would be hit hard. The dispensers in public restrooms will have to be redesigned and replaced as their coin slots are rendered obsolete. Vending machines in office buildings and school campuses will need hardware and software upgrades. Even coin organizers of cashiers in toll booths, ticket outlets and banks, among others, would be useless. The primary consideration of the BSP was to produce cheaper and stronger coins however, the new generation coins can at least match the weight, diameter and thickness of the widely circulated coins, so people will not be confused, and machines will no longer be replaced. The BSP has appealed to the public to give the new coins a chance.

Bar-Hillel and Wagenaar, (2001) [3] Psychologists have studied people's intuitive notions of randomness by two kinds of tasks: judgment tasks (e.g., "is this series like a coin?" or "which of these series is most like a coin?"), and production tasks (e.g., "produce a series like a coin"). People's notion of randomness is biased in that they see clumps or streaks in truly random series and expect more alternation, or shorter runs, than are there. Similarly, they produce series with higher than expected alternation rates. Production tasks are subject to other biases as well, resulting from various functional limitations. The subjectively ideal random sequence obeys "local representativeness"; namely, in short segments of it, it represents both the relative frequencies (e.g., for a coin, 50%-50%) and the irregularity (avoidance of runs and other patterns). The extent to which this bias is a handicap in the real world is addressed.

Haslbeck and Zimmermann (2015) [7] Eyes can provide insight into cognitive processes (attention, mental and visual workload,

effort, drowsiness), Eye movements are driven by properties of the visual world and processes on a person‘s mind, Eye movements require visual attention, Attention and eye movements usually go together (eye-mind-hypothesis). Eye-Tracking is the observation / record of a person‘s eye movements / visual behavior mainly consisting of fixations (points to look at) and saccades (fast eye movements). Eye-Tracker are technical systems to record and analyze these eye movements.

3. METHODOLOGY

3.1 Research Locale

The research is conducted in areas situated at the center of Manila namely; Quiapo, San Miguel, Sampaloc, Ermita, Intramuros and Sta.Mesa as shown on Figure 1. The research locale encompasses the Manila City Hall, Quiapo Church, University Belt, tourist spots and one of the biggest districts of Manila where the use and exchange of New Generation Currency coins is prominent. The said location is ideal for experimental surveys because pedestrians found in these areas probably came from different parts of Manila, and not from the mentioned places alone, and are indeed the general public.

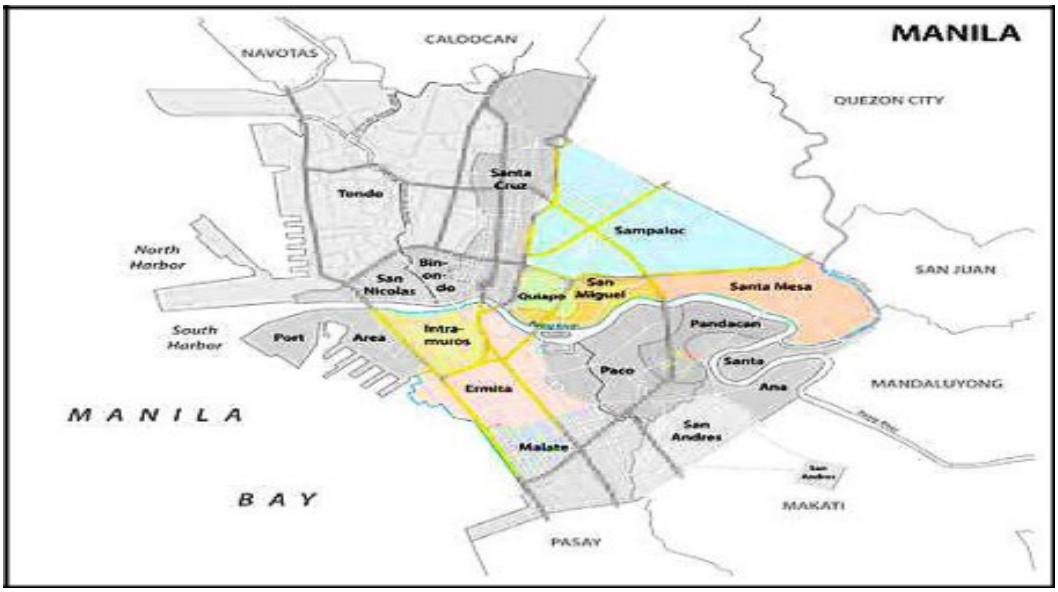

Figure 1. Map of the Research Locale

3.2 Sample Size and Sampling Method

For the purpose of this study, the researchers had to examine the New Generation Currency coins recognition time of participants from four (4) age brackets to further explore if generation gap affects recognition time. To be able to construct a reliable conclusion and recommendation, the researchers must have a suitable number of samples.

A process of Stratified Sampling method was used to know the suitable number of participants. This method is chosen because it can provide greater precision than a simple random sampling of the same size. Hence, often requires a smaller sample, which saves time and effort. Stratified Sampling can also help the researchers in obtaining enough sample points to support a separate analysis of any sub-group.

Table 1. Distribution of Respondents per Age Group (in seconds)

Age Group	Range	Sample Size
Centennials	19 and below	20
Millennials	20-37	20
Generation X	38-55	20
Baby Boomers	56 and above	20

Since Stratified Sampling offers precision despite a small sample size, the researchers decided to have eighty (80) participants, in total, for the four (4) age groups. It is also decided to have equal number of participants for each age group, which is twenty (20), to ensure an equal representation of the variables for the study. To determine the sample size to be used for the time study, the conventional method was implemented using the cycle time and the frequency of the activity as a basis (Freivalds and Niebel, 2013) [4] . Since the activity would take less than a minute to perform and the activity would take less than 10,000 per year, at least 60 samples are needed for the time study. To have an equal number of samples per age group, 20 samples were taken for each category.

IF CYCLE TIME, min (h)	AND ACTIVITY IS LESS THAN 1,000/yr	1,000 to 5,000/yr	5,000 to 10,000/yr	Over 10,000/yr
<1 (.017)	40	45	50	60
1 to 2 (.017 to .033)	25	30	35	40
2 to 5 (.033 to .083)	18	20	22	25
5 to 10 (.083 to .167)	15	16	18	20
10 to 20 (.167 to .333)	9	10	11	12
20 to 40 (.333 to .667)	7	8	9	10
40 to 60 (.667 to 1.0)	5	6	7	8
>60 (1.0)	3	4	5	6

Figure 2. Minimum number of cycles to study

3.3 Data Collection Technique and Tools

For the purpose of this study, experimental surveys and interviews were used. As far as data collection tools were concerned, the conduction of the research involved handing six (6) New Generation Currency coins, one for each denomination, to the participants who are asked to identify the value of each coin. A

stopwatch application of a mobile phone was then used to determine the total recognition time of each participants from the moment the coins are handed to them up to the second they identify all the coins correctly. While doing the task, the researchers observed the senses that the participants were using. A quick interview about coins was also done right after the experimental survey. The experimental surveys were completed within three (3) weeks.

3.4 Analysis Tools

After the experimental surveys, the researchers prepared the gathered data and checked if it's complete with eighty (80) entries. The dataset was then analyzed using statistical and figurative tools. Pareto Chart was used to describe the demographics of respondents. Ishikawa Diagram identified the causes of confusion of the respondents on distinguishing the value of the currency. The hypothesis on this study is there is a difference between the time to distinguish the value of the NGC coins between the age groups. Analysis of Variance, Tukey's Comparison of Means and Descriptive Statistics were used to distinguish the which of the age groups differ from each in terms of the standard time in distinguishing the coins.

4. RESULTS AND DATA ANALYSIS

4.1 Demographics

According to the researchers' survey from eighty (80) respondents, most of them are employed, unemployed and college students while some of them are already retired, high school students and elementary students. But majority of these respondents are employed individuals.

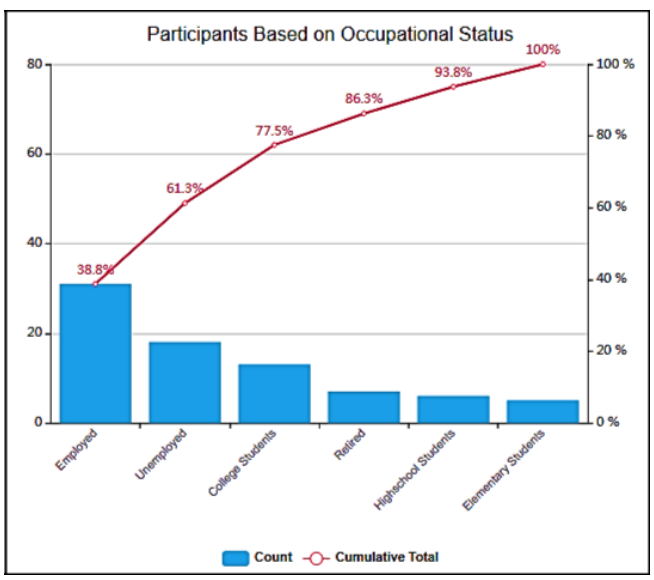

Figure 3. Pareto Chart of the respondents based on occupational status

The researchers used Ishikawa Diagram (Cause-and-Effect Diagram) to identify and visualize the relationships between the coin confusion and its potential causes. From these findings, the researchers can prioritize the problem areas and develop improvement ideas and recommendations.

The researchers identified various causes of coin confusion, which is the effect, or the dependent variable. The main branches such as coin, people, and surroundings are the major factors that might contribute to the effect. These major factors are also caused by sub-factors such as design, color and size for the coin, eyesight of the respondent, familiarity with the coin and cognition for the people, and illumination of the coins and distraction from the environment the surroundings.

It is observed that when it comes to the coin itself, coin confusion can be a result of similarity of its design, its identical color, and similarity of its sizes. In terms of people, coin confusion can be caused by a poor eyesight, unfamiliarity with the new design and weak cognition. In terms of surrounding, coin confusion can be a result of poor illumination, distractions like bumping of people, and transportation such as riding a moving vehicle.

4.2 Time Study

Time Study is a tried and tested method of work measurement for setting basic times and hence standard times for carrying out specified work. The aim of this study is to establish a time for a qualified worker to perform specified work under stated conditions and at a defined rate of working. The calculation of standard time is illustrated in Equation 1 to 3.

$$\text{Normal Time} = \text{Observed} \times (\text{Rating } \%)/100 \quad (1)$$

$$\text{Allowance Time} = \text{Normal Time} \times (\%\text{Allowance})/100 \quad (2)$$

$$\text{Standard Time} = \text{Normal Time} + \text{Allowance Time} \quad (3)$$

In this research paper, the researchers used Time Study in a slightly different manner. Such method is done because the researchers did an experimental survey wherein all the collected data are considered as true values hence, ratings are all one-hundred percent (100%) and allowance is always zero (0), thus the average observed time is used as comparison of processing time between age groups. In this case, Time Study is used to establish a standard time for an individual to recognize the New Generation Currency coins.

According to Table 2, in terms of standard time, it is evident that the fastest age group to recognize the New Generation Currency coins is the Millennials followed by the Generation X and Centennials, and the slowest age group is the Baby Boomers.

Table 2. Calculation of Standard Time per Age Group

Age Group	Centennials	Millennials	Generation X	Baby Boomers	Pooled Total
Average Observed Time	8.5975	7.5890	8.1295	10.7065	8.7556
Sample Variance	10.7643	4.9812	8.5108	8.5887	9.3131
Sample Standard Deviation	3.2809	2.2319	2.9173	2.9306	3.0517

4.3 Hypothesis Testing Using ANOVA

In order to test for the equality of means and to assess the differences between pairs of means, the researchers used one-way ANOVA with multiple comparisons.

Null Hypothesis (H_0): There is no significant difference in the speed of reaction time between age groups.

Research Hypothesis (H_1): There is a significant difference in the speed of reaction time between age groups.

Table 3. Analysis of Variance between Age Groups

Source	Sum of Square (SS)	Deg. of Freedom (v)	Mean Square (MS)	F-Value	P-Value
Age Group	111.6793	3	37.2264	4.5336	0.0056
Error	624.0563	76	8.2113		
Total	735.7356	79			

The p-value for the coin recognition time of the one-way ANOVA above is lower than the significance level of α=0.05, suggesting that one or more age groups are significantly different. Thus, rejecting the null hypothesis (H0).

The researchers already knew that some of the age group means are different, but not which specific pairs of groups. The Tukey HSD (Honestly Significant Difference) test is one of the post-hoc tests that would likely identify which of the pairs of age groups are significantly different from each other. As seen in the Table 4, the p-value of Millennials-Baby Boomers that is 0.0051 and of Generation X-Baby Boomers which is 0.0286 were both lower than the significance levels of α=0.05, α=0.01, suggesting that these two pairs of age groups are the significantly different from each other .In addition, the range of confidence interval for the difference between the means of Millennials-Baby Boomers and Generation X and Baby Boomers do not include zero, which indicates that the difference between these means is significant. While the confidence intervals for the remaining pairs of means all include zero, which indicates that the differences are not significant.

Table 4. Tukey Simultaneous Tests for Differences of Means for Multiple Comparison of Age Groups

Difference of Levels	Difference of Means	95% CI	P-Value
Centennials-Millennials	-1.0085	-3.3888 to 1.3718	0.6827
Centennials-Generation X	-0.4680	-2.8483 to 1.9123	0.9549
Centennials-Baby Boomers	2.1090	-0.2713 to 4.4893	0.1008
Millennials-Generation X	-0.5405	-2.9208 to 1.8398	0.9328
Millennials-Baby Boomers	3.1175	0.7372 to 5.4978	0.0051
Generation X-Baby Boomers	2.5770	0.1967 to 4.9573	0.0286

5. SUMMARY AND CONCLUSION

The researchers, after conducting the experimental survey and analyzing the data gathered, found that people rely on their visual sense more than on their other senses when recognizing the Philippine coins. Time Study helped the researchers to compute for the standard time in distinguishing the New Generation Currency (NGC) coins, which is 7.5890 seconds and with this as a basis, it is then found that the Millennials recognized the coins the fastest and Baby Boomers the slowest. ANOVA showed that there is a significant difference of means between the Baby Boomers and Millennials, and between Baby Boomers and Generation X.

In the tests and examinations done, the researchers found out that Baby Boomers make smart decisions and do not part with their money easily and this may be the reason why they are the slowest in terms of distinguishing coins. They tend to over-investigate the coins just to make sure that they're right. While Centennials are described as less-focused with short attention spans and maybe, this is the reason why they are also slow in distinguishing the coins. Because they can't focus in inspecting the coins hence, having a hard time recognizing them. On the other hand, Millennials are said to be serial multi-taskers and are comfortable in doing several things at the same time. No wonder that they are the fastest to distinguish the coins, they might have been inspecting all the six (6) at the same time. Lastly, Generation X were known in adapting well to change, this might be the reason why they easily distinguish the coins, next to Millennials, because they were already comfortable with the new design of the coins.

The researchers came up with the recommendation to cater the needs of the people but at the same time, minimizing the cost of production. Since the respondents mostly rely on their sense of vision across all generations, the researchers thought of focusing on the quality of the coin that is seen, such as size, shape, and color. Focusing on the easily distinguishable features can help the users to properly identify the Philippine currency coins. The color and composition of the coins were maintained, as it is the cheaper to produce.

As a conclusion, though several people are confused by the newly release design coins by its texture, shape, and color, it is not necessary to change the current design of the Philippine coin since people reacted fair enough to it. By giving some more years to adapt from the new generation coin, people would definitely know the difference between the coins. Finally, the researchers conclude that generation gap influences in distinguishing the Philippine currency coin.

The current research can be treated as a preliminary study given that there is a number of respondents on a specific area. Further studies can be pursued such as classification based on gender to generalize the behavior of generations in distinguishing the Philippine currency coins.

6. ACKNOWLEDGMENTS

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A Model of Consumer Perception and Behavioral Intention for AI Service

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ABSTRACT
The success of AlphaGo makes artificial intelligence once again widely reported and concerned. At present, artificial intelligence has gone from speech recognition to natural language processing to smart voice assistants, from graphic recognition to machine vision to smart supermarkets. The application of artificial intelligence has made significant progress in many fields, and smart speakers with natural language processing as the core technology are currently attracting attention. AI application services based on natural language technology include mobile phone voice assistants, smart speakers, and humanoid robots. Although these different types of AI application services are given the important task of human-machine communication and service interface in the future AI society, the common point is that these smart speakers have the service function of dissemination. The application of AI is an important issue for the development of various types of industries in the next few years. Unfortunately, there is a lack of research in this area in the previous literature. We also build some propose management of AI service implications for physical bookstores management based on the results of model analysis.

CCS Concepts
• **Human-centered computing→ Human computer interaction**

Keywords
AI customer service; smart speaker; planned behavioral theories; technology acceptance models

1. INTRODUCTION
In the past, the popularity of mobile commerce and the advancement of information technology have made major changes in human lifestyles. The rise of the accompanying Internet has brought about big data and cloud computing let artificial intelligence has a succeeded basis. The development of artificial intelligence has gone from speech recognition to natural language processing to smart voice assistants, from graphic recognition to machine vision to unmanned smart supermarkets. AI technology has achieved quite successful progress in various fields. When the application of AI gradually penetrates into our lives, artificial intelligence technology will inevitably lead to another wave of new lifestyles, trading concepts, and consumption habits, and also provide new types of media needed under a brand new technology operation structure (Zhang, 2019). State propagation mode and information acquisition (such as asking the smart speaker for weather and playing news information) and ways to use information services (such as the use of smart speakers to play songs or e-books). Therefore, the application of smart speakers will be an important platform that cannot be ignored.

Chatbots or AI customer service is an application service with natural language processing as the core technology, and smart speakers are common products of this type of AI customer service. Generally speaking, smart speakers or chatbots are software that constructs dialogues through methods such as speech recognition and text analysis and simulates human dialogue behaviors through such software. Although AI customer service still cannot pass the Turing test in 2019, Chatbots have begun experimental applications in many areas of the service industry. At present, AI customer service can analyze the obtained text data through the natural language processing system and then retrieve the most matching keywords or the most similar wording patterns from the database to respond so that the user-machine communication interface can imitate the type of communication with real people.

The smart speaker expands the new concept of human-machine communication, making the process of human interaction with the machine more humane (Kambhampati, 2018; Abid *et al*., 2014). However, the emergence of smart speakers has gradually given birth to multiple forms of human-machine cooperation and has allowed the application of AI technology in various service industries to produce multiple possible looks. If we can discuss the intent to influence the use of such AI services, it will help us to clarify which factors are important influencing factors when constructing AI application services (Thiebaut, 2019; Rodríguez *et al*., 2015).

With smart speakers, not only can the service processes of existing industries be optimized, but also the diverse applications of industries in various fields can be further increased through natural language processing technology. This study uses the service of smart speakers in a physical bookstore as an analysis scenario, constructs a theoretical model through the technology acceptance model and planned behavior theory, and explores the factors that

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influence consumers' use of smart speakers and the structural relationship.

2. SMART SPEAKER

Smart speakers based on natural language processing technology are now important products for artificial intelligence-related applications, such as Google's assistant and Amazon's echo. These smart speakers expand the new concept of human-machine communication and make the process of human-machine interaction more humane. Chain stores (such as convenience stores and bookstores) are the manufacturers that most need customer service personnel. However, in recent years, Taiwan has faced the impact of declining birthrates, causing a shortage of manpower in many companies. In order to cope with the service manpower gap caused by the declining birthrate, many companies have begun to think about using AI customer service, hoping that AI customer service can make the human service planning of customer service more flexible and efficient.

At present, many important AI companies have smart speaker products and services, such as Google's Home, Amazon's Echo and the open Alexa platform, and Apple's HomePod. Tmall Genie, which belongs to Alibaba Group, is one of the most important smart speaker products in China. Tmall Genie is based on the AI business integrated service provided by the AliGenie platform. This product was officially launched on August 8, 2017. Currently, it already has functions in areas such as entertainment, life, and shopping. The most commonly used functions include Taobao shopping, storytelling, listening to music, setting alarms, and so on.

AI products of natural language processing technology generally include five main functions: speech recognition, natural language understanding, dialogue management, natural language generation, and speech conversion. The execution steps of these different functions are: (1) speech recognition is used to receive users Voice input and convert it into text form, (2) the natural language understanding module processes and understands the semantics of user input, (3) enters specific semantics into the dialog management module, and the dialog management module evaluates the current Conversation status, and select a specific reply method and hand it over to the natural language generation module for processing. (4) Generate the required reply text, and then send it to the speech synthesis module to convert the text into speech and output it to the user. Generally speaking, the technical core of smart speakers includes the following three parts (Rodríguez, 2015):

- Collect the questions accumulated by the customer service, build a highly scalable corpus, and summarize the question and answer knowledge that can be applied in the future based on the corpus.
- The forms of questions asked by users are usually non-standard. There are many ways to ask the same question. Therefore, it is necessary to unify various forms of questions so that the algorithm can use the semantic database to find the best answer.
- Quickly and efficiently retrieve correct answers in a large corpus.

The three parts mentioned above not only involve machine learning, natural language processing, search technology, etc., but also require many basic constructions, such as the construction of a corpus and a semantic knowledge base. Therefore, the size and quality of the knowledge base often determine the intelligence level of the customer service robot.

3. METHOD

In psychology, the Theory of planned behavior (TPB) is a theory that associates an individual's beliefs and behaviors. The theory states that attitudes to behaviors, subjective norms, and perceived behavioral control collectively shape an individual's behavioral intentions and behaviors (Ajzen, 1991). The planned behavior theory is an extended theory based on the Theory of Reasoned Action (TRA). The planned behavior theory is to improve the prediction of inferential action theory by including perceived behavior control, and have been used to study the relationships between beliefs, attitudes, behavioral intentions and behaviors in these areas including advertising, public relations, advertising campaigns, healthcare, sports management and sustainability.

The Technology Acceptance Model (TAM) is one of the most influential extended models based on Ajzen's Rational Action Theory (TRA). The purpose of this model is to explain the user's acceptance of new technology products or services, and analyze what factors that influence users 'acceptance of new technologies or services (Adams, 1992). For new technology products or services, the technology acceptance model provides a theoretical basis for researchers to understand the impact of external factors on users' internal beliefs, attitudes, and intentions, and then affect the use of new technology. Models can be applied universally to explain or predict the influencing factors of information technology use.

Behavior intention is one of the important issues for marketing practitioners because of the rapid business environment (Kidwell, & Jewell, 2008). To improve our understanding of users' decision-making process, the study based on the literatures review (Hsu & Lin, 2008) build the research model as Fig.1. This research explores consumer behavior when facing the physical bookstore's use of AI speakers with smart speakers. The structure of the research model refers to the technology acceptance model proposed by scholars such as Davis et al. (1989) and the planned behavior theory proposed by scholar Fishbein This study combines these two theories to construct a theoretical framework. The connotation of this research model includes aspects such as ease of use, usefulness, attitude, subjective norms, and perceived behavior control. This model is used to analyze consumer use of physical bookstore AI customer service. Behavior.

The hypothesis and measurement model are formulated for the exogenous variable and the endogenous variables as shown in Fig. 1 to explain the relationships among Perceived usefulness (PU), Perceive ease of use (PEU), Attitude (AT), Subjective Norm (SN), Perceived Behavioral Control (PBC) and Behavior intention (BI). The facets of the research model are explained as follows:

- Attitude (AT): Consumers 'preferences for the AI customer service provided by smart bookstores in smart book stores. When consumers' attitude toward the AI service is more positive, their behavior in using AI customer service will also be higher.
- Subjective norm (SN): refers to the social pressure that consumers feel about using the AI customer service provided by smart bookstores in physical bookstores, such as the pressure of parents, spouses, friends, colleagues, etc., whether to use the service. The stronger the positive subjective norms, the easier it is to generate an intention to engage in that behavior.
- Perceived behavioral control (PBC): Refers to the ability of consumers to control the required resources, such as time,

money, ability, etc., when they use the AI customer service provided by smart speakers provided by physical bookstores. Therefore, even if individuals want to use the services of smart speakers, they may not be able to actually engage in this behavior because they lack the ability to control resources.

- Behavior intention (BI): Refers to the consumer's behavioral tendency and degree of using the AI speaker provided by the physical bookstore, that is, the psychological intensity of whether an individual has acted in the decision process of the behavior choice.
- Perceived usefulness (PU): It means that the user believes that using the AI speaker provided by the physical bookstore will increase the satisfaction of the bookstore and increase the efficiency or fun of book purchases. When the user recognizes that the AI customer service of the smart speaker is easy to use, it will increase the positive attitude of the user to use the AI customer service of the smart speaker.
- Perceived ease of use (PEU): refers to the user's awareness of the ease of use of the AI customer service provided by the smart bookstore in the physical bookstore. When the system is easier to use, users will have more confidence in self-efficacy and self-control and the attitude will also be more positive.

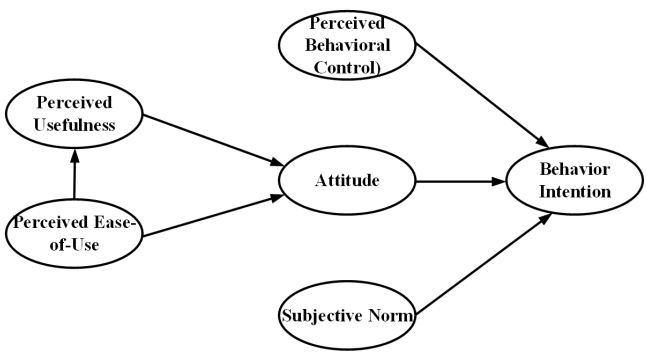

Figure 1. Research model.

4. DATA AND ANALYSIS

4.1 Data Collection and Sample Description

The design of the survey questionnaire is based on multiple-item measurement scales. Data was collected via e-mail invitations, web-based questionnaires, and paper questionnaires within the period of January to February 2020. For the final survey, a total of 237 questionnaires were collected.

There are more than 58% of the respondents are female. More than 71% of the respondents are 21-40 years old while less than 6% of the respondents are over 51 years old. Most respondents (65%) are single, and more than half of the respondents are students or employees of a company. Furthermore, more than 41% of the respondents live in northern Taiwan. The frequency of bookstore shopping (including online bookstore and physical bookstore) is 1 times per quarter (31.1%), followed by 2-3 times (21.9%).

In the experience of using AI customer service, the total number of samples that have been used or will be used in the future is 57.1%. The most important two factors in the use of AI customer service are “saving waiting time” and “hopefully effective to solve the problem”, the proportions are 61.1% and 22.7% respectively. The results of the chi-square analysis showed that the p-value of “gender” vs. “smart speaker styling” was 0.001, which reached a statistically significant level of less than 0.05. The results showed that female preferred cartoon styles more than male.

4.2 Confirmatory Factor Analysis

Because of the proposed measurement model was consistent with the data, the hypothesis were tested with LISREL, using the covariance matrix. Factor analysis is an interdependence technique whose primary purpose is to define the underlying structure among the variables in the analysis. For the purposes of this research, the following six major constructs are defined and Table 1 shows each construct and their measurement item.

Table 1. Each construct and measurement item

Constructs	Index	Measurement Items
Behavior Intention	BI_1	I will to use AI customer service system
	BI_2	I will to recommend others to use AI customer service
	BI_3	I will to continue to use AI customer service
Perceived Ease-of-Use	PEU_1	Learning the AI customer service using smart speaker modeling is simple for me.
	PEU_2	I think the operation of AI customer service in the form of smart speakers is generally easy to understand.
	PEU_3	I don't think need to spend a lot of time to learn how to use the AI customer service of smart speaker modeling.
Perceived Usefulness	PU_1	AI customer service using smart speakers in a physical bookstore will help me find books.
	PU_2	AI customer service using smart speakers in a physical bookstore will help me evaluate a book
	PU_3	AI customer service using smart speakers in the physical bookstore will help me find books in related fields.
Attitude	AT_1	I have a positive view of AI customer service using smart speaker modeling in physical bookstores.
	AT_2	I think it's interesting to use smart speaker’s AI services in physical bookstores.
	AT_3	I think it is an inevitable trend for physical bookstores to provide AI services based on smart speakers.
Perceptual Behavior Control	PBC_1	AI customer service using smart speaker modeling in a physical bookstore, I will feel embarrassed because the smart speaker response may be too loud or I need to speak louder.
	PBC_2	I think that the services provided by physical bookstores should be based on real people, and AI customer service is more impractical.
	PBC_3	I don't think the AI customer service provided by the smart speakers in the physical bookstore may actually help me solve the problem.
Subjective Norms	SN_1	I will try to use the AI customer service of smart speakers in a physical

		bookstore because of recommendations from friends
	SN_2	I will try to use the AI speaker of the smart speaker in the physical bookstore because of the recommendation of the spokesperson of the physical bookstore.
	SN_3	I will try to use the AI speaker of smart speakers in the physical bookstore due to the promotion of the government.

By using LISREL, the simultaneous estimation of: (1) a measurement model can be obtained that items in each scale to the construct represented, giving factor loadings for each item; (2) a structural model that related constructs to one another, providing parameter value. The LISREL model represents a series of hypothesis, and how the variables are related (Xiao *et al*, 2015). We introduce factor analysis as our first multivariate technique because it can play a unique role in the application of other multivariate techniques. In this study, the reliability and validity of the research constructs was also tested. Reliability refers to the consistency of a measure, whereas internal consistency is that the individual items of a scale should be measuring the same construct and be highly interrelated.

The most common ways of testing internal consistency are computing Cronbach's alpha. When the reliability coefficient alpha value is above 0.7, the items demonstrate high internal consistency and hence reliability of each dimension. Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. The validity of the variables was explored by confirmatory factor analysis (CFA). According to CFA, if the standardized factor loading and t-value are greater than 0.5 and significant at the 0.01 level, the convergent validity can be assessed (Xiao, *et al*., 2014).

Table 2 demonstrates all relevant estimates for the six constructs, the analysis results indicated that all of the standardized factor loadings range from 0.61 to 0.92 and is greater than the 0.50 guideline; values of average variance extracted exceed the commonly used criterion of 0.50; and Cronbach`s α is above 0.70. The above tests indicated that the discriminate validity was upheld for the measurement model. Overall, the confirmatory factor model adequately reflected a good fit to the data.

Table 2. Convergent validity for each construct

Constructs	Index	Factor loading	Cronbach`s α	Average Variance Extracted
Behavior Intention	BI_1	0.84	0.932	0.927
	BI_2	0.92		
	BI_3	0.90		
Perceived Ease-of-Use	PEU_1	0.83	0.881	0.881
	PEU_2	0.81		
	PEU_3	0.79		
Perceived Usefulness	PU_1	0.89	0.835	0.846
	PU_2	0.89		
	PU_3	0.87		
Attitude	AT_1	0.82	0.921	0.935
	AT_2	0.88		
	AT_3	0.85		
Perceptual Behavior Control	PBC_1	0.61	0.711	0.657
	PBC_2	0.70		
	PBC_3	0.66		
Subjective Norms	SN_1	0.78	0.849	0.733
	SN_2	0.81		
	SN_3	0.66		

4.3 Structural Equation Modeling

The purpose of this study is to examine the relationships among the perceived variables of the behavior intention of smart speaker's AI service. Structural equation modeling (SEM) was performed using Lisrel 8.54 to estimate the hypothesized relationship. By using LISREL, the simultaneous estimation of: (1) a measurement model can be obtained that items in each scale to the construct represented, giving factor loadings for each item; (2) a structural model that related constructs to one another, providing parameter value. The LISREL model represents a series of hypothesis, and how the variables are related.

Figure 2 and Tab. 3 shows the standardized path coefficients for our research model. All of our hypothesized associations were significant at p=0.01. In general, NFI, NNFI, CFI and GFI almost greater than 0.9 are indicative of good model fit; the SRMR value of 0.05, PGFI value of 0.52 and most other value surpass the recommended level. The results of structural equation modeling obtained for the proposed conceptual model revealed a good model fit.

Table 3. Each construct and their measurement item

Goodness-of-Fit Index	Value
Non-Normed Fit Index (NNFI)	0.88
Comparative Fit Index (CFI)	0.89
Incremental Fit Index (IFI)	0.90
Standardized RMR	0.05
Goodness of Fit Index (GFI)	0.91
Parsimony Goodness of Fit Index (PGFI)	0.52

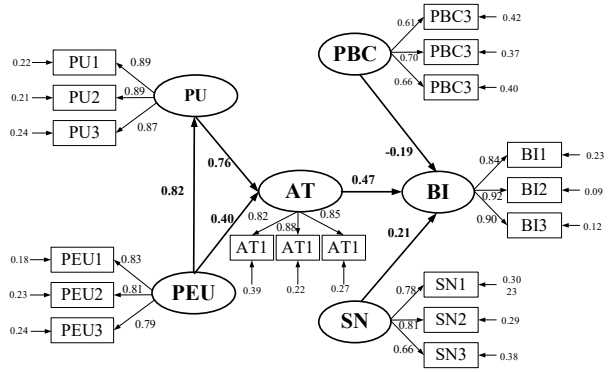

Figure 2. Results of Structural Model (male)

The goodness-of-fit test in SEM can be classified into three types. The first one is absolute fit measures, which assess the fit of the overall model without adjustment of the over-fitting degree. The goodness-of-fit index (GFI), and root mean square error of approximation (RMSEA) are used to indicate the absolute fit. The results are shown in Table 3 with suggested values listed. It shows that the absolute fit measures are acceptable in the case. The second type is the incremental fit measures, which compare the proposed model to a null model and indicate the improvement degrees. The non-normed fit index (NNFI), normed fit index (NFI), and comparative fit index (CFI) are used to indicate the incremental fit. The third type is the parsimonious fit measures, which indicate the over-fitting degrees in the model. Their main idea is to select the simplest model that achieves similar goodness of fit among others. The parsimonious goodness of fit index (PGFI) is used to indicate the parsimonious fit.

Our model describes how endogenous constructs depend upon the exogenous constructs and included that all hypotheses of the relationship between behavioral intentions and the antecedent factors are supported. Figure 2 also shows the standardized path coefficients for our research model. Results indicate that perceived ease of use (β = 0.82, $p < 0.05$) was a significant determinant of perceived usefulness. Perceived ease of use (β= 0.40, $p < 0.05$) and perceived usefulness (β= 0.76, $p < 0.05$) were significant determinants of attitude towards use, respectively. Perceptual behavior control (β= -0.19, $p < 0.05$), attitude towards use (β= 0.47, $p < 0.05$) and subjective norm use (β= 0.21, $p < 0.05$) were, in turn, significant antecedents behavioral intention of AI service.

4.4 Analysis and Discussion

According to the results of structural equation analysis, in addition to the direct correlation between variables, some variables also have indirect effects. We evaluated the direct and indirect effects subsumed in the proposed research model. Here are the paths of several indirect effects in this research model:

- Path A: The perceived usefulness of AI customer service will have an indirect effect on the behavioral intention of AI customer service through attitude construction
- Path B: The perceived ease of use of AI customer service will have an indirect impact on the behavioral intention of AI customer service through attitude construction
- Path C: The perceived ease of use of the AI customer service will first affect the perceived usefulness of the AI customer service, and then the attitude of the AI customer service will be indirectly affected through attitude construction

The three paths above illustrates the indirect effects of each variable on behavioral intent in the structural equation model. Perceptual ease of use and perceptual usefulness are two variables that have an indirect effect on consumers' behavioral intention to use AI customer service in physical bookstores. Taking path A as an example, the perceived usefulness of the AI customer service will have an indirect effect on the behavioral intention of the AI customer service through attitude construction. The path is as follows: perceived usefulness → attitude → behavioral intention. The calculation formula for the weight value that affects the above path is the weight of "perceptual usefulness → attitude" multiplied by "attitude → behavioral intention", that is, 0.76 * 0.47 = 0.36.

Perceptual ease-of-use affects behavioral intentions through two different paths, namely path B and path C. According to the data in Fig. 2, we know that the perceived ease-of-use have an indirect impact on the behavioral intention through by attitude, the standardized indirect effects of weight is 0.19 (0.40 * 0.47). Path C is another type of perceived ease-of-use that indirectly affects behavioral intentions: perceived ease-of-use → perceived value → attitude → behavior intention, the standardized indirect effects of weight is 0.29 (0.82*0.76*0.47). The total effect of perceived ease-of-use that affect behavior intention is the impact coefficient of path B plus path C, the total standardized indirect effects of weight is 0.48 (0.19 + 0.29).

Both perceived ease of use and perceived usefulness have positive indirect effects on behavioral intentions through attitudes. According to the analysis results, it is shown that the impact of perceived ease of use on behavioral intentions is greater than the effect of perceived usefulness on behavioral intentions.

5. CONCLUSION AND SUGGESTION

With the drastic changes in the external environment, companies will inevitably encounter new technologies and new competitors, and the impact of different external factors such as consumers. The past two decades have been the era of e-commerce development. From its inception, growth, innovation, and maturity, e-commerce has made online bookstores become the most important sales channel for book channels after two decades. And now in 2020, combined with online and offline O2O services, as well as smart speakers and AI customer service based on artificial intelligence technology, these technologies make the operation of physical bookstores need to rethink how to apply AI technology to provide innovation service.

If innovation management can be done in a changing environment, it will help companies make better use of resources to develop efficient operating strategies. The application of AI is an important issue for the development of e-commerce in the next few years. The scope of AI applications is quite extensive, including medical care, finance, education and manufacturing, and even entertainment, AI improving the productivity and value of the industry. In addition, AI can also integrate with manufacturing fields such as home appliances, mobile phones, and automobiles, and use the Internet's technology and equipment to interconnect and provide better services to improve our quality of life.

If this is the "Internet +" era, then the next prosperous era is the "AI +" era. The era of large-scale commercialization of artificial intelligence technology has arrived, and the development of AI has begun to affect the life and work of human society, and the development of AI is bound to make humans and machines must work together intimately, so "Symbiosis" will be a portrayal of future collaboration between consumers and AI, and corporate employees and AI.

With the development of AI technology and big data technologies, the service will become increasingly diverse. The application of AI will inevitably affect the way of life and work of human beings. In the process of artificial intelligence progress, the topic of human-machine communication and interaction using natural language processing technology will be an interesting and important research topic.

Unfortunately, there is a lack of research in this area in the previous literature. This study integrates the technology acceptance model and planned behavior theory to construct the theoretical model of this study, and explores the behavioral intentions that affect consumers' use of AI customer service in physical bookstores. The results of structural equation model analysis show that attitudes, subjective norms, and perceived behavior control have three

aspects that have a direct impact on behavioral intentions of AI service, and the biggest factor influencing consumers' behavioral intentions of using smart speakers in physical bookstores is attitude. In addition, perceptual ease of use and perceptual usefulness have positive and indirect effects on behavioral intentions through attitudes, and perceptual ease of use has a greater degree of influence on perceptual intentions than perceptual usefulness.

Internet technology has made online bookstores the most important book sales channel today, but combining two technologies such as O2O and AI will have the opportunity to make physical bookstores an important book sales channel in the future. Therefore, a deeper understanding of the research on the application of AI technology in physical bookstores will be an important subject in the field of book-related research. It is recommended that subsequent researchers further add different variables to increase the explanatory power of the model, such as factors such as perceived risk, perceived value, service quality, or transfer cost. In addition, applying other selection behavior models will also help us to clarify the different characteristics that affect consumers' choice of AI services in physical bookstores, such as logit model, catastrophe model, etc. (Arentze , 2014; Ram, *et al*., 2014; Xiao *et al*., 2014; Rodríguez *et al*., 2015). The exploration of "human-machine collaboration" using these models will help us understand the structure of the utility function of selecting AI customer service and the characteristics of discontinuous changes in selection behavior.

6. ACKNOWLEDGMENTS

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Ambuquick: Mobile-based Ambulance Sharing System

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ABSTRACT
Ambuquick is a mobile application for Android mobile phones which aims to provide fast emergency response using private ambulances. The platform will improve the traditional way of calling an ambulance through landline during emergency and non-emergency cases. Users and system requirements were identified through interviews with private ambulance owners, staff as well as customers/patients. The application also aims to provide the customers/ patients with at minimal cost of interfacility transfer. The business model as well as proposed business processes were presented to determine the components needed for the development of the application.

CCS Concept
Information systems→ Mobile information processing system

Keywords
Emergency Medical Service; Interfacility transfer; Private ambulance; Computer reservation system

1. INTRODUCTION
Each year, almost 7,000 Filipinos die or injured from all types of accidents every day [1]. Due to the high number of accidents and cases wherein patients need to be brought to hospitals, emergency medical responders are always in need especially in a country with dense population like the Philippines. The People who are in the mid of an accident usually encounter difficulty in contacting an available ambulance because each city in the country has a different emergency hotline and traditionally, they call different hospitals to look for an available ambulance [2]. There are two kinds of ambulance service provider in the country: public and private. Public ambulance service providers are in the barangay levels which follows the American standard EMS system thus private companies have their own protocols, since there is no standard EMS system, it depends on the company what EMS system will they use for their operation. Due to the lack of EMS law, the rule of one group is set against the protocol of another leading to a diversity of ideas. There are too many patients asking for medical service, but ambulance service providers are very limited in the country, others are also unknown to the community [3].

The data gathered by the researchers showed that there are cases when ambulances arrive late on the scene of the incident because they come from far location. Also, some ambulances are being personally used or used for other services and there is another case which they call 'load and go' where patients are poorly assessed, simply loaded in the ambulance and rushed to the hospital that can worsen the condition of the patient. With these data gathered, the researchers discover the need for a mobile application which provides a platform to help our fellow Filipinos who need immediate emergency and non-emergency response through ambulance transfer.

1.1 Objective of the Study
The study aims to develop a transportation network mobile application that connects users to available ambulances for emergency situations and transporting between hospitals.

2. REVIEW OF RELATED LITERATURE
A. EMS (Emergency Medical Service)

EMS is a three-letter acronym that stands for Emergency Medical Service, it is an intricate system and network of resources linked together for giving aid and transport to patients or victims of sudden illness before reaching the hospital. The EMS system did not start from the Philippines, but in the US or UK [4][5]. These countries found out that the survival rates increased, if something is done prior to bringing the patient to the hospital. The system serves as a bridge between the scene of the emergency and the hospital. The Emergency Medical Services is a coordinated system where its personnel provide aid to acute trauma victims before they are transported to a hospital [6]. The services they provide fill in the gap between the scene of emergency and the hospital – where the EMS vital role comes into play.

B. Interfacility transfer

Transferring of patients from one medical facility to another has become a national issue [7]. The patient transfers between facilities or between facilities and a specialty care resource have increased,

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but the number of ambulance respondents are low, expensive or either unknown to patients in need. Transport of care is provided to patients with an immediate life-threatening illness or injuries associated with single or multiple organ system failure. This level of care requires an expert level of provider knowledge and skills, a setting providing necessary equipment, and the ability to handle the added challenge of transport. These are central to any transfer, after initial assessment and stabilization, from and to a healthcare facility (National Highway Traffic Safety Administration. 2006).

C. Ambulance Dispatch

The model emergency dispatch system contains a dedicated central office for emergency response and operates a toll-free, 24- hour emergency hotline; an updated directory of the trauma centers, hospitals, satellite emergency response centers and other concerned non-profit/private institutions; stable government subsidy; and trained staff capable of phone triaging and pre-arrival instructions[2]. The existing communication system by which ambulances are dispatched needs to facilitate the process of saving lives. Every second of delay in an emergency can cause a big percentage in a patient's chance of survival. In the country we still mainly relied on radio communications following a numerous request answered by an operator via information often from a caller at the scene describing what had occur in the accident and saying the exact location. Newer Computer Aided Dis-patch systems have been reported in the literature however, various problems have been reported with these systems such as the inability of the dispatch system to be able to track the locations of ambulance units outside their station; making it impossible to determine the closest unit to dispatch in an emergency call [8].

D. Computer reservation system

A computer reservation system, or central reservation system, is a system used to store and save necessary information and conduct transactions related to air travel, hotels, car rental, or other activities. Originally designed and operated by airlines, CRSs were later extended for use by travel agencies. And now with the improvement of the internet and technology, it is also use for various kinds of services.

The proposed mobile based ambulance sharing system will provide more efficient emergency services, dispatching and interfacility transfer.

3. METHODOLOGY

3.1 Business Model

Key Partners

1. Private Ambulance Companies Registered by the DOH that will partner with Ambuquick.
2. Map & GPS API Providers for the necessary interface of the mobile application
3. Messaging API Providers for the messaging interface of the application
4. Investors who are willing to allocate capital and share stake and investment

Key Activities

1. Ambulance Company Acquisition to build up roster
2. Marketing seeks to bring more users into the app
3. Product Development through research, development, and maintenance of the application

Key Resource

1. Technology refers to the tools to develop and maintain the application

Value Propositions

1. Private Ambulance companies gain through the increase exposure and additional customers brought by the application
2. Regular Users will be provided with an ensured quality service of a licensed ambulance

Customer Relationship

The maintenance of good customer relationship is through feedback and reviews of the application, ratings systems for the ambulances, and an available customer support system

Channels

The touch points for Ambuquick to reach customer will be through the Google Play Store and social media channels

Customer Segments

1. Private Ambulance Companies
   Those that will subscribe annually to the Ambuquick that avail the service of the application. They will be included in the Ambuquick roster and have access to the application's features and functions.
2. Regular Users
   Users refer to our customers. They will be provided with the application's features and the ambulance roster.

Cost Structure

1. Technology Infrastructure
   Refers to the costs involved with the creation of the application, implementation of the application, maintenance of the application, and improvement of the application.
2. Marketing Expense
   This refers to all the expenses that will be put into the promotion of the proposed application.
3. Mobile Services
   Refers to the cost of utilizing the application.

Revenue Stream

Ambuquick will generate their income from Private ambulances through taking a .6% commission based on their base flat rate per request made through the system.

Business Roles

- Users- also known as the customers and as patients are the people who will make use of the application to request ambulances and report accidents.
- Private Ambulance Company- Private Ambulance companies are the partners of the Ambuquick, they make use of the application to respond the regular user's request.
- Administrator- Administrators will oversee the maintaining the application. They handle creating, updating, and deleting records within the app

3.2 Analysis of the Current Situation

Interviews to private ambulance service providers were made to determine the current emergency response processes. The caller calls the ambulance hotline, then connected to the nearest command center of the ambulance. The dispatcher is the one informing the user if there is an available ambulance, if ambulance is not available the user needs to call a different ambulance service provider. All incoming calls are filtered by the dispatcher. The dispatcher will assess if the patient is qualified for medical assistance, or if it is a prank call. The command center handles the dispatching process of the ambulances themselves. While the call is being handled, the

dispatcher will begin to provide the ambulance crew the needed information (location, person, age, sex, etc.) and dispatch them to the location as soon as possible. Once the ambulance crew arrives on the scene, they begin to assess the situation and people. They will report their findings to the command center once again, to be filed and recorded, and begin to request for hospital endorsements. Once an available hospital is found (preferably with the appropriate environment, equipment, and personnel to treat the patient) then the patient will be sent to that hospital. The patient will be billed (hospital fee and ambulance fee) depending whether the patient is conscious and able, if the patient is not, the billing will be referred to their next known kin. It was also found out that the cost of transferring a patient to a hospital has been very expensive which range from Php20,000 – Php50,000 (specifically by a hospital ambulance). Furthermore, patients who need this service usually have a hard time looking for available ambulance.

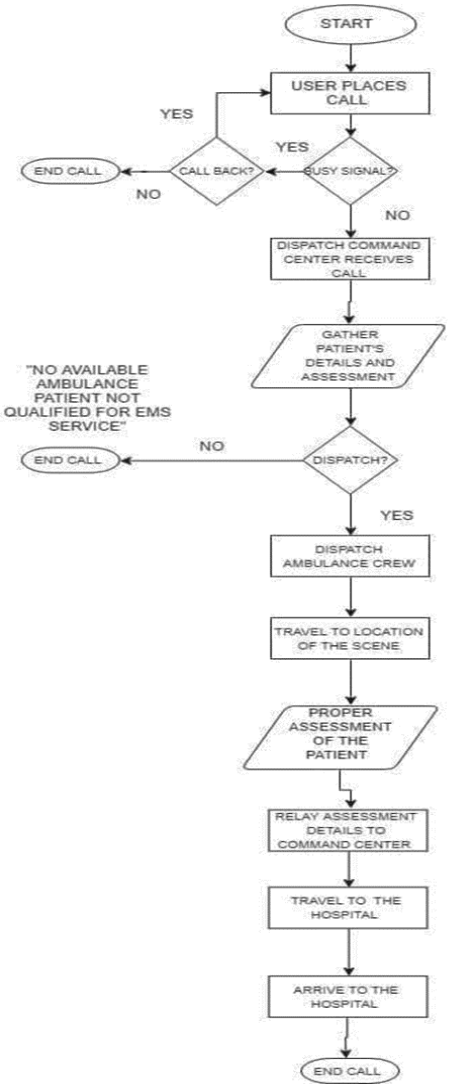

Figure 1. Flowchart of Independent Ambulance Services

3.3 Functional and Non-Functional Requirements of the proposed system

Ambuquick mobile application will create a user profile module that holds the user's basic information. The user profile will also be able to help ambulances distinguish users. The application will also allow users to contact the emergency hotline in a press of a button, then it will provide a map that would allow users to see available ambulance within their vicinity. Ambuquick holds the ambulance driver's basic information as well as the emergency response team with him.

Non-functional Requirements refer to how the system should work. Ambuquick mobile application must be accurate and user-friendly, the application should be accessed with no delays by both user and ambulance service provider. As long as both the users and the service providers have a stable internet connection it must give and show an accurate information.

3.4 Software Requirements

The tools to be used will be:

1. Google Maps API
2. Python 3 for the development of the System
3. Android OS and Android SDK as the system is an Android based application
4. Mongo Database for the database requirements with the added capability of being flexible
5. PyCharm was used for the IDE Quality Assurance is done through the development of a test strategy which includes: unit, integration, system, and user acceptance tests.

4. RESULTS AND DISCUSSION

4.1 Proposed Business Process and User Interfaces

Figure 1 displays the transactions of the users using the Ambuquick app which include registration and logging into the system, setting up of profile, emergency and non-emergency request and reporting as a witness. While Figure 3 displays the transactions of the ambulance which cover checking and monitoring of user account, receiving and accepting request and billing.

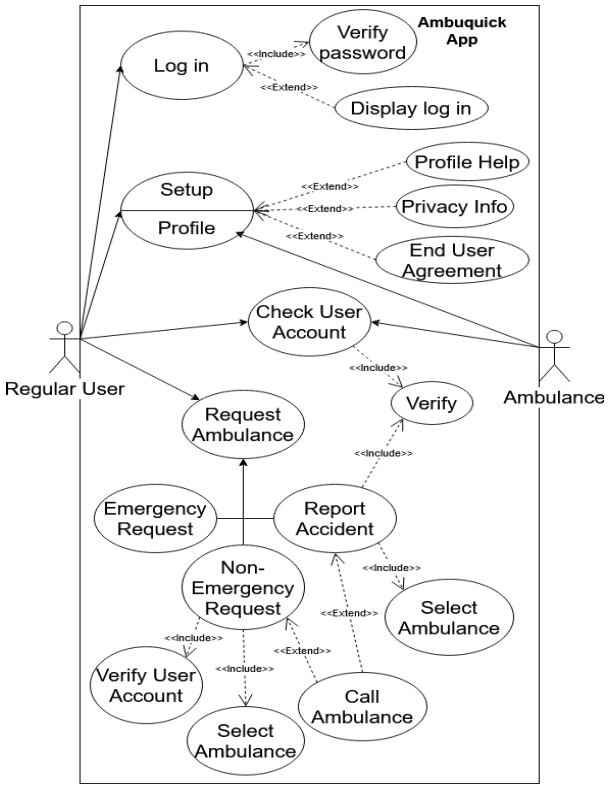

Figure 2. Use Case Diagram (Regular User Side)

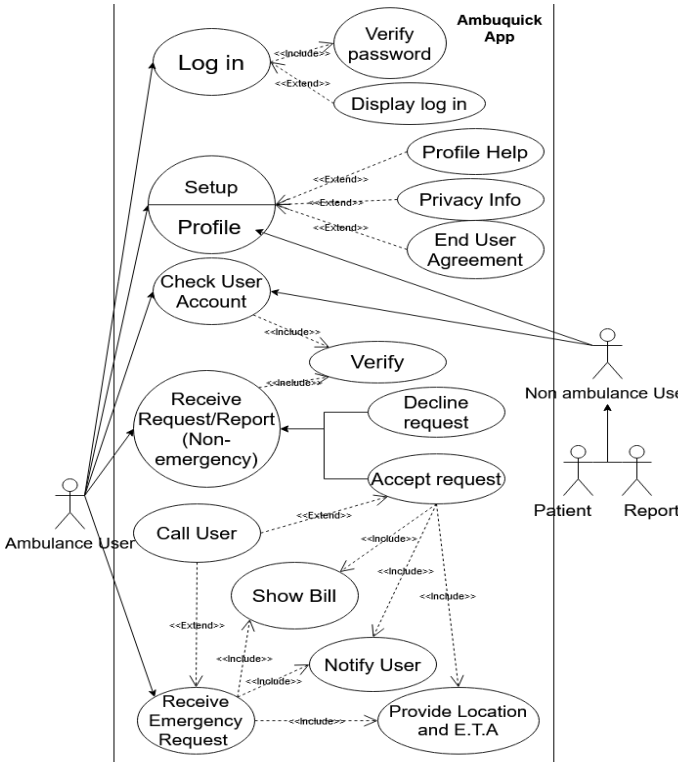

Figure 3. Use Case Diagram (Ambulance Side)

There are three major processes involved with our mobile app

4.2 Registration of Users and Ambulance Users for the application.

- Regular Users are to agree and accept the End User License Agreement (EULA) and to enter their details along with their password.
- Ambulance Users first must prove their legitimacy (as a business and as emergency medical services) by producing their D.O.H license. After being reviewed they will be allowed to input their details and their password and log into the system.

Figure 4. Log-in Screenshot

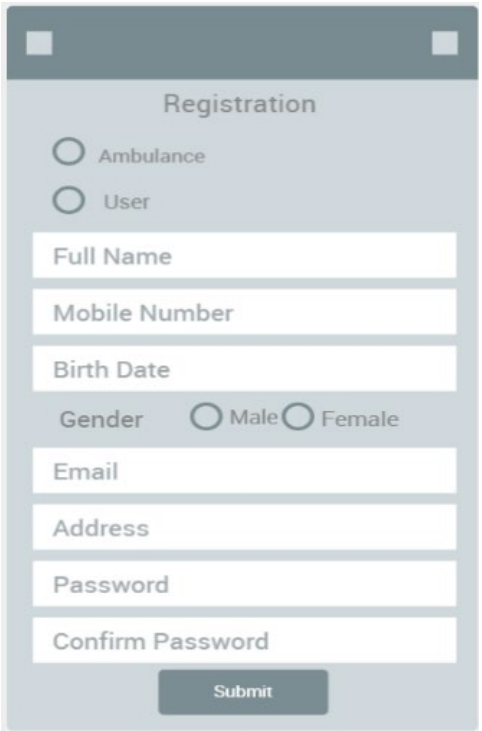

Figure 5. Registration Screenshot

Figures 4 and 5 displays the interface for registration and log-in respectively.

4.3 Emergency Service

Ambuquick Emergency Services is located at the homepage interface of the system. The system will provide a big red SOS button for emergency cases. Regular users would press the S.O.S button (aptly named) and immediately the system will notify the nearest ambulance available within the area. Refer to Figure 6.

- Regular user is prompted whether they are the ones in need or if they are reporting someone else.
- Nearest ambulance user receives notification/alert and are automatically given the user's location and details.
- System will give both the user and the ambulance user the estimated travel time and the route to be taken.
- Once a successful delivery has been done, the ambulance user may generate the total costs of their services along with additional charges (as needed by the user/patient during transport) and displays it for the user.
- The system takes note of everything during this process and saves/stores the data as a case for the user.

Report as a witness- This feature can be used by witnesses to report an emergency case. The witness will pin the location of the emergency scene and the system will also prompt the ambulance service provider. Refer to Figure 7.

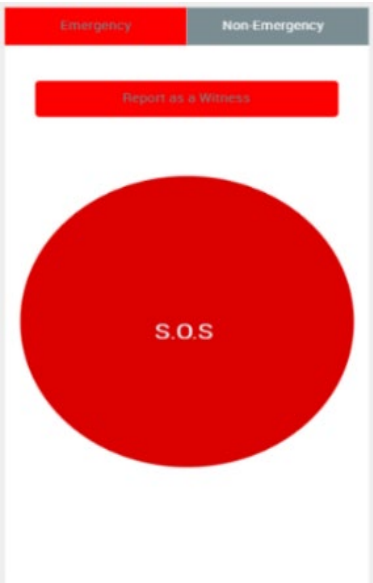

Figure 6- SOS Button

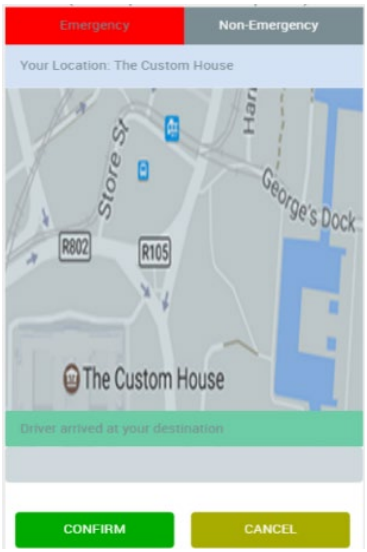

Figure 7. Report as witness screenshot

4.4 Non-emergency Service

It provides regular users the ability to hail ambulances for transfer (ex: hospital-to-hospital, hospital-to-home

a. Regular users would choose their location and destination from the map.
b. Regular user presses non-emergency transfer button.
c. Systems sends ambulance users non-emergency request along with user details and location.
d. Ambulance user can accept or decline non-emergency request.
e. System looks for different ambulance if declined, if accepted, system notifies regular user of ambulance
f. System provides user with details and location, time of arrival, and the route to be taken by the ambulance.
g. After successful delivery has been done the ambulance user may generate the total costs of their services along with additional charges (as needed by the user/patient during transport) and displays it for the user. Refer to Figure 8.
h. The system takes note of everything during this process and saves/stores the data as a case for the user.

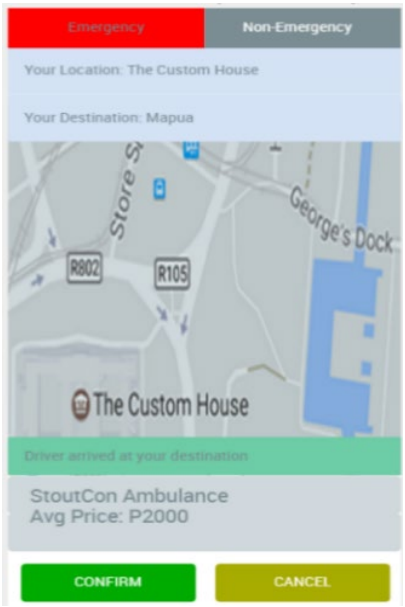

Figure 8- Non-emergency service screenshot

4.5 Cost-Benefit Analysis

Implementing Ambuquick application will provide benefits to both patients and ambulance providers.

For an ambulance provider:
The current operating costs which include manpower, internet, mobile and landline expenses was estimated to be **₱511,108.00**. But by partnering with Ambuquick, the provider will only have an annual expense of **P51,840.00,** which covers services using the app, which is about 10% of the total expense.

For the patients:
Since it is expected that having this kind of application will promote the use of private ambulance which can be an option to hospital ambulance, the patient will save more money since the rate of using Ambuquick will only range from Php3,500 to Php 5,000 as compared to hospital ambulance charge of P20,00 to P50,000.

5. RESPONSE TIME COMPARISON (PRESENT AND PROPOSED)

With Ambuquick Application

The time it will take for a user to tap "SOS" button through the smartphone is 7 seconds; the time the ambulance service provider to receive the alert is just 2 seconds, then the time the ambulance service provider can respond to the SOS alert will just be 2 seconds, and lastly the time it will take for the location to show is 2 seconds. The total time to use the application is 13 seconds.

Without Ambuquick Application

The time it will take for the user to grab his/her phone to dial the emergency number; 12seconds, the time the dispatch centre to pick the call is about 10 seconds, then the dispatcher will need to look for an available ambulance and it will take him 1-2 minutes. Next, the dispatcher will need another minute or two to explain to the available ambulance service provider the exact location and patient's status. Lastly, the total time it will take the dispatcher to dispatch an ambulance is 4 minutes and 22 seconds.

Saving human lives is precious thus, the use of Ambuquick lessen the time to respond to the user request, hence, will be more efficient and quick to detect the location of the patient.

6. SYSTEM TEST

To determine whether the system performs with the required functionalities, test plans for each task were made and administered to the sample users (ambulance providers and customers). Table 1 shows the test plan.

Table 1. Test Plan

TASK	TEST CASE	EXPECTED RESULTS
Registration	User needs to fill up all the requirements fields. Users press the "SOS" button System verifies the users' account	User is logged into the system User's account is saved into the database User can now use the app
Set-up of profile	User's enter correct account information: username and password User can put all the information and medical record for their account. 1. Users press "save" and all the data inputted/change is saved in the user's account	User is brought back to the homepage User can go to their profile and see all the changes they made to the system
Use of homepage map to see locations near them	User puts information into the text box above the map System accepts the input and starts looking for nearby locations that matches user's input System points map to the nearest location that matches user's input	User sees the location they wanted to look for in the map
Use of emergency request	User press the "SOS" button to summon a nearby ambulance to the area. System will send SOS request to the nearest ambulance to the user System will send all of the user's information to the ambulance user System will show profile information to the ambulance user System will give both user and ambulance user ETA and Route to take Ambulance user inputs their total cost to the user	User is displayed to the ambulance that has responded to their emergency request The current location and ambulance ETA are displayed to the user System will show successful trip made The total amount of service will be displayed and billed to the user
Use of non-emergency request	User selects non-emergency request User pins their desired location Systems sends non-emergency request to ambulance System will show profile info to the ambulance Ambulance user accepts request System will give both user and ambulance user ETA and Route to take Ambulance user inputs their total cost to the user	User is displayed to the ambulance that has responded to their emergency request The current location and ambulance ETA are displayed to the user System will show successful trip made The total amount of service will be displayed and billed to the user
Use of a report request	User reports an accident User pins the location of the accident Systems sends report to the nearby ambulance System will show inputted information to the ambulance Ambulance user accepts request System will display location and ETA to the user Ambulance user inputs their total cost to the user	User is displayed to the ambulance that has responded to their emergency request The current location and ambulance ETA are displayed to the user System will show successful trip made

7. CONCLUSION

The paper presents the current challenges that Filipinos experience with respect to public health care facilities like medical emergency services. Patients found it difficult to access quick medical ambulance transport during emergency situations that, consequently, leads to the loss of lives which could have been prevented. With such challenges, the researchers proposed a solution by developing a Mobile-based Shared Ambulance Application Service System for Private Ambulance Companies. Based on simulated results, the proposed system's goal to provide quick emergency response has been achieved.

The groups aim to improve the current ambulance transportation availability and other services when requests are made without having to call or wait for a long time. The paper analysed, designed and implemented a prototype to demonstrate the operation of the system to show its effectiveness with respect to the current existing systems. Ambuquick will reduce the expenses of a partnered ambulance company's communication software & computer software. The researchers have found that there will be a saving of up to 4.67% in properties breakdown. They will be able to reach more clients/patients who are in direct need of their services. On the other hand, with the use of the application, patients will be able to get an ambulance within 13 seconds compared to the current technology used based on the test that the researchers conducted. Saving a human life is precious and with the use of Ambuquick it will take less time to respond to the user request,and it will be efficient and quick to detect the location of the patient.

8. RECOMMENDATION

For future enhancement of the mobile application platform, it can be improved by incorporating technologies of Internet of things (IoT) to scale it up and link it with all nearby hospitals such that if a service is not available in one, another hospital that offer such service can be suggested immediately alongside its distance, arrival time and the availability of paramedics, doctors and so on to attend to the emergency situation

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Session VII

Information Industry and Automation

Facilities Layout Design with System Simulation for Pre-Employment Services on Diagnostic Centers and Laboratories

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ABSTRACT
This paper proposes to develop a layout model for a diagnostic clinic in Metro Manila that caters the pre-employment medical examination of applicants from different companies serviced by this diagnostic clinic. The assessment of the current diagnostic clinic focused on the current layouts within Metro Manila in coordination with the patient's perspective. The assessment was done through survey for the three diagnostic clinics for both doctors/staffs and patients using different tools and technique in facilities layout and design to come up with the best possible combination of departments that should be close together and add possible facility that help utilize and maximize space while reducing the queue. The researchers used the systematic layout planning for the design and simulation software (ProModel) to evaluate if the proposed layout design is effective. Moreover, visual representation is needed in order to appreciate the new layout design and this was done using Auto-Cad or Google Sketch-Up. This paper were able to show the design of 3 layouts that cater to a capacity and inflow of 40, 60 and 80 patients in a day.

CCS Concepts
•General and reference → Document types → General conference proceedings

Keywords
Space allocation; Queuing; Systematic Layout Planning; Simulation

1. INTRODUCTION
Facility layout is defined as the physical arrangement of equipment, machinery, furnishings, production areas, production related areas and personnel areas within the building [3]. Facility layout and design are important components in relation to business overall operations, both in terms of maximizing the effectiveness of the process and meeting the needs of employees. The basic objective of layout is to ensure a smooth flow of work, material, and information through a system [7]. The basic meaning of facility is the space in which a business activity takes place. The layout and design of that space impacts greatly on the performance of work – how it is performed, the flow of work, materials, and information through the system. The key to good facility layout and design is the integration of the needs of people that includes the personnel and customers, materials, and machinery in such a way that they create a single, well-functioning system.

Most studies about diagnostic clinic or center refers to the layout design of a clinic in order to maximize the space with minimum costs. According to the study made by Cardon, the facilities of the diagnostic center should compose of moveable partitions and create a flexible clinic that can adapt to changes. For patients that take the pre-employment medical examination, there is a need to study the facility layout strategy in order to know the capacity of the diagnostic center and to measure whether the flow of patients can accommodate the current layout. Moreover, there was no discussion on how the room assignment are close to one another to avoid far travel distance. The policy of some diagnostic centers are based on the first come-first serve basis, and others do random calling on customers to different departments that has no queue, and some choose to have their own set of procedures wherein the customer should follow these procedures before they can proceed to the next department [10].

The objectives of the study aimed to assess current layout or facility arrangement of 3 diagnostic centers in Metro Manila, identify the problems encountered for the existing layouts, propose a standardize layout, appropriate facilities and room arrangement for medium size diagnostic centers, and simulate the design model.

The significance of this study is to design a layout that will fit into the need of diagnostic centers in the Philippines.

2. METHODS
Three diagnostic centers in Metro Manila were selected that offer pre-employment diagnostic checkups. The Department of Health (DOH) accredits these diagnostic clinics. The researchers administered a survey to 45 respondents for each diagnostic clinics, comprising of 135 respondents in order to determine issues patients encountered during their use of the facility was administered to. Moreover, they also conducted interviews to the owners of the three diagnostic clinics in order to validate the problems or issues identified by the respondents.

A measurement on the current spaces allotted for each facility was undertaken. Furthermore, the researchers observed the current

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operations involved in pre-employment activities. The current layouts of each diagnostic center were drawn using Google sketch up to be able to visually illustrate the current situation of the diagnostic clinic, and compare it to the guidelines posted by the DOH in building a healthcare facility. We also gathered the procedures of the diagnostic clinics together with their capacity. The three diagnostic centers have almost the same area. The total clinical area for each diagnostic center is approximately 120-200 sq. meters. All of these collected data become the basis to improve the current facility layout of the diagnostic clinics.

After identifying the issues, the researchers subjected the identified issues using the systems design analysis in order to solve the issues and problems. With the use of different facilities layout and design technique such as SLP [2] , space relationship chart/diagram [8], from/to chart, the best possible combination of department that should be close to one another was determined. After identifying possible arrangements, these were subjected to simulation [1], [6] using the ProModel software [5] to evaluate if the proposed layout design [9] is effective. Moreover, AutoCad or Google Sketch-up was used for visual representation of the proposed layout.

Lastly, the simulated data from the ProModel results were subjected to statistical t test to determine whether they are typical of the actual data.

3. RESULTS AND DISCUSSION

According to the previous studies, the facility layout of a building affects the flow in the system. It states that, the most important issue concerns the alignment of the workflow with the layout of the facility. This decision should take into consideration the facility that provides the service in relation to the preferences of the public and the projected service flow work the facility will host. The criterion involve includes efficiency of flows through the facility, the flexibility and sustainability of the facility, and the comfort of users within the facility.

The three diagnostic centers have common services and facilities. The common services that they have are the basic pre-employment medical examination, but they do not have the same room sizes since most of them states that their room size depends on the available space on their lot area. Most of them rented a place and refuse to renovate and just use the available resources present. According to the Department of Health, there are only medical procedures required to pass the pre-employment diagnostic examination. These are the following:

1. Checking the basic vital signs. In this procedure, the nurse will get the height, weight, blood pressure, heart rate, respiratory rate check, Body mass index check, and determining the medical history of the patient.

2. Laboratory tests. These include urinalysis, fecalysis or stool analysis and blood tests (CBC, cholesterol, sugar, HIV, Hepatitis etc.)

3. Radiology or Chest X-ray.

4. Optical. In this procedure, the optometrist will instruct the patient to read the letters in the Snellen chart to determine the eye grade. In case of poor eyesight, the optometrist will refract the patient and prescribe the appropriate eyeglasses.

5. Physical Examination. In this procedure, the medical doctor will examine the body of a person.

The Department of Health gave the guidelines in planning and designing of hospitals and other healthcare facilities. These diagnostic clinics were not able to follow the standard space requirements in setting up a room because some of them want to maximize the room by including all facilities that they think would benefit them. Furthermore, these three diagnostic clinics have narrow hallways that give discomfort to the patients. Results of the survey indicated that 83% of the patients ranked first this issue. Based on the interview with the owners, they have to do this because they wanted to provide more space to the rooms. Furthermore, these three diagnostic clinics have high volume of people coming in, and the comfort room serves both male and female and for both laboratory and personal use. The size of the comfort room is also small which includes toilet and sink. The Department of Health (DOH) does not have standard facilities to be included in building a diagnostic clinic, and the owners decided on what facilities to build based on their own interests. Table 1 presents the capacity [4] of each room inside the diagnostic clinics. The theoretical maximum capacity per room was determined using the estimated processing time of patients in each room. Diagnostic Clinic A has an average of 65 patients per day. On the other hand, Diagnostic Clinic B has an average of 54 patient's per day and Diagnostic Clinic C has average of 44 patients a day.

Table 1. Processing Time and Maximum Capacity of the three Diagnostic Centers

Stations	Diagnostic Center A		Diagnostic Center B		Diagnostic Center C	
	Processing Time (min)	Maximum Capacity	Processing Time (min)	Maximum Capacity	Processing Time (min)	Maximum Capacity
Registration	2.4	175	4.2	100	5.4	78
Cashier	3	140	4.2	100	6	70
Records	1.8	233	-	-	-	140
Audiometry	3.6	116	3.6	117	-	-
X-Ray	3.6	116	3.6	117	12	210
ECG	-	-	5	84	-	-
Optical	3	140	3	140	-	-
Dental	15	28	7.2	58	9	34
Laboratory	11.4	37	10.2	42	28.8	34
Vital Signs	7.2	58	8.4	50	12	60
Physical Exam	10.8	39	9.6	44	12.6	34
Psychology	20	22	30	13	-	-
Releasing	2	210	5	84	-	-
Total Duration	81		73.2		86	
Average number of Patients/day	65		54		44	
Estimated Area (in sq. m.)	161.3		152.7		112.5	

The significant difference between the time in the actual model and in the simulated model was determined using the t – test. The result showed no significant difference between the actual and the

simulated model (t - value = 0.87 for Diagnostic Clinic A, t-value = 0.94 for Diagnostic Clinic B, and t –value = 0.13 for Diagnostic Clinic C) for the 3 diagnostic clinics which are less than the critical t - value of 1.4. Therefore, it indicates that the model can be a typical representation of the current design of the different diagnostic clinics. Based on this result, the design for a standardized layout for the diagnostic clinic can be implemented using the top five pre-employment services since these are the common services patients usually take for pre-employment requirements and these were also the highest percentage based on the survey result conducted.

Based on Figures 1, the entrance should be close to registration, while the registration should be close to the cashier for payment. It is important that the guard location should be near the registration area because it also serves as an information booth in order to address the concerns of the patients and the guar can assist them. With respect to the cashier, he or she should be close to the nurse's station so that after the patients pay their payment, they will immediately proceed to the nurse's station to get their vital signs. These comprise of getting the height, weight, blood pressure, heart rate and other pertinent data required by the physician. The nurse's and laboratory stations have also the highest closeness rating since after the patients got their vital signs, the nurse will ask the patients to proceed to the laboratory submit themselves for the stool and urine examination. This may take time since not all patients were ready to give stool samples. The nurse's station has ordinary closeness to optical and x-ray stations since the activities performed in the nurse's station is totally different from the optical and x-ray stations so either department can interchange its position. It is also shown in the diagram that the comfort room should be close to the laboratory and x-ray area, since it is required in the x-ray area to take off clothes in order to proceed with the imaging screening, and as for the laboratory purposes, the patients should give a present urine sample for the urinalysis. Both departments have absolute necessary closeness to the comfort room. As a whole the departments are being arranged according to their importance and functions to each other and this is regardless of the area since the objective of this study is to create a standardize layout design for diagnostic center that require minimum medical employment needs. The sizes of rooms to will be based on the Department of Health guidelines in building a healthcare facility.

Table 2. Block Layout

SPACE REQUIREMENT	
FACILITY	AREA (m)
GUARD DESK	1.2
REGISTRATION	5.02
CASHIER	5.02
XRAY	14
OPTICAL	13.4
LABORATORY	7.43
NURSE STATION	5.02
PHYSICAL EXAM	7.43
TOILET	1.67
TOILET WITH SINK	2.4
WAITING AREA	0.65 sq.m/person

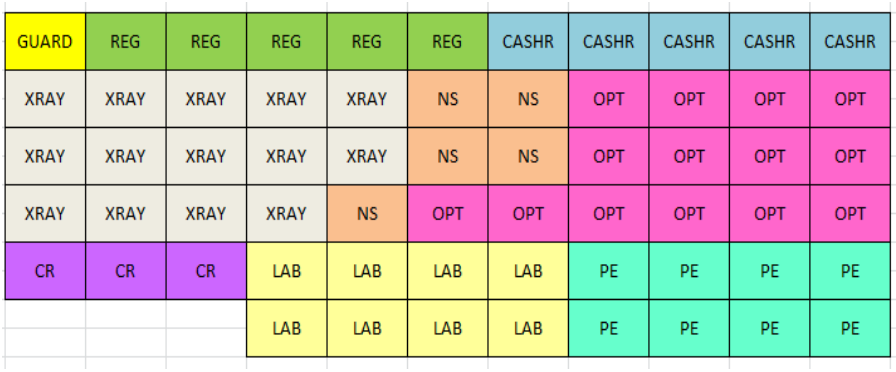

Figure 1. Block Layout

As presented in Table 2 and Figure 1, the size of the registration area and cashier should be 5.02 sq. meters per staff. This includes a work area with one desk, one chair and aisle space of 1 meter for clearance. The area of the nurse's station is also 5.02 square meters, the physical examination room is measured as 7.43 sq metes. This includes the bed, the doctor's table and chair. While the laboratory area has a total of 10 sq. meters dimension. This includes lavatory/sink and furniture and fixtures of the laboratory staff. On the other hand, the comfort room comprises of a toilet and sink. The toilet size has an area of 1.67 sq. meters and the average size of the comfort room is 2.4 sq.meters.

A proposed layout for the diagnostic center with a capacity of 40, 60 and 80 was designed. The physical examination area and laboratory have the longest processing time that usually takes 10 to 15 minutes. The physical examination is conducted only by one doctor and theoretically by computing its max capacity for a day, 1 doctor is equal to 42 patients, therefore the first layout is based only on one physical examination area as presented in Figure 2.

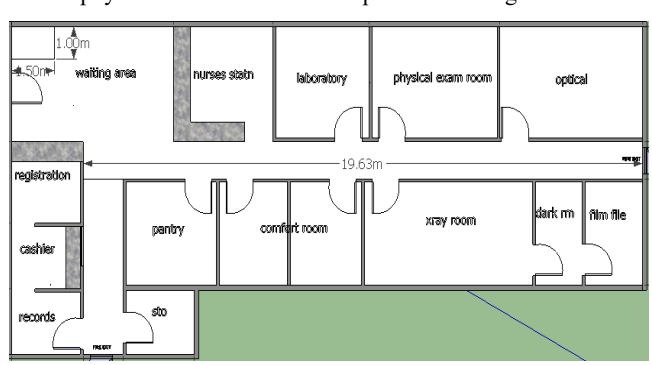

Figure 2. Proposed Layout 1 (40 Capacity)

The second layout design has 2 physical examination rooms (see Figure 3) and the third layout design is for diagnostic center having 3 physical examination area (refer to Figure 4).

Figure 3. Proposed Layout 2 (60 Capacity)

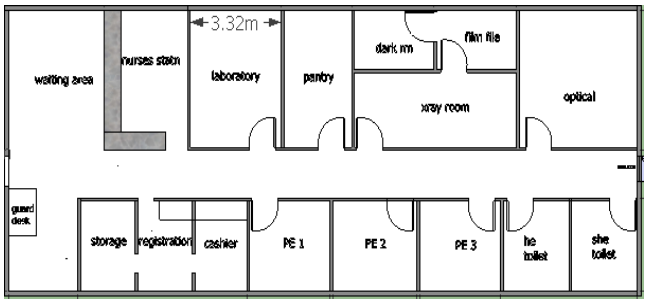

Figure 4. Proposed Layout 3 (80 Capacity)

This is to accommodate the demand for each diagnostic center since they all have different demands. Diagnostic Clinic A has an average demand of 65 patients per day, Diagnostic Clic B has 54 patients per day while Diagnostic Clinic C has 44 patients per day.

Based on these proposed designs, Diagnostic Clinc C can use Layout 1, while Diagnostic Clinics A and B can use the proposed Layout 2 or 3.

All measurements of the proposed layouts are in accordance with the standard building code of the Philippines and with the guidelines in building a healthcare facility posted by the Department of Health. All the room sizes are based on the actual measurement of the Department of Health guidelines for building a healthcare facility. Moreover, the size of the hallway ranges from 1.2 to 1.5 meters based on the standard size of hallway according to building Code of the Philippines. The fire exits are located at two dead-ends of the hallways. According to the OSHA standards, as much as possible the dead-end part of the building should have a fire exit for safety precaution and in case of emergency there will be 3 exit doors available.

4. CONCLUSION

The proposed layout's space requirements were also determined and this paper was able to provide thre proposed models. These data of these three proposed layouts were run using the ProModel simulation software to determine whether these can hold a 40,60 and 80 patients capacity. The proposed simulated model uses the same stastistical distribution that is also used in the present simulation to know if the model can handle the inflow of patients. The result the model indicated that it was able to accommodate the desired demand. With an infinite flow of patients coming into the system, the design layout was able to accommodate a total of 42, 60, and 97 numbers of patients.

Through this proposed layout, the diagnostic center with different demand will be able to cater all the patients in a day since the 3 layout is composed of different capacity.

As a recommendation for future study, undertake a study on the detailed pre-employment examination process by the diagnostic clinics in order to improve the current system. Analysis of the procedures can be done using sensitivity analysis and simulation models. This will help reduce the queuing in the system and to optimize the time to accommodate more patients. Moreover, it is highly recommended to study the layout of the whole facility in order to utilize the space provided and maximize the area.

Customization of pre-employment diagnostic clinic can also be studied so that it can meet the required medical procedures of different type of industries whether land or overseas. Because of the location and time constraints, only 3 diagnostic centers were visited and analyzed. More accurate results can be acquired if the 3 levels of diagnostic centers will be tackled and compare the differences of the demand and layout design between the 3 types of diagnostic clinics.

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Strategic Design for Warehouse 4.0 Readiness in Thailand

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ABSTRACT
In era of the growth of Thailand economy, industrial warehouses have become an essential need. They have been recently strengthened using technology 4.0 (i.e. robotics and internet of things) to enhance competitiveness and competitive advantages. The so-called warehouse 4.0 are operated productively when well-designed with lean concept along its supply chain (warehouse 4.0 readiness). It is initiated at the strategic level. It requires an organizational policy to emphasize warehousing performance indicators. Their related data is defined and acquired to be analyzed and formulated into mathematical equations. They are subsequently configured and simulated before verified and validated in an industrial case.

CCS Concepts
• **General and reference→ Cross-computing tools and techniques→ Design**

Keywords
Warehouse design; Technology 4.0; Warehousing performance

1. INTRODUCTION
In Thailand, warehousing has been one of three activities primarily influencing logistics cost. The others are transportation and inventory holding. In 2016, it was found that Thailand logistics cost to GDP was 13.9% higher than other countries e.g. Singapore (7.40%) and Malaysia (13.60%), Europe (9.50%), United State (7.50%), and Asia Pacific (12.70%). The higher cost of Thailand logistics has been caused by 81% of road utilization shown in Figure 1 [1].

To reduce the logistics cost for enhancing competitiveness, Thailand office of transport and traffic policy and planning has set up single- and double-track railway development plans. In 2022, they would be an economic mode linking Thailand to Cambodia, Laos, Myanmar and Vietnam (or CLMV) and China [2]. In addition, it was found that the growth of e-commerce (Figure 2) [3] has driven the growth of three business segments i.e. road transport, freight forwarder, and postal and couriers. They are supported by a business segment of warehousing having been grown [4].

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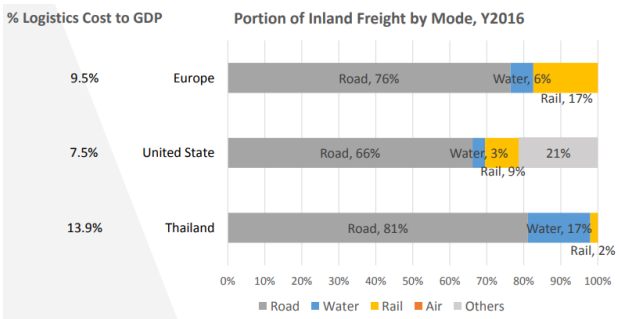

Figure 1. Logistics cost to GDP in 2016

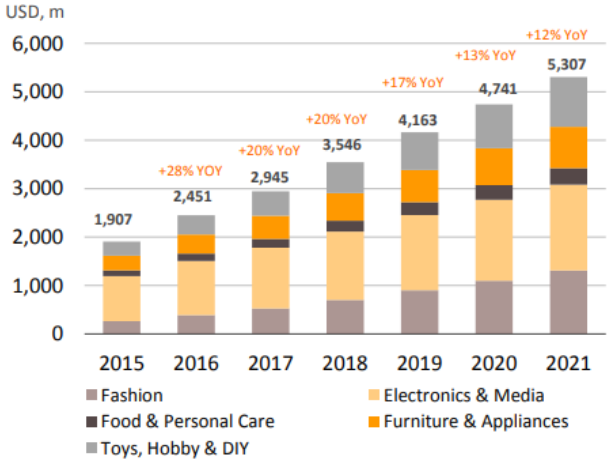

Figure 2. E-commerce market in Thailand

The business segment of warehousing has played important roles for storing goods before shipped elsewhere, warehousing raw materials and/or parts before processed to be goods, and distributing goods to downstream supply chain members (or customers). The goods are characterized and sub-divided into three types of warehousing, namely cold, silo or cereal, and general-purpose. The last one accounts for 77% of registered business operations and over 70% of total income in Thailand. They have been increased from 474 in 2011 to 564 in 2016 (Figure 3) [4]. Over 95% of warehouses in Thailand are classified into traditional [5]. The traditional warehouses require more resources (i.e. workforce, time, machines, etc.) than modern ones. They apply technology 3.0 (i.e. robotics) and technology 4.0 (i.e. internet of things). The so-called warehouse 4.0 are productive when well-designed with lean concept along its supply chain (warehouse 4.0 readiness). Its attentions have however been paid by few studies [6][7][8].

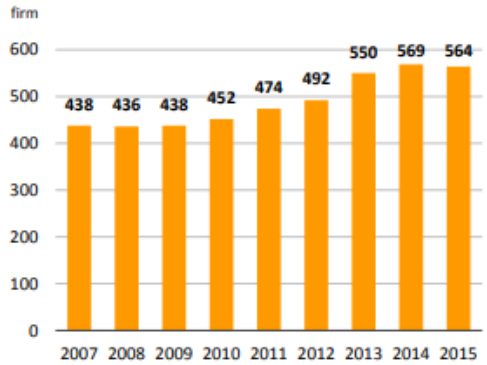

Figure 3. Number of general-purpose warehouses in Thailand

Accordingly, Stender et al. (2017) proposed a framework for systematic warehouse design. It was structured in three parts including inputs, design and implementation, and outputs as shown in Figure 4 [9]. The inputs consisted of product characteristics, supply chain design, and financial and operational factors. They were considered for the design and implementation in terms of layout, operations' strategy, resource dimensioning, information and control technology, and measuring and monitor performance. The warehousing performance as the outputs commonly aimed to maximize service level and/or minimize operations cost. They are in conflicts with each other.

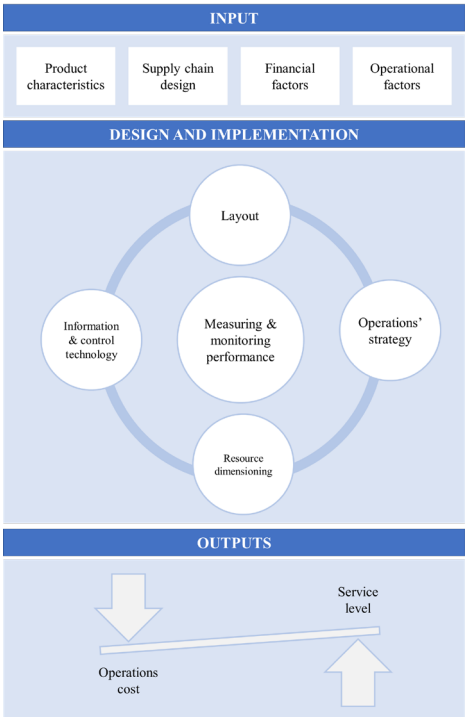

Figure 4. Framework for systematic warehouse design

In addition to service level and cost [10][11][12][13], the warehousing performance has been measured with time [13][14][15][16][17], quality [16][18], and productivity [14][19]. Firstly, the measures of warehousing time could be indicated by order lead time, receiving time, order picking time, delivery lead time, queuing time, put away time, shipping time, dock-to-stock time and equipment downtime. Secondly, the measures of warehouse quality could be on-time delivery, customer satisfaction, order fill rate, physical inventory accuracy, stock-out rate, storage accuracy, picking accuracy, shipping accuracy, delivery accuracy, perfect orders, scrap rate, orders shipped on time and cargo damage rate. Thirdly, the measures of warehousing cost could be indicated by inventory cost, order processing cost, cost as a % of sales, labor cost, distribution cost and maintenance cost. Fourthly, the measures of warehousing productivity could be indicated by labor productivity, throughput, shipping productivity, transport utilization, picking productivity, inventory space utilization, outbound space utilization, receiving productivity and turnover. Such the four warehousing performance measures are defined in Tables A1 to A4 [20].

The individual ones are however emphasized in relation to supply chain strategies. They are then deployed at three levels, namely strategic, tactical, and operational levels [21]. The strategic-level warehouse design concerns long-term impacts mostly relating to high investments. For examples, the concern in process flows has effects on selection of warehouse system types (i.e. manual, semi-automation, and automation). They are selected by trade-offs between their technical capabilities and financial feasibilities. The trade-off selections result in minimizations of investment and operational costs over a period of time.

Such the results of the strategic-level warehouse design are driven for the tactical-level one. It typically concerns areas of receiving, storing, picking and shipping materials, work-in-process, and finished goods. In addition, the typical concerns include number of receiving and shipping docks, material handling equipment, and workforce. Such the individual concerns are assigned and controlled independently at the operational level. Therefore, this paper aims to strategically design warehouses for supporting technology 4.0 (warehouse 4.0 readiness).

2. METHODOLOGY

In order to achieve the strategic design for warehouse 4.0 readiness, it undergoes seven steps as shown in Figure 5. Firstly, warehouse system requirements are framed into three stages including production, warehouse and customer. Hence, the frame of warehouse system is worked for four successive processes as follows.

(1) To receive finished good from the stage of production
(2) To store finished goods into the stage of warehouse
(3) To pick finished goods from the stage of warehouse
(4) To ship finished goods to the stage of customer

The warehouse system aims to maximize productivity. It enables to minimize space utilization for storing finished goods (SU), number of docks for receiving finished goods into warehouses (DI), and number of docks for delivering finished goods out of warehouses (DO). Such the three aims are expressed in (1)

$$\text{Min } (SU, DI, DO) \tag{1}$$

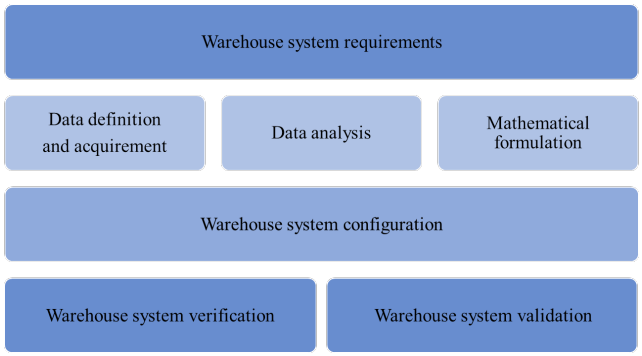

Figure 5. Methodology

In order to achieving all the three aims, their related data is defined and acquired in the second step, before analyzed in the third step. Fourthly, the analyzed data is formulated into mathematical equations.

The space utilization for storing finished goods (SU) is proportional to amount of pallets (PA), width (PW) and length (PL) of a unit of pallet, and inventory days (ID). In addition, width of an aisle (AW) is added on the width of a unit of double-pallets. Otherwise, height of a warehouse restricts amount of vertical pallets (PV) as expressed in (2).

$$SU = PA \times (PW + (AW / 2)) \times PL \times ID / PV \quad (2)$$

The amount of pallets (PA) are dependent on customer demand requiring amount of finished goods (FA). It is constrained by acceptable weights of a unit of pallet (PWA) and weight of a unit of finished goods (FW) as expressed in (3).

$$PA = FA \times FW / PWA \quad (3)$$

The number of inbound docks (DI) are specified by inbound frequency. It is dependent on customer demand in terms of weight (FA x FW), acceptable weights of a unit of inbound vehicle i.e. forklift (VIWA), inbound loading time (LI), and inbound working time (WI) as expressed in (4).

$$DI = FA \times FW / VIWA / (WI / LI) \quad (4)$$

With similar to DI, the number of outbound docks (DO) are specified by outbound frequency. It is dependent on customer demand in terms of weight (FA x FW), acceptable weights of a unit of outbound vehicle i.e. truck (VOWA), outbound loading time (LO), and outbound working time (WO) as expressed in (5).

$$DO = FA \times FW / VOWA / (WO / LO) \quad (5)$$

All the mathematical equations are configured into exact algorithm software (i.e. MS Excel) in the fifth step. It is verified in the sixth step and followed by its successful validation in the industry as the seventh step.

3. RESULTS AND DISCUSSION

Due to its sales growth, a large-sized company in Thailand manufacturing electrical wires requires a new warehouse. It is estimated at 5,000 square meters (m2) to store 30 days (ID) of 86-SKU finished goods with their maximum customer demand at 20,000 items a day (FA) along a one-year data period. The individual SKUs are weighted differently from 105 to 1,000 kilograms (kg) an item. They are contained on 4 vertical pallets at an acceptable weight not more than 1,000 kg. a pallet (PWA).

The individual pallets are sized at 1.105 meters of width (PW) and 1.105 meters of length (PL). Hence, the width of individual pallets is added with 1.105 meters as their aisles (AW).

All the finished goods on pallets manufactured by 2 plants are loaded into the warehouse using 2 forklifts (VI) every 5 minutes (LI) for 480 minutes a day (WI). Otherwise, all the finished goods on pallets demanded by numerous customers are loaded out of the warehouse – into 24 trucks (VO) – every 30 minutes (LO) for 120 minutes a day (WO). All of the above-mentioned parameters are shown in Table 1.

As a result, the effective warehouse design proposes 783 square meters (SU) for storing the 30-day finished goods on 1,710 pallets (PA). It includes 3 inbound docks (DI) and 8 outbound docks (DO) as shown in Table 2. All of the three performance is subsequently applied to design its distribution networks in Figure 6.

Table 1. Parameters of strategic warehouse design

Parameter	Unit	Value
AW	meters a pallet	1.105
FA	items a day	20,000
FW	kg. an item	105 – 1,000
ID	days	30
PWA	kg. a pallet	1,000
PW	meters a pallet	1.105
PL	meters a pallet	1.105
PV	pallets	4
VI	vehicles	2
VIWA	kg. a vehicle	2,000
WI	minutes a day	480
LI	minutes	5
VO	vehicles	24
VOWA	kg. a vehicle	17,000
WO	minutes a day	120
LO	minutes	30

It is noticeable that the proposed warehouse design could be improved by 84.34% when comparing with the existing one as shown in Table 2. The smaller-size warehouse causes a smaller-size technology 4.0 (robotics and internet of things) invested in a new warehouse. Its return on investment is hence faster.

In order to obtain the faster return of investment, a new warehouse requires its smaller size. It is caused by shortening inventory days. The 20-day and 10-day inventory respectively requires 522 and 261 m2 as shown in Figure 7.

Table 2. Performance of warehouse design

Performance	Unit	Existing	Proposed
SU	m2	5,000	783
DI	docks	1	3
DO	docks	1	8

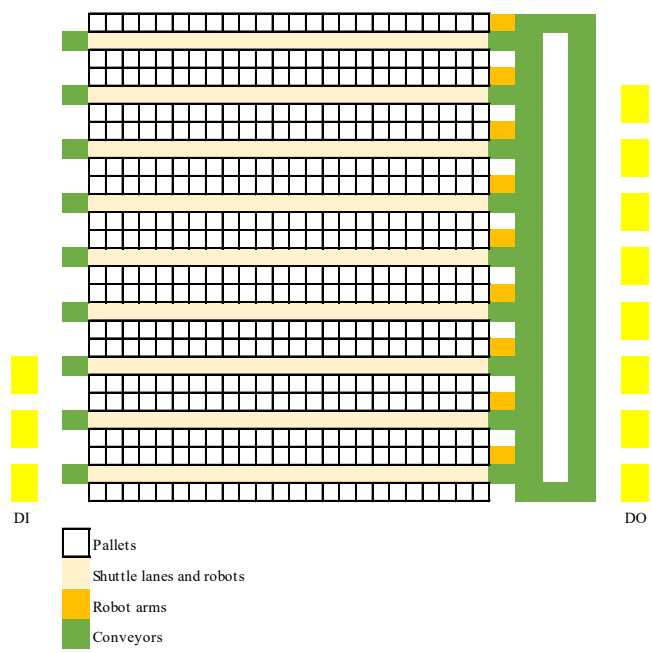

Figure 6. Proposed layout for warehouse 4.0 readiness

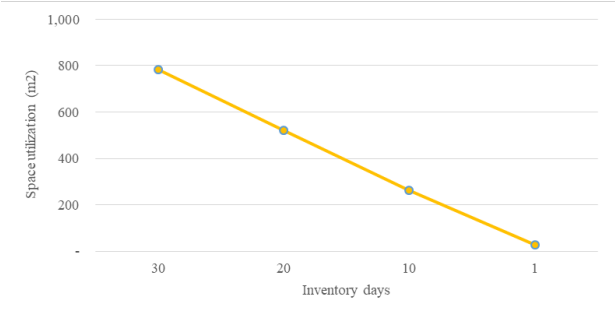

Figure 7. Sensitivity of space utilization to inventory days

4. CONCLUSION

This paper develops a strategic design system for warehouse 4.0 readiness. Its scope covers three stages including production, warehouse and customer. The system development under its scope aims to utilize less space, small number of receiving and delivering docks. They generate more productive, whereas spending shorter time, improving more quality, and expending lower cost. As a result, the developed system aims propose strategic layout for warehouse 4.0 readiness. In addition, its sensitivity of space utilization is analyzed for supporting decisions under differences in inventory days.

The developed system could however be extended. For example, other stages of a supply chain are included. Moreover, several industries are studied as cases in validation. Furthermore, a dimensional measure of environmental impact is considered. Apart from these extension, there are a number of warehousing performance indicators in reinforcements and conflicts each other. They could be assessed [22] [23] and optimized [24].

5. ACKNOWLEDGMENTS

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7. APPENDIX

Tables A1 to A4 [20] presents definitions of warehousing performance indicators in terms of time, quality, cost, and productivity, respectively.

Table A1. Warehousing time indicators

Indicator	Definition
Order lead time	Time from order placement to shipment
Receiving time	Time to unload an order
Order picking time	Time to pick an order
Delivery lead time	Times from a warehouse to a customer
Queuing time	Time products wait on hold to be handled
Put away time	Time to unload and store products
Shipping time	Time to load orders on a truck
Dock-to-stock time	Time from supply arrival to product availability for order picking
Equipment downtime	Period in which an equipment is not functional, downtime incurred for repairs

Table A2. Warehousing quality indicators

Indicator	Definition
On-time delivery	Number of orders received by customer on or before committed date
Customer satisfaction	Number of customer complaints/number of orders delivered
Order fill rate	Orders filled completely on the first shipment
Physical inventory accuracy	Accuracy (by location and units) of physical inventory pared to inventory reported
Stock-out rate	Number of products out of order
Storage accuracy	Products stored in proper locations
Picking accuracy	Number of errors free orders picked prior to shipment
Shipping accuracy	Number of errors free orders shipped
Delivery accuracy	Number of orders distributed without incidents
Perfect orders	Orders delivered on time, without damage and with accurate documentation
Scrap rate	Rate of product loss and damage
Orders shipped on time	Number of orders shipped on time per total orders shipped
Cargo damage rate	Number of orders damaged during delivery activity

Table A3. Warehousing cost indicators

Indicator	Definition
Inventory cost	Total storage cost per unit
Order processing cost	Total processing cost of all orders per number of orders
Cost as a % of sales	Total warehousing cost per total company sales
Labor cost	Cost of personnel involved in warehouse operations
Distribution cost	Cost incurred mean number of vehicles and total travel distance per day
Maintenance cost	Costs of building maintenance

Table A4. Warehousing productivity indicators

Indicator	Definition
Labor productivity	Ratio of number of items managed to amount of item-handling working hours
Throughput	Items per hour leaving a warehouse
Shipping productivity	Number of products shipped per time period
Transport utilization	Vehicle fill rate
Picking productivity	Number of products picked per labor hours in picking activity
Inventory space utilization	Rate of space occupied by storage
Outbound space utilization	Utilization of warehouse areas used for retrieving, order picking, packing and shipping
Receiving productivity	Number of vehicles unloaded per labor hour
Turnover	Ration between cost of goods sold and average inventory

Roller Chains Quality Enhancement using Six Sigma and Failure Mode and Effects Analysis (FMEA)

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ABSTRACT
Roller chain is an important part in the modern manufacturing industry. The purpose of this study was to enhance the quality of roller chains manufacturing process by utilizing Six-Sigma methodology and Failure Mode and Effects Analysis (FMEA). Through these approaches, it was found that pin diameter, pitch length of plate PH, and pitch length of the plate RH had significant effects to the quality of chain stretch. The continuous enhancement process could also reduce waste in the process from 158,629.86 PPM to 3.64 PPM (99.97% reduced). Moreover, the process capability (C_{pk}) increased from 1.10 to 3.39, (67.55% increased). The proposed Six-Sigma and FMEA approaches could also be applied to other chain stretch manufacturing industries worldwide.

CCS Concepts
• **General and references → Cross computing tools and techniques → Design**

Keywords
Quality improvement; Chain stretch; Design of experiment; Manufacturing process; FMEA

1. INTRODUCTION
Roller Chain plays an important part in modern society. It is widely recognized as one of the most effective platforms of power transmission in the modern industry [1]. In addition, it is also widely utilized due to its timing capabilities [2-4]. Transportation, machinery, and even medical fields are constantly utilized roller chain to enhance the productivity and safety.

Thailand is widely known as one of the roller chain producers. As the automotive industry growth high, the demand of roller chain is also significantly increased, thus, it is extremely important to enhance the quality and productivity of roller chain in Thailand to maintain its competitiveness.

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Despite the significant increasing number of chain manufacturing in Thailand, the quality of the manufacturing process is quite low. In addition, the waste that generated from the roller chain production is quite high, thus, it is required to consistently enhance the efficiency of the production line through controlling the variability of the chain stretching value. In addition, it is also important to investigate factors that affect the chain production process, enhance the measurement system of the roller chain quality, and consistently do the process inspection to minimize the production cost.

The purpose of this study was to enhance the quality of chain stretch manufacturing process by utilizing Six Sigma and Failure Mode and Effects Analysis (FMEA) in Thai Metro Industry. This case company has more than 40 years of experience in manufacturing high-quality roller chain under ICM™ brand and production capability per year more than 1.5 million feet of roller chain. The company has received various certifications i.e. Asian Recognition for Quality Promotion Award from Asian Network for Quality, First rank of best practice in Toyota production system project by Toyota Motor Asia Pacific-Engineer & Manufacturing and Thailand Automotive Institute. In the end, this study can contribute to the enhancement of chain stretch manufacturing in Thailand which would be very beneficial for engineers [5-8], government, and even for academicians [9,10].

2. METHODOLOGY
This study utilized Six Sigma and FMEA approaches to enhance the quality of chain stretch manufacturing process. The data collected in this study were gathered from one roller chain manufacturing company in Thailand.

2.1 Define Phase
A Flow chart was utilized to derive the chain manufacturing process. Metal parts of the roller chain were obtained from the production department, then, workpieces were sliced, stamped, hole punched, hardened, oil washed, water washed, rustproof coated and assembled. Aside from a flow chart, a Pareto chart was also utilized to gather the problems in the roller chain production process. The length deviation of the roller chain which not in accordance with the standard of each model was recorded. Figure 1 represents an example of a chain product in the current study. It had 34 segments, 28 pieces of plate PH, 34 pieces of plate RH, 32 pieces of PIN, 32 pieces of a roller, and 32 pieces of a bush.

Figure 1. The 120G chain product

2.2 Measure Phase

Analysis of measurement system (MSA) was utilized to measure the workpieces and to determine all relevant variables affecting the production quality of the roller chain. In general, there were three important variables need to be considered: pin diameter, the production capability of Plate Ph, and production capability of Plate RH.

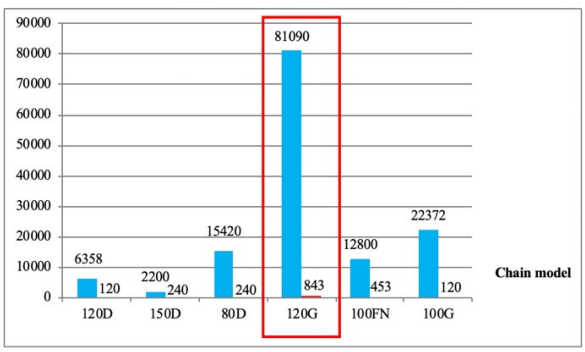

Figure 2. The waste in chain manufacturing process

Figure 2 represents the largest amount of waste in the production process. It was found that the chain model 120G had the highest waste in the manufacturing process.

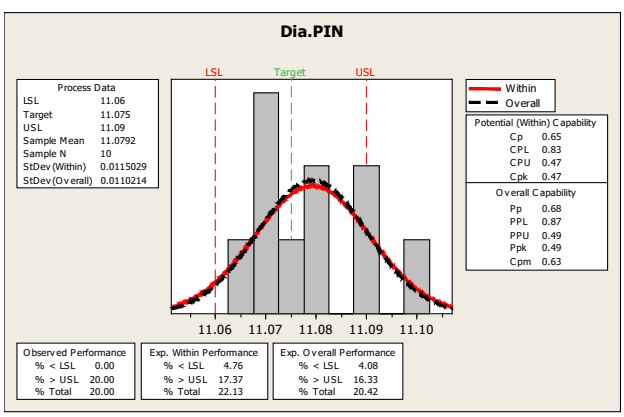

Figure 3. The production capability of Pin diameter

From Figure 3, it was found that the value of C_{pk} was equal to 0.47, which indicated that the production capability was lower than the standard normal of 1.33 or above. Therefore, it was necessary to enhance the pin diameter in the manufacturing process.

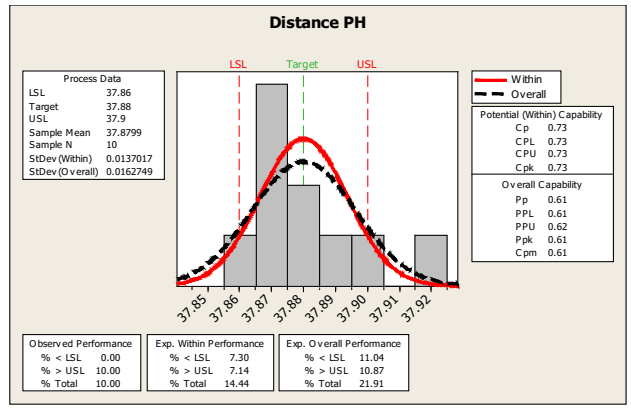

Figure 4. The production capability of Plate PH

From Figure 4, it was found that the value of C_{pk} was equal to 0.73, which indicated that the production capability was lower than the standard normal of 1.33 or above. Therefore, it was also necessary to enhance the plate PH manufacturing process.

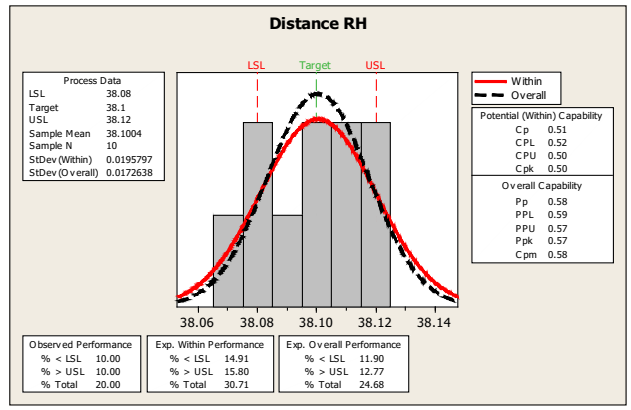

Figure 5. The production capability of Plate RH

From Figure 5, it was found that the value of C_{pk} was equal to 0.50, which means that the production capability was also lower than the standard normal of 1.33 or above. Therefore, it was also necessary to enhance Plate RH manufacturing process.

2.3 Analyze Phase

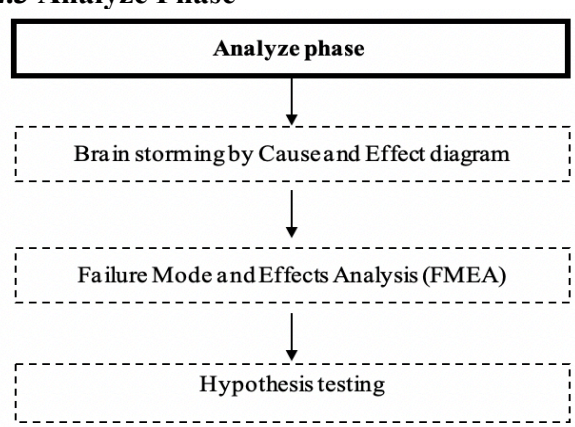

Figure 6. The flow chart during analyze phase

Table 1. Failure Mode and Effects Analysis

Model	Failure Mode	Effect	S	Cause	O	Current States		D	RPN
						Preventive	Inspection		
Plate RH	Pitch distance not meet standard	Chain stretching fluctuate	3	1.WIRE CUT die doesn't meet standard 2.Deviation from machine set-up	4	1.Mold inspection 2.Inspect the machine before start	Inspect the workpieces every 100 pieces	3	36
Pin	Distance not meet standard	Chain stretching fluctuate	3	1.WIRE CUT die doesn't meet standard 2.Deviation from machine set-up	4		Inspect the workpieces every 100 pieces	3	36
Bush	Cannot water the plate	The chain cannot be assembled	3	From QC error checking	3		-	2	18
Roller	Cannot wear the bush	The chain cannot be assembled	3	From QC error checking	3		-	2	18

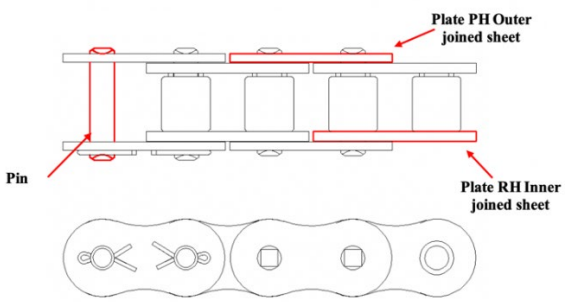

Figure 7. The 120G chain part that affects the chain quality

Two-Sample T-Test and CI: Diameter1, Diameter2
Two-sample T for Diameter1 vs Diameter2

	N	Mean	StDev	SE Mean
Diameter1	10	11.06730	0.00283	0.00090
Diameter2	10	11.09720	0.00899	0.0028

Difference = mu (Diameter1) - mu (Diameter2)
Estimate for difference: -0.02990
95% CI for difference: (-0.03616, -0.02364)
T-Test of difference = 0 (vs not =): T-Value = -10.03 P-Value = 0.000
DF = 18 Both use Pooled StDev = 0.0067

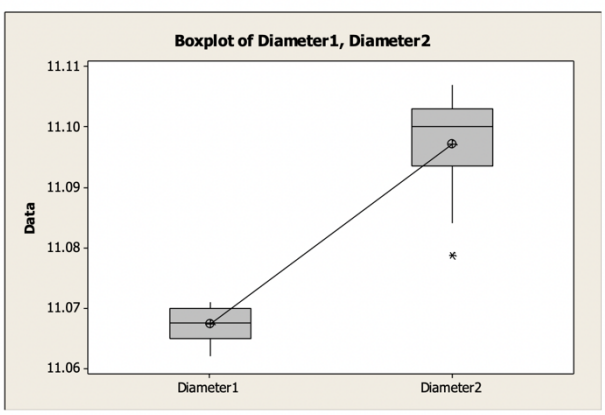

Figure 8. T-test results of Pin diameter

The T-test was utilized to test the effect of Pin diameter on chain length. There were 10 samples with the following assumptions;
H0: Pin diameter had an insignificant effect on the chain length value

H1: Pin diameter had a significant effect on chain length value
The result indicated that P-value was equal to 0.000 which was less than 0.05, thus the Pin diameter was found to have a significant effect on the chain length value.

Two-Sample T-Test and CI: Distance1, Distance2
Two-sample T for Distance1 vs Distance2

	N	Mean	StDev	SE Mean
Distance1	7	37.8586	0.0107	0.0040
Distance2	7	37.9397	0.0203	0.0077

Difference = mu (Distance1) - mu (Distance2)
Estimate for difference: -0.08113
95% CI for difference: (-0.09999, -0.06227)
T-Test of difference = 0 (vs not =): T-Value = -9.37 P-Value = 0.000
DF = 12 Both use Pooled StDev = 0.0162

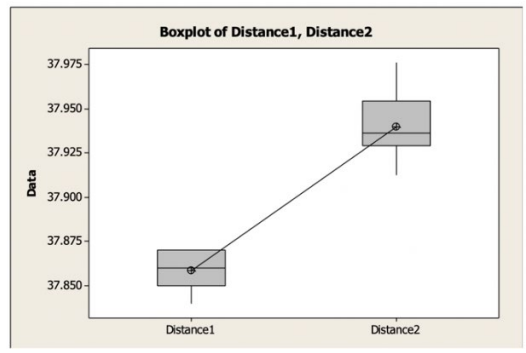

Figure 9. T-test results of Plate PH

The T-test was utilized to test the effect of Plate PH on chain length. There were 7 samples with the following assumptions;
H0: Plate PH had an insignificant effect on the chain length value

H1: Pin diameter had a significant effect on chain length value
The result indicated that P-value was equal to 0.000 which was less than 0.05, thus the Plate PH was found to have a significant effect on the chain length value.

Two-Sample T-Test and CI: Diameter1, Diameter2
Two-sample T for Diameter1 vs Diameter2

	N	Mean	StDev	SE Mean
Diameter1	10	11.06730	0.00283	0.00090
Diameter2	10	11.09720	0.00899	0.0028

Difference = mu (Diameter1) - mu (Diameter2)
Estimate for difference: -0.02990
95% CI for difference: (-0.03616, -0.02364)
T-Test of difference = 0 (vs not =): T-Value = -10.03 P-Value = 0.000
DF = 18 Both use Pooled StDev = 0.0067

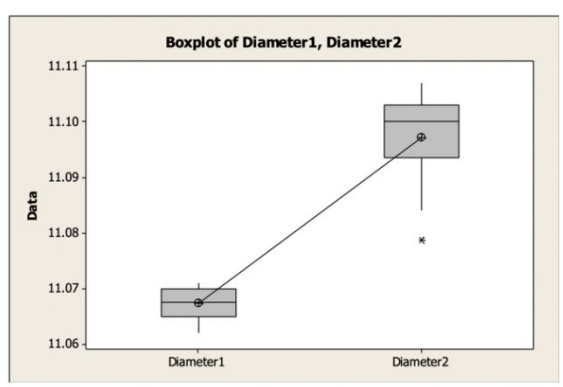

Figure 10. T-test results of Plate RH

The T-test was utilized to test the effect of Plate RH on chain length. There were 7 samples with the following assumptions;
H0: Plate RH had an insignificant effect on the chain length value

H1: Pin diameter had a significant effect on chain length value
The result indicated that P-value was equal to 0.027 which was less than 0.05, thus the Plate RH was found to have a significant effect on the chain length value.

Figure 11 represents input, process, and output of the current study.

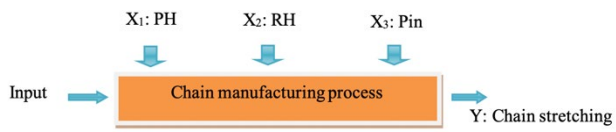

Figure 11. Input, process, output of the study

2.4 Improve phase

Based on the previous analysis, 4 steps were proposed in the improve phase as follows:

1) Sample design: by determined the standard deviation equal to 0.2, the critical difference equal to 0.63, and the power value equal to 0.9. Figure 12 represents the result of the iteration analysis and it was found that it is required 16 samples for the yields and 2 replications for the DOE.

Power and Sample Size
General Full Factorial Design
Alpha = 0.05 Assumed standard deviation = 0.2
Factors: 3 Number of levels: 2, 2, 2
Include terms in the model up through order: 3
Not including blocks in model.

Maximum Difference	Reps	Total Runs	Target Power	Actual Power
0.63	2	16	0.9	0.999748

Figure 12. The result from the iteration analysis

2) Factorial design: 2^k factorial design experiment with the number of replicated value equal to 2. From the data gathering, Analyzing the Model Adequacy Checking using residual analysis as shown in Figure 13. After consideration, it was found that there was no abnormality data, therefore, the data gathering from the experiment can be analyzed further.

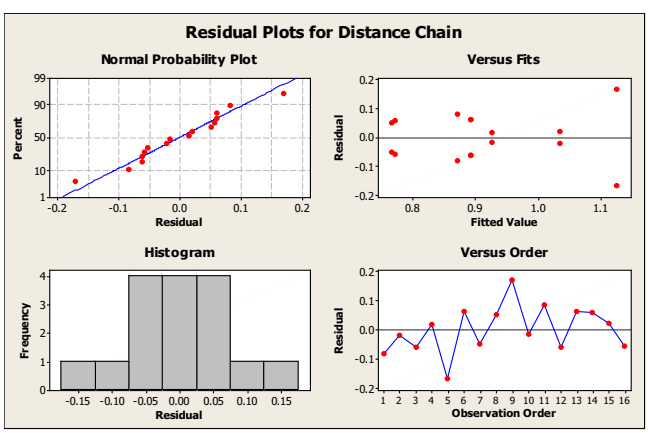

Figure 13. The result of residual analysis

3) Finding the appropriated value: by analyzing the factors that affect the chain stretching value as shown in Figure 14. The significant factors that affect the chain stretching value were Pin diameter, plate PH pitch length, and Plate RH pitch length.

Factorial Fit: Distance Chain versus PH, RH, PIN
Factors: 3 Base Design: 3, 8
Runs: 16 Replicates: 2
Blocks: 1 Center pts (total): 0
Analysis of Variance for Distance Chain (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	3	0.056141	0.056141	0.018714	1.50	0.038
PH	1	0.024571	0.024571	0.024571	1.97	0.049
RH	1	0.001208	0.001208	0.001208	0.10	0.04
PIN	1	0.030363	0.030363	0.030363	2.43	0.038
2-Way Interactions	3	0.036516	0.036516	0.012172	0.97	0.235
PH*RH	1	0.002525	0.002525	0.002525	0.20	0.045
PH*PIN	1	0.000410	0.000410	0.000410	0.03	0.021
RH*PIN	1	0.033581	0.033581	0.033581	2.69	0.040
3-Way Interactions	1	0.113738	0.113738	0.113738	9.10	0.017
PH*RH*PIN	1	0.113738	0.113738	0.113738	9.10	0.017
Residual Error	8	0.100026	0.100026	0.012503		
Pure Error	8	0.100026	0.100026	0.012503		
Total	15	0.306421				

S = 0.111818 PRESS = 0.400106
R-Sq = 67.36% R-Sq(pred) = 0.00% R-Sq(adj) = 38.79%

Figure 14. The result of factors that affected the chain quality

MINITAB was utilized to run the multiple linear regression [5-10]. P-value of 0.05 was set as a basis of significance level [11-14]. Figure 15 represents the result of the multiple linear regression and the distance chain can be predicted as follows:

Distance Chain = 91 - 1.96 PH + 0.43 RH - 2.90 PIN

Regression Analysis: Distance Chain versus PH, RH, PIN
The regression equation is
Distance Chain = 91 - 1.96 PH + 0.43 RH - 2.90 PIN

Predictor	Coef	SE Coef	T	P
Constant	90.7	100.6	0.90	0.005
PH	-1.959	1.805	-1.09	0.009
RH	0.434	1.805	0.24	0.004
PIN	-2.904	2.407	-1.21	0.001

S = 0.144418 R-Sq = 18.3% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.05614	0.01871	0.90	0.006
Residual Error	12	0.25028	0.02086		
Total	15	0.30642			

Figure 15. The resulted of regression analysis by MINITAB

Table 2. Control range and process set-up

Input Factor	Control Range (mm)	Process set-up Min	Mean	Max
Pin diameter	11.08 + 0.01	11.07	11.08	11.09
Plate PH pitch diameter	37.88 + 0.03	37.85	37.88	37.91
Plate RH pitch distance	38.10 + 0.02	38.08	38.10	38.12

4) Analyze the process capability after improvement by using MINITAB and use the gathered value to setup and control by random measuring (3 pieces per lot; 30 lots) as shown in Figure 16.

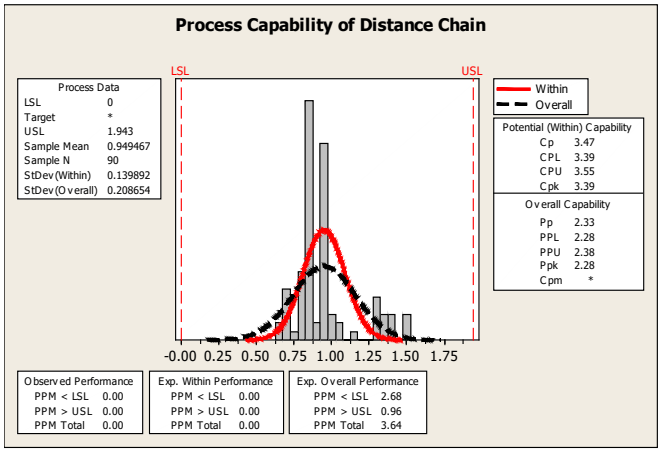

Figure 16. The result of process capability after improvement

The result of the process capability after improvement indicated that C_{pk} was equal to 3.39. Therefore, the process capability level was better than the standard of 1.33 or above, and P_{pk} was equal to 2.28. indicating a very high quality. Based on this improvement, the waste can be reduced in long-term process from 158, 629.86 PPM to 3.64 PPM.

2.5 Control Phase

During control phase, control charts and process variability by collected samples before and after improvement were utilized. The data were used in the control chart was the new data collected in a period of 2 months. Based on Figure 17, it was found that there was no waste generated from the roller chain production process.

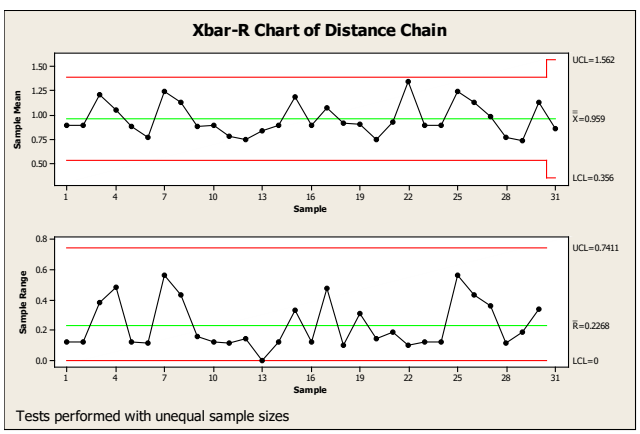

Figure 17. The x̄- R chart of chain stretching value

Table 3. Before and after improvement

Benchmark	Before Improvement	After Improvement	Percentage
Amount of waste (PPM)	158629.86	3.64	- 99.97%
Process capability (P_{pk})	0.50	2.28	+ 78.10%
Waste cost (THB)	37290	365	- 97.88%

It was found that the amount of waste before improvement was equal to 158,629.86 PPM and it could be reduced to 3.64 PPM (99.97%) after improvement. Furthermore, the production capability (P_{pk}) before the improvement was 0.50 and after the improvement was increased up to 2.28 (78.10%). Moreover, the waste cost before improvement was equal to 37,290 THB and it could be reduced to 365 THB (97.88%) after improvement.

3. RESULT AND CONCLUSION

This study aimed to enhance the efficiency of the manufacturing process and variation control of the roller chain value by utilizing the Six-Sigma techniques which can reduce the waste from the process of unappropriated size of the 120G chain.

From the analysis of production capability, P_{pk} value could be increased from 0.50, which was lower than the standard, to 2.28 (78.10% improvement), and could also reduce the defects from 158,629.86 PPM to 3.64 PPM (99.97% improvement)

Based on Failure Mode and Effects Analysis (FMEA), it was found that Pin diameter, plate PH pitch length, and Plate RH pitch length were indicators affecting the production quality. Consequently, the factors were tested to find the suitable factors by Design of the Experiment (DOE) and obtaining a suitable value. For Pin diameter, plate PH pitch length, plate RH pitch length were 11.08 ± 0.01 mm., 37.88 ± 0.03 mm., 38.10 ± 0.02 mm., respectively, and will be applied in the production process.

Six-Sigma methodology (DMAIC), Failure Mode and Effects Analysis, and sophisticated improvement tools and techniques were applied to determine those problems [15-19]. It was found that the defect significantly decreased. To sustain the results, the company should strictly follow the new operational standards. Simple but suitable tools and techniques can improve productivity in manufacturing enterprise according to previous studies [15-19] In the end, the proposed Six-Sigma and FMEA approaches could also be applied to other chain stretch manufacturing industries worldwide [20-22].

4. ACKNOWLEDGEMENT

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Load Distribution and Lifting Duration Effects on Upper Limb Strain for Manual Handling

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ABSTRACT
The effects of load distribution and lifting duration on muscular strain of upper limbs were examined in the study. Fifteen task conditions that consisted of 5 load distributions (1 balanced and 4 unbalanced patterns) and 3 lifting durations (1, 2 and 3 s/lift) were performed in the experiment. A total of 15 subjects were recruited. Electromyographic data were measured from 5 muscles of right upper limb. Hand forces were obtained at both handles, which were equipped with load cells. The results showed that the upper limb muscular strains increased when the load distribution of objects lifted was not balanced. The lifting durations had the significant effect on the biomechanical behavior of upper limbs. The risk of musculoskeletal disorders of upper limbs became higher when fast lifting was performed. The study results suggested that the center of mass should be located at the center of the load and the lifting duration should not be shorter to reduce the risk of musculoskeletal injury to the operator.

CCS Concepts
• **Applied computing→ Life and medical sciences → Consumer health**

Keywords
Lifting; electromyography; load cell; upper limb

1. INTRODUCTION
Manual materials handling (MMH) tasks, such as lifting, are common in various industries [1] and are considered as a major occupational safety and health risk issue [2][3][4]. The weight and its distribution, shape, stiffness, and handles are the object characteristics that must be taken into account in the design of lifting tasks [5]. Lifting of non-homogeneous loads is commonly found in many industrial tasks. Unbalanced lifting occurs when a load lifted is not homogeneous in its content, or the content is unstable (liquid), which changes its center of gravity while the object is handled. The load distributions of objects are often unbalanced in lifting tasks and these loads would generate counter balance body behavior acting to compensate the content or shape of the load, which results in a non-symmetrical lifting [4]. Meyers and Keir [3] stated that peak electromyographic activity of the upper erector spinae and latissimus dorsi increased with the weight in the compartments nearest the body and/or the ipsilateral handle. Thus, lumbar spine could be often damaged mechanically due to asymmetric or unbalanced lifting movement [3].

Numerous studies have discussed the effects of lifting activities on low back (e.g., [3][4][6][7][8]) because the most significant injuries could occur in this body part while lifting. Lifting is a complex dynamic task involving not only the spine but also the upper and lower extremities [6]. Oliveira et al. [9] stated that the part of the body most affected is the lumbar spine and the epidemiological studies also reported high prevalence of work-related musculoskeletal disorders in other body sites. While the spinal load during several types of MMH activities has been well studied, the upper limb load effect still remains neglected.

Lifting duration, which might be used the term 'lifting speed' in some studies, is a biomechanical variable to be considered during lifting tasks. However, the revised lifting equation developed by National Institute for Occupational Safety and Health (NIOSH) does not apply the lifting with high speed motion [10]. Lin and Cheng [11] stated that the lifting duration/speed was a significant factor in the lifting capacity and also indicated that the maximal lifting capacity was achieved around the optimal speed that was neither too fast nor too slow. An increase of the lifting speed is known to increase the torque at the low back in asymmetric lifting movements [12]. Lavender et al. [13] indicated that the lifting tasks tested showed increased sagittal plane (forward bending) spine moments with the heavier load and at the faster lifting speed.

Compared with the lifting tasks with unbalanced load, there are few studies on biomechanical behaviors of upper limbs in the literature. The purpose of this study was to explore the biomechanical behaviors of upper limb muscles for the lifting tasks with various load distributions and different lifting durations. This study hypothesized that the unbalanced distributions and shorter lifting durations would increase the upper limb muscular strains.

2. MATERIALS AND METHOD
2.1 Subjects
Fifteen university male students were recruited to participate for the experiment as paid volunteers. Their ages ranged from 20.9 to 25.4 years (mean 23.9 /SD 1.7); body height from 165.7 to 185.3 cm (mean 173.9 /SD 5.7); and body weight from 54.2 to 76.0 kg (mean 67.8 /SD 6.5). The body mass index (BMI) were calculated and ranged from 19.3 to 25.0 kg/m^2 (mean 22.4 /SD 2.0). All subjects were free of known musculoskeletal injuries and described themselves as right-handed. The study was approved by

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the Institutional Review Board for Ergonomics Experiment of Chaoyang University of Technology.

2.2 Apparatus

A simulated box designed and manufactured in the study was made of an acrylic board (45×25×1.7 cm). To obtain lifting hand forces applied on acrylic board two tri-axial load cells (LSM-B-500NSA1, Kyowa) were equipped between the acrylic board and the wooden handles located at both sides as shown in Figure 1. The dimension of the wooden handle was 2.38 cm in diameter and 12 cm in length. Two handles were 35.8 cm apart, which was adopted from 50th percentile of shoulder width of Taiwanese male [14]. The handle height is 17 cm above the acrylic board bottom. The anterior-posterior direction of lifting hand force is defined as x component which is parallel to the handle of the box lifted, the medial-lateral direction as y component perpendicular to the handle and the upward-downward direction as z component in the vertical plane. The load cell of 1.6 kg weight has maximum measurable force of 500 N and safe moment of 59 Nm. This device converts force into electrical signals. The total load weight lifted in the experiment was 9 kg. The load weights were adjusted by attaching 2 standard weights (2 kg each) on the acrylic board in this study and secured so that they did not move during lifting. The hand forces measured using the tri-axial load cells were considered as the reaction forces acting on the subject's hands during the experiment.

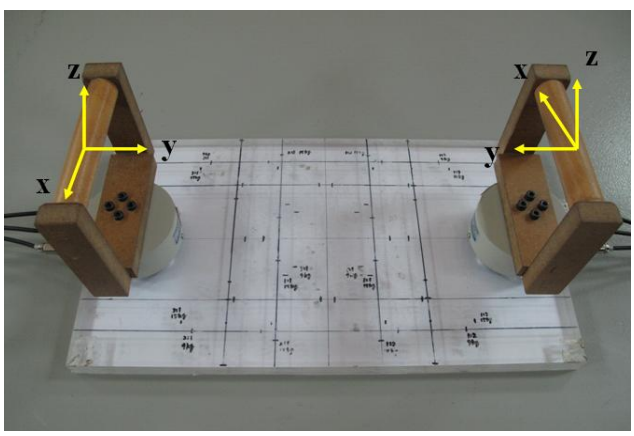


Figure 1. A simulated box equipped with 2 tri-axial load cells and 2 wooden handles. The standard weights attached on the acrylic board are not shown in the figure

Surface electromyographic (sEMG) measurements taken from five muscles of subjects' upper limb using disposable skin surface electrodes were obtained with a computer-based data acquisition system (MP150, Biopac Systems) during lifting. These muscles selected in the hand-arm-shoulder complex were brachioradialis, biceps brachii, triceps brachii, anterior deltoid, and upper trapezius. Muscles involved, movement types and the studies referred for the experiment are shown in Table 1. The raw sEMG signals were amplified with gain of 5000, lowpass filtered at 500 Hz, and digitized at a rate of 1000 Hz. Both EMG and load cell systems were synchronized using an event marker.

Table 1. Muscles involved, movement types and the studies referred

Muscles involved	Movement type	Referred studies
Brachioradialis,	Forearm flexion	Habes et al.(1985), Strasser and Müller (1999), Kothiyal and Kayis(2001)
Biceps brachii	Forearm flexion	Habes et al.(1985), Strasser and Müller (1999), Kothiyal and Kayis(2001)
Triceps brachii	Forearm extension	Kothiyal and Kayis (2001)
Anterior deltoid	Upper arm flexion	Habes et al.(1985), Kothiyal and Kayis (2001)
Upper trapezius	Elevation of the scapula	Habes et al.(1985), Strasser and Müller (1999)

2.3 Tasks

Five load distribution patterns with different load center of mass (CoM) locations on the acrylic board were designed and used in the experiment, consisting of one balanced and four unbalanced patterns. Two standard weights of 2 kg each were attached so that the CoM on each half side of the acrylic board formed a specific load pattern shown in Table 2. Three lifting durations used in the experiment were 1, 2 and 3 sec/lift. The lifting duration of 2 sec/lift could be considered as normal lifting duration according to the experiment of De Looze et al. [12]. The lifting durations of 1 and 3 sec/lift were thus taken as the fast and slow movements in this study. The experimental settings are summarized in Table 3. In the Table, the horizontal lift origin and lifting destination were measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps, where an object was lifted at the start and placed at the end of the lift, respectively.

Table 2. Five load patterns with different load center of mass locations for experiment setting

Orientation	Load distribution pattern		
	Balanced pattern	Unbalanced pattern	
Left-right (coronal plane)	1 : 1[a] (center)[b]	2 : 1 (left)	1 : 2 (right)
Posterior-anterior (sagittal plane)	--	2 : 1 (posterior)	1 : 2 (anterior)

[a] indicates the ratio of load weights to two half sides of the acrylic board when standard weights were attached at specific locations.
[b] denotes the location of CoM with a short term in the following.

Table 3. Summary of the experimental settings

Lifting parameter	Type / Magnitude
1.Vertical lift origin	Handle height: 17 cm above the floor
2.Vertical lifting destination	Waist height
3.Horizontal lift origin	45 cm
4.Horizontal lifting destination	70 cm
5.Total load weight lifted	9 kg
6.Lifting type	Free style with standing posture and sagittally symmetric lifting
7.Lifting duration	1, 2, 3 sec/lift

2.4 Experimental Protocol

The parameter settings of surface electromyographic measurement system and tri-axial load cell system were calibrated at the start of the experiment. After a clear explanation of the objectives and procedures of the experiment was given and a written consent from subject was obtained, anthropometric data were measured. Surface electrodes were then attached to five muscles in the hand-arm-shoulder complex shown in Table 1. Before the experiment the maximum voluntary contraction (MVC) of each muscle of the subject was obtained. The positions and tests for the MVCs were taken according to the suggestion of Hislop et al. (1995) [15].

Subjects were asked to lift a simulated box sagittally and symmetrically with free style (i.e., both the knees and the torso were required to flex) in an upright standing posture in the study. A brief training period for subjects was provided to get enough practice and familiarity with the task before actual data were collected. Subjects were also trained to comply with the imposed work rate by following a metronome, which was used to pace subjects during the experiment. The order of fifteen lifting conditions was randomized for each subhject. Subjects were instructed not to move their feet during lifting. The measurements of sEMG and load cell were collected and two trials for each task condition were made. At the end of each experiment subject was asked to take a 3-minute break or more if required. When the oral consent from the subject was obtained another task was then performed. The experimental measurements were preliminarily checked during the break. Repetition of the experiment was needed if the experimental data errors were found. Subjects were given the opportunity to ask any question in the study and had the option to withdraw any time during the experiment.

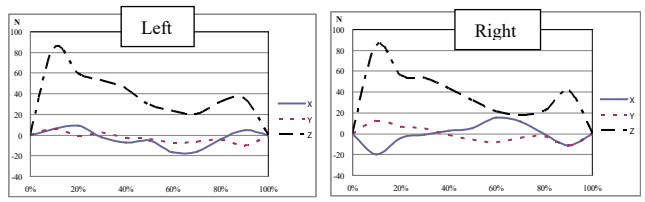
2.5 Data Analysis

The sEMG measurements obtained in the experiment were processed with a window-based software, Viewlog, which was developed with LabVIEW 7.0 (National Instruments, USA) in the laboratory [7]. The root mean square (RMS) values, obtained from the raw sEMG signals, were normalized using the formula suggested by Lavender and Marras [16]: nRMS = (RMS(lift)—RMS(resting)) / (MVC—RMS(resting)). The nRMS indicates normalized root mean square. The calculation details were described in Chen et al. [7]. The peak and mean hand forces measured from load cells were calculated with Excel software. The repeated measures analysis of variance (ANOVA) was used to examine the statistical significance and Duncan's new multiple range test was applied for post hoc test (α=.05) for the experimental parameters.

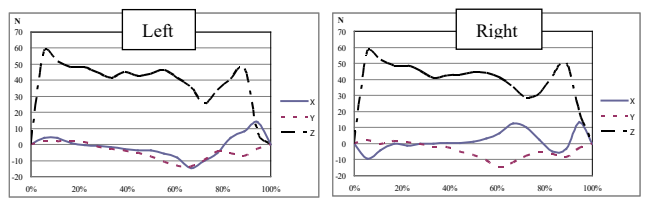
3. RESULTS

3.1 Hand Force

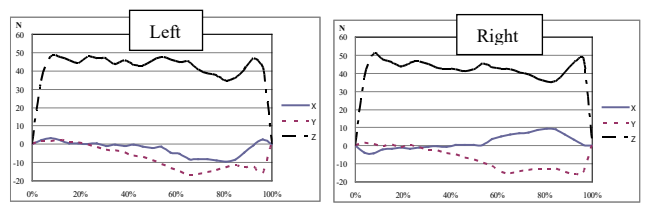
The pattern of hand forces for the lifts performed by subjects was similar for virtually all trials in this study. An example of hand forces over time performed by a subject (body height of 167.4 cm and body weight of 54.2 kg) to lift a balanced load with three lifting durations is demonstrated in Figure 2. In the figure, the x axis represents the lifting cycle time in percent, where 0% denotes the starting time and 100% is the finish time for a lifting cycle. As would be expected, the z-component hand forces (i.e., in upward-downward direction) illustrate the most dominant part of the forces during lifting. The z-component hand forces at 1 sec/lift varied more apparently during the lift compared to those with the other two lifting durations. The hand forces varied gradually during the lift when the lifting duration became greater. The mean hand force percentages on both hands for different load patterns and lifting durations were shown in Table 4.



(a)Lifting duration=1 sec/lift



(b)Lifting duration=2 sec/lift



(c)Lifting duration=3 sec/lift

Figure 2. Hand forces at different lifting durations obtained from a subject

Table 4. Mean hand force percentages on both hands for different load patterns and lifting durations

Lifting duration	1 s/lift	2 s/lift	3 s/lift
1.Balanced pattern	50.5% / 49.5%	50.4% / 49.6%	50.5% / 49.5%
2.Unbalanced pattern			
2:1(coronal plane)	60.1% / 39.9%	59.8% / 40.2%	60.5% / 39.5%
1:2(coronal plane)	41.8% / 58.2%	39.9% / 60.1%	40.5% / 59.5%
2:1(sagittal plane)	51.3% / 48.7%	50.5% / 49.5%	50.0% / 50.0%
1:2(sagittal plane)	50.5% / 49.5%	50.4% / 49.6%	50.4% / 49.6%

The statistic result of peak resultant forces obtained with ANOVA is shown in Table 5. Both lifting duration and load pattern have significant effects on the peak resultant forces of both hands. However, no significant interactions were found between lifting duration and load pattern on each hand. The Duncan's multiple range test analysis is shown in Tables 6 and 7 by lifting duration and load pattern, respectively, when the statistically significant difference was found.

Table 5. The ANOVA results of peak resultant forces. (n=15)

Hand	Left	Right
Load duration (LD)	*	*
Lifting pattern (LP)	*	*
LD × LP	NS	NS

NS: no significance

Table 6. The Duncan's new multiple range test results of peak resultant hand forces by lifting duration. (n=15)

Hand	Lifting duration (s/lift)	Mean (N)	Duncan grouping
Left	1	77.81	A
	2	55.78	B
	3	51.87	C
Right	1	74.72	A
	2	55.21	B
	3	51.03	C

The same letters in Duncan grouping are not significantly different (α=.05).

Table 7. The Duncan's new multiple range test results of peak resultant hand forces by load pattern. (n=15)

Hand	Load pattern	Mean (N)	Duncan grouping
Left	Right	51.73	A
	Anterior	60.78	B
	Posterior	61.87	B
	Center	62.62	B
	Left	73.10	C
Right	Left	49.68	A
	Anterior	59.06	B
	Center	60.24	B
	Posterior	61.18	B
	Right	71.43	C

The same letters in Duncan grouping are not significantly different (α=.05).

3.2 Surface Electromyography

Mean sEMG followed similar patterns to the peak sEMG, thus only peak sEMG data were presented in the study. The statistic results of %MVC obtained with ANOVA are shown in Table 8. Lifting duration had significant effects on the upper limb muscles tested in this study. However, load pattern had significant effects on the upper limb muscles only at left and right brachioradialis, right biceps brachii and right anterior deltoid. There were no significant interactions found between lifting duration and load pattern on each hand. The Duncan's multiple range test analysis is shown in Figure 3 and Table 9 when the statistically significant difference was found by lifting duration and load pattern, respectively.

Table 8. The ANOVA results of %MVC. (n=15)

Tested muscle	Lifting duration (LD)	Load pattern (LP)	LD×LP
Brachioradialis			
Left hand	*	*	NS
Right hand	*	*	NS
Biceps brachii			
Left hand	*	NS	NS
Right hand	*	*	NS
Triceps brachii			
Left hand	*	NS	NS
Right hand	*	NS	NS
Anterior deltoid			
Left hand	*	NS	NS
Right hand	*	*	NS
Upper trapezius			
Left hand	*	NS	NS
Right hand	*	NS	NS

NS: no significance

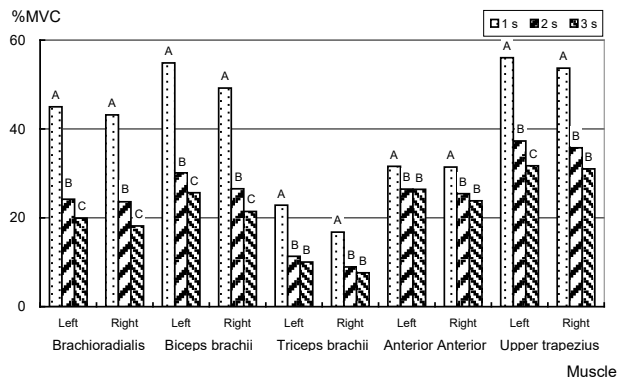


Figure 3. The Duncan's new multiple range test results of %MVC by tested muscle and lifting duration. Scores with the same letter are not significantly different. (α=.05)

Table 9. The Duncan's new multiple range test results of %MVC by load pattern. (n=15)

Tested muscle	Load pattern	Mean (%MVC)	Duncan grouping
Brachioradialis			
Left	Posterior	24.2	A
	Right	25.6	AB
	Center	29.2	BC
	Left	33.3	CD
	Anterior	36.3	D
Right	Posterior	24.1	A
	Left	24.6	A
	Center	28.1	AB
	Right	31.0	BC
	Anterior	33.8	C
Biceps brachii			
Right	Left	27.0	A

	Posterior	30.2	AB
	Center	32.2	B
	Anterior	33.7	B
	Right	38.9	C
Anterior deltoid			
Right	Left	23.7	A
	Posterior	25.9	AB
	Center	26.7	AB
	Anterior	28.1	B
	Right	30.1	B

The same letters in Duncan grouping are not significantly different (α=.05).

4. DISCUSSION

The forces exerted in previous studies of biomechanical modeling (e.g., Agruss et al. [17]) were usually assumed to be the same on each hand of the subject while performing manual handling. The mean hand force on each handle was about the same (i.e., 50% each) shown in Table 4 when the CoM was located at the center, posterior or anterior (in the sagittal plane) of the box. However, the ratio of mean hand forces was about 40%: 60% when the load distribution was 33.3%: 66.7% in the coronal plane. The peak resultant force results showed the same tendency with different load distribution patterns as shown in Table 7. This implied that the forces exerted did not equally distribute to each hand when the unbalanced loads occurred in the coronal plane. Unilateral musculoskeletal injury might be easily accumulated due to such asymmetric manual lifting for long periods of time. Furthermore, care should be taken to apply the hand forces for biomechanical study when performing unbalanced manual lifting.

The upper limb muscular strain was examined in this study. It was found that brachioradialis obtained the smallest and the greatest %MVCs among load distribution patterns when the CoM was located at posterior and anterior, respectively. The other four upper limb muscles tested did not show significant difference or appear at the same activity level but the %MVCs of biceps brachii and anterior deltoid at anterior were larger than those at posterior. Based on the study results, this might suggest that the CoM should be located closer to the subject to reduce the %MVC values. Meyers and Keirs [3] examined the effects of unbalanced lifting on trunk muscles and found that the highest erector spinae muscle activity occurred with the load lifted was nearer to the subject. Future study to observe the biomechanical responses of both upper limb and trunk muscles should be discussed.

Uniaxial hand forces were measured during manual lifting in some studies (e.g., Meyers and Keirs [3]). Tri-axial load cells were used to measure hand forces during the lifting in this study. It was observed in Figure 2 that the most dominant part of the hand force was the z-component. However, the effects of x- and y- component forces should not be negligible during lifts to obtain more accurate estimate of biomechanical strains.

The peak resultant hand forces and %MVC values increased when the lifting duration became shorter (i.e., faster lifting speed) in the study. Gundogdu et al. [18] used a two-dimensional sagittally symmetric human-body model to examine manual lifting tasks and addressed that if one too greatly increases the rate at which a task is accomplished, the task may require over exertion, which can be injurious to the individual involved. The present results were consistent with some previous studies. Lavender et al. [8] indicated the peak dynamic moment increased with greater load magnitudes, and when lifting faster. Bernard et al. [19] stated that average absolute inertial moment increased when the lifting speed increased. Gundogdu et al. [18] stated that higher levels of joint moments, as well as significantly more energy were required in fast lifting. However, the back muscles and intervertebral discs (L4/L5 or L5/S1) were the body parts to be observed for lifting duration in previous studies. The hand force and sEMG results of upper limb muscles during lifting at various lifting durations in this study could provide some useful experimental data.

When the load characteristics are not known or incorrectly judged, lifts could result in higher moments on the lumbar spine and loss of balance (Meyers and Keir [3]). Meyers and Keir [3] stated no electromyographic activity differences on trunk muscles were found between the known and unknown load distributions during lifting. De Looze et al. [20] concluded that in the unknown conditions, the risks of low back injury were increased in comparison with the conditions where the actual weight was known in advance. The load distributions could be observed by subjects before the experiment due to the box design in the study. It is unknown and need to be further examined if the results obtained from the upper limb muscles would be the same.

5. CONCLUSION

The load distributions of objects lifted are often unbalanced in industrial environment and might result in the increase of the musculoskeletal disorders when manual lifting is performed. The experimental results of this study found that the CoM should be located at the center of the load and the lifting duration should not be shorter to reduce the risk of musculoskeletal injury to the operator.

6. ACKNOWLEDGMENTS

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Session VIII

Mechanical and Electronic Technology

Data Augmentation Using Generative Adversarial Networks for Electrical Insulator Anomaly Detection

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ABSTRACT

Electrical insulators, which are widely used for electricity transmission, are prone to be damaged and need constant maintenance. Traditionally, the inspection job is time-consuming and dangerous as workers have to climb up the electricity tower. Deep learning, which has offered a safe and quick way to inspections, however, requires large amounts of data. Generative adversarial networks (GANs) are introduced as a novel approach to augmenting data. However, traditional state-of-art GANs are either incapable of generating high quality images or fail to generate minority class images when minority class examples are far less. In order to mitigate drawbacks of existing GANs, a novel GAN model, Balancing and Progressive GANs (BPGANs), was proposed for effectively making use of all classes information and generating high quality images simultaneously. Results showed that PGANs, StyleGANs, and BPGANs were able to generate high-resolution images and improve classification performance. PGANs achieved the better results than BPGANs. This might be because BPGANs only provides 2 additional latent codes since it is a binary classification, having little effect on generating desired images. BPGANs seemed to have difficulties generating class-specific images, which might be because that the classification loss is too little compared to the source loss and optimization was more focused to optimize the source loss. This indicated that learning representations of data progressively from low resolution to high resolution is an effective approach, however, embedding class label information in the fashion of AC-GANs and BGANs might not be appropriate for augmenting binary class datasets.

CCS Concepts

• **Computing methodologies → Artificial intelligence → Computer vision → Computer vision tasks → Scene anomaly detection**

Keywords

Data augmentation; generative adversarial networks; anomaly detection; insulators

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1. INTRODUCTION

There is a huge demand for electricity in the U.S. U.S. net electricity generation increased by 4% in 2018, reaching a record high of 4,178 million megawatt hours (MWh), surpassing once again the pre-recession peak of 4,157 million MWh set in 2007. Both the residential (about 1,500 MWh) and commercial sectors (about 1,400 MWh) reached all-time highs for retail sales of electricity in 2018 [25]. Power cut can cause large loss to all sectors of society. According to the report from the U.S. Energy Information Administration in 2013 [19], between 2003 and 2012, an estimated 679 widespread power outages occurred due to severe weather. Power outages close schools, shut down businesses and impede emergency services, costing the economy billions of dollars and disrupting the lives of millions of Americans. Therefore, regular inspections are required to prevent faults that cause power outage. Visual inspections on transmission lines is the common way to maintain electricity supply. They are usually carried out by skilled worker foot-patrolling or using helicopter-assisted methods [16], which is costly and risky.

Many efforts have been made to help inspect electrical transmission lines more efficiently. Drones and robots that are capable of patrolling are made to increase inspection safety and lower costs [11, 6, 23]. After images and videos are collected from robots, trained workers spend huge amount of time to look at them looking for any faults. This obviously is time-consuming and prone to human bias. To reduce the human bias and better classify insulators, new approaches should be explored.

Huge advances have been seen in the field of deep learning in recent years. Various types of deep neural networks (DNN) have achieved great success in various computer vision tasks, such as image classification [12, 24, 7] and object detection [2, 22, 21]. One of the drawbacks of deep learning methods is that they generally require huge amount of data in order to classify insulators. When training examples are not sufficient, there are several approaches to augmenting data, including image oversampling, random rotation, shifts, and etc. However, traditional data augmentation techniques do not improve the results significantly [1]. In addition to limited datasets, class imbalance also creates many problems for neural network classifiers [13]. Thus, it is necessary to propose new strategies to enrich dataset and mitigate data imbalance issues.

In recent year, generative modeling, as a more promising approach to data augmentation, has risen, especially generative adversarial networks (GANs). GANs were first introduced in 2014 [5]. Since then, various GAN extensions were proposed, such as CycleGANs, DCGANs, and PGANs [29, 20, 9]. GANs have shown superior results compared to traditional data augmentation techniques as they are capable of imaging different alterations to images such that they have a better understanding of them [13]. However, these GANs might not work well when

dataset suffers severe class imbalance issue, because they are trained on the minority class examples for generating new examples and the GANs are not likely to learn well from a minority class, which has very few examples. In order to mediate the class imbalance issue, another branch of research has been focusing on developing the conditional version of GANs [18, 15, 14] aiming to include class label in GANs training. However, these conditional version of GANs generally works well with relatively low-resolution dataset, such as images whose size are only 64×64 or 128×128.

To overcome the limitations of existing GANs, we need to assess the ability of various GANs on data augmentation and propose new approaches based on their existing limitations. Thus, the objectives of this study include:

- Train a DNN classifier on the original dataset, which is not augmented and is imbalanced, to classify damaged insulators against good insulators. The classification results can serve as the baseline.
- Train various GANs models to augment and balance the dataset. Then, train the same classifier on the augmented dataset and compare the classification performance against the baseline.
- Propose and develop a new model that is able to make use of class label information and can generate high-resolution images.

2. RELATED WORK

In this section, we review on recently proposed GANs for generating high-resolution images and GANs for conditional image synthesis.

2.1 Generative Adversarial Networks

Generative models try to learn the statistical distribution of the training data, allowing synthesizing data from the learned distribution. The key incentive behind GANs is estimating the underlying probability density or probability mass function of the observed data. GANs learn the probability distribution implicitly by computing the similarity of the distribution between the real training examples and the fake data generated by the learned model. After the model is trained well, it naturally can be used to generate data that have similar distribution as the real data.

GANs typically consist of a generator and a discriminator. The two compete against one another: the generator tries to fool the discriminator by producing fake data and the discriminator aims to distinguish the fake data from the real data. The learning process is guided by a minimax game (See Equation 1) where the discriminator (D) desires to increase the log-probability when images (x) are sampled from the real distribution ($p_{data}(x)$) and wishes to decrease the log-likelihood when data is sampled from the generator. Meanwhile, the generator (G) wishes to increase the log-likelihood of fake images being classified as real when images are sample from the generator $p_z(z)$, where z is called the latent vector and is usually sampled from a normal distribution. As learning progresses the discriminator gets better at classifying the data being real or not and the generator becomes better at producing realistic data. Naturally, the generator can then be used to generate data when training examples are not sufficient.

$$\min_G \max_D V(D,G) = \mathop{E}_{x \in p_{data}(x)} [logD(x)] + \mathop{E}_{z \in p_z(z)} [\log(1 - D(G(z)))] \quad (1)$$

2.2 GANs for Generating High-resolution Images

GANs have difficulties in generating high-resolution images as they make it easier for the discriminator to distinguish the fake images among the real data. High-resolution data also prevents from using larger minibatches due to GPU memory limitations and thus compromising training stability [9, 18]. Based on the work of Wang et al., 2017 [26], Durugkar et al., 2016 [4], and Hierarchical GANs [3, 8, 27], Karras et al., 2018 [9] proposed PGANs, whose key idea is to grow both the generator and discriminator progressively, starting from easier low-resolution images, and add new layers that introduce higher-resolution details. This speeds up training and improves stability. Following the trace of PGANs and the idea of style transfer, Karras et al., 2019 [10] proposed a style-based generator for GANs. It features an automatically learned, unsupervised separation of high-level attributes and stochastic variation in the generated images, which enables intuitive, scale-specific control of the image synthesis.

2.3 GANs for Conditional Image Synthesis

Another branch of research focuses on GANs that can embed label information into GANs training process, aiming to generate class-dependent images [14, 15]. Conditional GANs [15] incorporate labels (y) into both generator and discriminator by modelling the conditional probability: $logD(x|y)$ and $\log(1 - D(G(z|y)))$. As a result, the objective function in Equation 1 is slightly modified into the conditional form (See Equation 2).

$$\min_G \max_D V(D,G) = \mathop{E}_{x \in p_{data}(x)} [logD(x|y)] + \mathop{E}_{z \in p_z(z)} [\log(1 - D(G(z|y)))] \quad (2)$$

Mariani et al., 2018 proposed Balancing GANs (BGANs) [14] as an augmentation tool to restore balance in imbalanced datasets. They argued that the few minority-class examples may not be enough to train a GAN, so they incorporated all available images of majority and minority classes. BGANs try to achieve class balance by applying class conditioning in the latent space to drive the generation process towards the target class. BGAN features an autoencoder that learns an accurate class-conditioning in the latent space and then initializes the generator with the encoder.

Based on conditional GANs, Odena et al., 2017 proposed Auxiliary Classifier GANs (AC-GANs) [17], which not only supplies both the generator and discriminator with class labels, but also includes a classifier to classify the image category. This model produces good results and appears to stabilize training compared to the standard GAN formulation. The objective function has two parts: the loglikelihood of the correct source, L_s, and the log-likelihood of the correct class, L_c.

$$L_s = E[\log \mathrm{P}(S = real|X_{real})] + E\left[\log \mathrm{P}\left(S = fake\middle|X_{fake}\right)\right] \quad (3)$$

$$L_c = E[\log \mathrm{P}(C = c|X_{real})] + E\left[\log \mathrm{P}\left(C = c\middle|X_{fake}\right)\right] \quad (4)$$

D is trained to maximize $L_s + L_c$ while G is trained to maximize $L_c - L_s$. C denotes class labels and S is the source of images fed into the discriminator.

3. METHOD

As mentioned in the previous section, existing GANs cannot produce high-resolution images and embed class label information at the same time. In order to address this limitation, a new GANs model, which is called Balancing and Progressive Growing GANs (BPGANs), is proposed.

The idea of BPGANs comes from BGANs, AC-GANs, and PGANs. In AC-GANs [17], the GANs embeds the class label information by having an extra classifier to predict which class images that are fed to discriminator belongs to. Instead of sampling from a standard normal distribution for initializing the latent vectors when training GANs, BGANs [14] uses a variational autoencoder that is trained to obtain a class-independent latent vector generator, which is then used to provide initialization for the random latent vectors for different class labels. Lastly, BPGANs also borrows idea from PGANs [9], which is able to generate high-resolution data by training the generator and the discriminator progressively from low resolution to high resolution. The proposed BPGANs model embeds class label information during training and is capable of generating high-resolution images. The architecture of BPGANs is shown in Figure 1, where both generator and discriminator are trained from low resolution of 4×4 to a high resolution of 512×512. The objectives of BPGANs are illustrated in Equation 3, 4 and the latent vectors (z) were sampled from a dense representation that was learned from a class label dependent variational autoencoder.

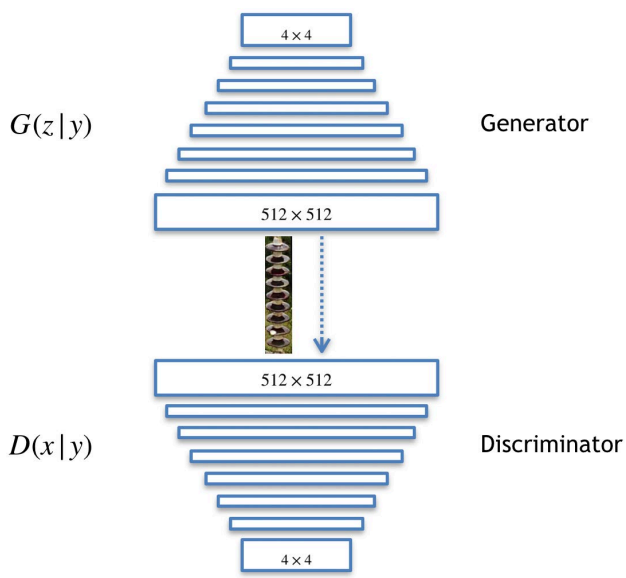

Figure 1. Architecture of BPGANs

4. DATASET

Drones were used to take images of insulators. Raw insulator images were then annotated and labeled as damaged or undamaged. Next, images were cropped, and 3,861 individual insulators were obtained in total, among which 2,972 are good insulators and the rest of 989 insulators are damaged. 80% of images were used as training dataset and the rest was equally split as validation and test dataset. Some examples of insulators are shown in Figure 2. (a) is a raw image of insulator image taken by a drone. (b) and (c) are examples of good and damaged insulator, respectively.

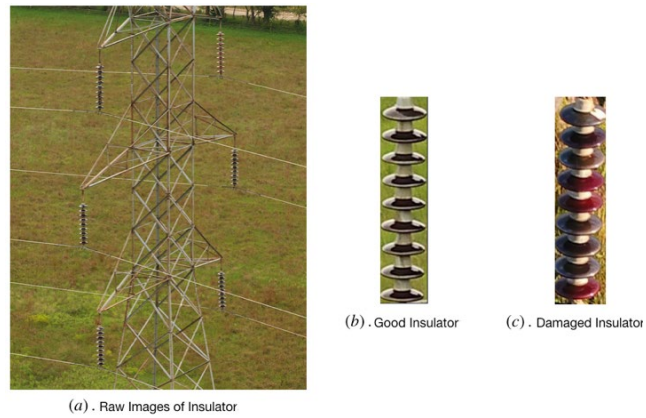

Figure 2. Examples of Insulators

5. RESULTS

In this section, results of various GANs models from the previous section, are discussed. GANs were trained with the purpose of augmenting the unbalanced dataset, so different GANs were then used to generate minority-class images. Therefore, a DNN classifier trained with dataset with and without augmentation was used to evaluate the quality of generated images by different GANs. In order to assess the diversity of images generated by GANs, structural similarity indices (SSIM) [27] were calculated and compared among different GANs.

5.1 Image Quality Assessment

Several examples of generated damaged insulators by BGANs are shown in Figure 3. BGANs is designed to work with images whose size is 64×64, and since the final output image resolution is 512×512, so the generated images from BGANs are blurry.

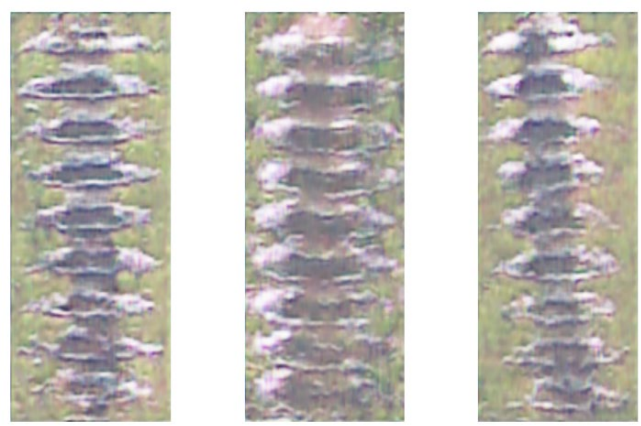

Figure 3. Damaged Insulator Examples Imagined by BGANs

Three examples of damaged insulators produced by AC-GANs are shown in Figure 4. AC-GANs produced images that have better quality than that of BGANs, but they are still blurry and difficult to distinguish damaged versus good insulators. This might be owing to that the classification loss was dominated by the source loss and much optimization was done to decrease the source loss.

Figure 4. Damaged Insulator Examples Imagined by AC-GANs

Compared to images generated by BGANs and AC-GANs, StyleGANs was able to produce images with much higher quality. Four examples are shown in Figure 5, where the first three images are of better quality and the last one is one of the poorly produced image examples.

Figure 5. Damaged Insulator Images Imagined by StyleGANs

PGANs was able to produce images with similar quality as StyleGANs. Four examples are shown in Figure 6, where the first three images have better quality and the last one is a little blurry. Compare to images generated by StyleGANs, PGANs seems to be able to produce images with better image quality, where flashovers (white dots on insulators) are clearer to spot.

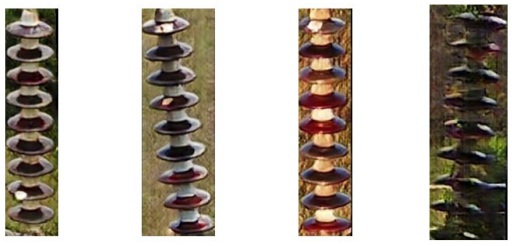

Figure 6. Damaged Insulator Examples Imagined by PGANs

BPGANs produced mixed results. Some damaged insulators are shown in Figure 7. (a) and (b) look like damaged insulators. (c) seems to be a good insulator and (d) and (e) are blurry. The reason that some damaged insulators imagined by BPGANs look like undamaged insulators might be because that the classification loss is too little compared to the source loss and more optimization was done to reduce the source loss.

(a) (b) (c) (d) (e)

Figure 7. Damaged Insulator Examples Imagined by BPGANs

In order to assess the quality of generated images from GANs, the images were evaluated by a trained classifier. The rationale behind this assessment strategy is that more examples can be recognized as damaged by the trained classifier, the better the image quality. The results from different GANs are summarized in Figure 8. It showed that the trained classifier only recognized nearly 30% of damaged insulators produced by BGANs as damaged, which makes sense as the image quality of the generated images is poor. AC-GANs achieved better results than BGANs. StyleGANs and PGANs produce images with much higher quality, and as a result more images are recognized as damaged. Since BPGANs generated images with mixed quality, it did not achieve highest result among all GANs. The results showed that PGANs, StyleGANs, and BPGANs produced images with high recognition rate.

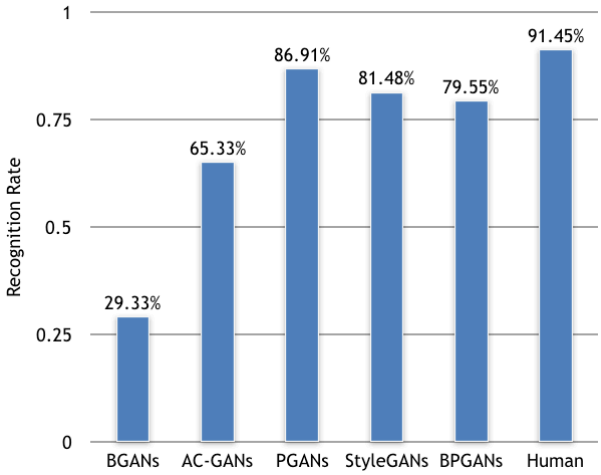

Figure 8. Recognition Rate of Damaged Insulators by Different GANs

5.2 Image Diversity Assessment

In order to assess how diverse the generated images are, SSIM values were calculated for images from different GANs. For each groups of images produce by GANs, 100 images were randomly selected and SSIM values were calculated. Figure 9 shows the maximum SSIM values and standard deviations for different GANs. Low similarity results from all of GANs indicated that images do not look like one another within each group.

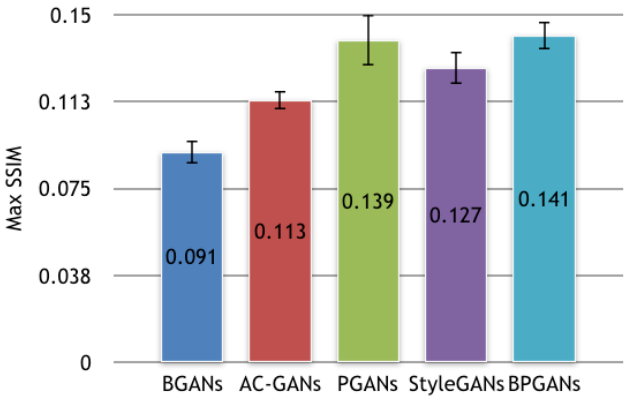

Figure 9. Similarity Comparison on Images Produced by GANs

To verify how similar imagined examples by GANs to the training examples, in other words whether the training overfitted, SSIM

values were compared against the closest images in the training dataset. Similarly, 100 images were randomly selected from each GANs-produced result, to which 100 closest images from the training set were chosen. Then, 100 closest images of the selected real images from the training set were chosen. Eventually, the two sets of SSIM values were calculated and compared.

Figure 10 showed the maximum SSIM values and standard deviations for different GANs. Bars labelled as fake are similarity results from the generated images by GANs and bars labelled as real are SSIM values for the training dataset. Except for StyleGANs, all other GANs models produced images with low similarity values than the training dataset, which indicates that the images produced by GANs are not similar to the training images and models did not overfit.

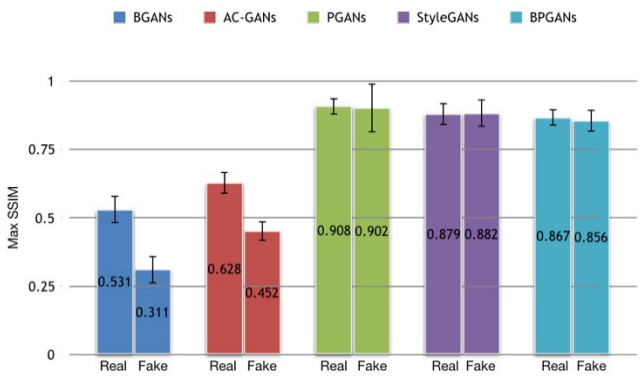

Figure 10. Similarity Comparison between Imagined Examples and Training Examples

5.3 Classification Results

The ultimate goal of this study is to utilize GANs to augment and balance the dataset in hope that a better classifier can be obtained to distinguish damaged insulators and good insulators. Therefore, the final assessment is to train the same classifier on the augmented dataset, observing if the classification performance would increase or not.

Figure 11 showed that the F1-scores and classification accuracy improved for all GANs, expect for the BGANs and AC-GANs, compared to the classifier trained on the original classifier. Results indicated that classifier trained on dataset augmented by PGANs achieved highest F1-score and accuracy.

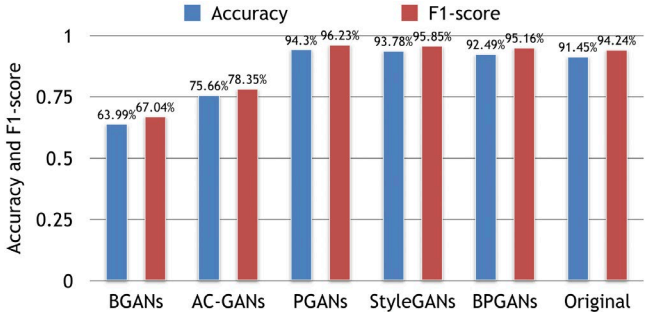

Figure 11. F1-score and Accuracy of Classifier Trained on Dataset Augmented by GANs

6. CONCLUSION

Electricity is of great importance to ensure functionalities of all aspects of society, and thus regular electrical inspections are needed. Recent advances in deep learning has offered viable approaches to automate inspection jobs. However, data availability can restrict how deep learning can be successfully applied. Generative adversarial networks are capable of learning good representations of images and generate imagined ones based on learned representations. Therefore, in this study, extensive experiments have been conducted on generating images, especially damage insulators, based on GANs.

Results showed that BGANs and AC-GANs are able to combine class label during training, and thus provide more information guiding the generation of damaged insulators. However, they are designed to produce relative low-resolution images, and thus images generated are blurry and even sabotage the classifier when augmenting the dataset with images produced by them. StyleGANs and PGANs are capable to generate images of much higher quality because of the hierarchical architecture in both generator and discriminator. However, they are both trained only on the damaged insulators, and therefore does not make any use of information from the good insulators. Motivated by the advantages and drawbacks of existing GANs models, BPGANs is proposed. BPGANs is able to make full use of label information to generate images with good quality.

StyleGANs, PGANs, and BPGANs are able to produce damaged insulators examples with high quality. PGANs produced the best quality images with recognition rate about 87%, followed by StyleGANs (81%) and BPGANs (80%). The rest of GANs models failed to produce good quality images, having low recognition rate less than 70%. Low SSIM values by all the GANs models indicated that generated images are of great mode and are not similar to training dataset. The classification accuracy and F1-score trained on the unaugmented dataset is 91.45% and 0.9424. After augmenting the original dataset, the classifier achieved higher F1-scores and classification accuracy. Highest improvement was seen on results from PGANs, with classification accuracy increased by about 3% and F1-score by 2%. StyleGANs and BPGANs also improved classification performance. The former achieved accuracy of 93.78% and F1-score of 0.9585, and the latter had accuracy of 92.49%, F1-score of 0.9516. BGANs and AC-GANs degraded the classification performance compared to the baseline as images generated by the two were of low quality.

The reason why BPGANs had difficulties distinguishing good versus damaged insulators might be because the classification loss is too little in magnitude compared to the source loss, which tried to tell if the images shown to the discriminator are from real or fake images. As a result, the optimizer focused more on optimizing the parameters to reduce the source loss. Another reason might be because there are only two class labels, which only provide 2 additional latent codes compared to original 512 latent codes, having limited effect on the model. Results indicated that learning representations of data progressively from low resolution to high resolution is an effective approach, however, embedding class label information in the fashion of AC-GANs and BGANs might not be appropriate for augmenting binary class datasets.

7. ACKNOWLEDGMENTS

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Predicting Remaining Useful Life of Ball Bearing Using an Independent Recurrent Neural Network

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ABSTRACT
Planning maintenance of facilities is an important role for production line. From preventive maintenance to predictive maintenance, the main purpose is cost down by reducing the chance of the unexpected shot down. Thus, this study intends to apply independent recurrent neural network (IndRNN), which is a kind of deep learning technique, and apply it to predict remaining useful life for the ball bearings using vibration signals. The result of the proposed method is compared with original RNN. The experimental results indicate that IndRNN is able to perform better than the other method in terms of score.

CCS Concepts
• **Computing methodologies → Machine learning → Machine learning approaches → Neural networks**

Keywords
Predictive maintenance; Remaining useful life; Recurrent neural network; Independent recurrent neural network.

1. INTRODUCTION
The fast-growing information technologies have provided some new techniques, such as 4G/5G internet, mobile payment, streaming movie/music, artificial intelligence (AI), etc. Gradually, the living habit of human is changed. It also affects manufacturing process a lot. In such a rapid era, every decision in the factory should be made fast and precisely. Thus, the planning of maintenance can be redefined. In the past, preventive maintenance is the main method in the area of maintenance. Preventive maintenance is driven by time, distance or condition-based triggers. By carrying out regular maintenance, it can reduce the probability of equipment shot down during working. So, the cycle time of maintenance is always decided by the mean time between failures (MTBF). However, it has some drawbacks. The main weakness of preventive maintenance is that sometimes it results in unnecessary maintenance which brings to predictive maintenance. On the other hand, predictive maintenance is a process of predicting the failure time for a machine by monitoring the machinery signature features and the condition of the equipment. This can overcome the aforementioned problem resulting from preventive maintenance.

Thus, this study intends to apply a deep learning technique, IndRNN, to predictive maintenance in order to achieve better prediction performance.

The remainder of this paper is organized as follows. Section 2 provides related literature review, while Section 3 presents the IndRNN for preventive maintenance. Section 4 shows the detailed experimental results. Lastly, the research conclusions are discussed in Section 5.

2. LITERATUR REVIEW
2.1 Deep Leaning
Deep neural network, also called deep learning, is one of the ways to reach artificial intelligence (AI), but a special type of machine learning [1], since it contains the study between artificial neural network (ANN) and machine learning. Basically, if the neural network structure stacks many layers, then it can be called as a deep neural network. In the traditional neural network, the activation function always uses sigmoid or hyperbolic tangent function. It will cause the gradient vanishing problem when the neural network is deep. Gradient will be squeezed to close to 0 during the back-propagation through the network. Thus, the early layers of neural network can-not be tuned well. Therefore, the problem can be solved by using rectified linear unit (ReLu) to replace the logistic function [2]. In addition, softmax function combining cross entropy can deal with the classification problem more efficiently [1].

In recent years, deep learning possesses different types of architecture, such as deep belief network [3], Boltzmann machine [4], auto encoder [5], convolutional NN (CNN) [6], recurrent NN (RNN) [5], etc. Different structures can apply to different areas. Deep learning reaches a lot of successful applications on these areas. Breakthroughs on deep learning have been achieved by Hinton *et al*. [3], who proposed a new training method called layer-wise-greedy-learning. This technique can make deep belief nets reach a better local minimum and achieve a faster converge rate. Thereafter, many powerful frameworks have been proposed with deep neural network architectures. In this study, it will focus on the application of recurrent neural network (RNN). Thus, RNN will be discussed more detailed in the following section.

2.2 Recurrent Neural Network (RNN)
RNN is a specific architecture of ANN whereas the neuron self-connect to itself across time [7]. Based on the feedforward neural network, RNN augmented a notion of time to neural network. The notion is connecting hidden layer within the adjacent time steps, known as recurrent layer. As shown in Figure 1, recurrent layer h_t input with information not only from the input layer x_t but also from the previous time period h_{t-1}. Thus, the network can pass the information across time steps. The output will consider the all

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information from each time period. This model achieves a good performance on speech recognition [8], language modeling [9], and machine translation [10].

Mathematically, the procedure can be illustrated as follows:

$$h_t = \sigma(W_{hx}x_t + W_{hh}h_{t-1} + b_h) \quad (1)$$

$$\hat{y}_t = \sigma(W_{yh}h_t + b_y) \quad (2)$$

where σ is an activation function which usually uses hyperbolic tangent or sigmoid function. W_{hx} is the matrix of weights between the input and the hidden layer and W_{hh} is the matrix of fully connected weight between the two hidden layers at adjacent time steps. b_h and b_y are the bias of two layers. These parameters can be trained by backpropagation, namely backpropagation through time (BPTT), was introduced by Werbos [11]. In general, all current uses of RNN apply it.

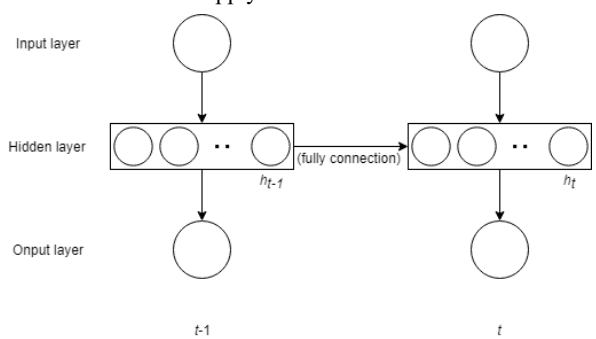

Figure 1. Recurrent neural network.

Bengio *et al*. [12] and Hochreiter *et al*. [13] pointed out that training RNN can be a challenging task due to the difficulty of learning long-term information. The vanishing gradient and exploding gradient problem occur when the time steps grow large. The derivative of the error with respect to the input will be vanishing or exploding by go through many time steps. RNNs have had different variants including LSTM [14] and independent RNN (IndRNN) [15]. Different from the basic structure of RNN, the recurrent inputs of IndRNN are not fully connected with all neurons in the next time step. They only utilize Hadamard product, which is a binary operation that takes two matrices of the same dimensions, and produces another matrix where each element *i* or *j* is the product of elements *i* and *j* of the original matrices. Thus, each neuron in recurrent state is independent to the other neurons.

2.3 Predictive Maintenance

Predictive maintenance is a condition-driven preventive maintenance method [16]. Park [17, 18] and Gertsbakh [19] demonstrated that the condition-based preventive maintenance method is more effective than the preventive maintenance based only on the system age and the statistical indicators on its lifetime. Predictive maintenance techniques are intended to determine the condition of operating equipment in order to predict when the failure will occur or when the maintenance will be required [20].

Ideally, companies are able to recognize failure patterns in a way they are predicted. However, increasing the accuracy of prediction can be difficult. Thus, the ultimate aim of this technique is to provide a cost reduction by reducing the amount of over schedule-based preventative maintenance or unplanned reactive maintenance, which result in the unavailable of machines during the production periods.

Some methods have been proposed to deal with this problem. Sutrisno *et al*. [21], for instance, deployed the anomaly detection, degradation feature extrapolation, and survival time ratio to estimate the remaining useful life (RUL). Recently, Guo *et al*. [22] applied a recurrent neural network based health indicator (HI) for RUL prediction, by using six related-similarity features and eight time-frequency domain features to form a feature set. After that, the authors utilized a double exponential model for curve fitting and prediction of the final solution.

The increasing availability of data is changing the way the enterprises make a decision. In addition, machine learning provides a complementary approach for maintenance planning by analyzing the data collected from sensors mounted on the machine and environment information. Ideally, the machine learning technique can identify the failure signatures and profiles, and then provide an actionable prediction of failure for individual parts or machine [23]. Among the deep learning methods, LSTM networks are especially appealing to the predictive maintenance domain, due to the fact that this method is excellent at learning from sequences. This fact has also been indicated by numerous applications with time series data, which provides a possibility to look back for the past periods of time to detect the failure patterns [22].

3. METHODLOGY

3.1 Methodology Framework

This study utilizes IndRNN [15] to deal with the remaining useful life (RUL) problem for predictive maintenance. The main purpose of predictive maintenance is to reduce the unscheduled maintenance. There are two crucial issues that need to be considered in the RUL problem, the first issue is to find a suitable model, while the second is to choose the better features. In this study, IndRNN is chosen to be the model.

In the degradation process, the health indicator (HI) values will increase. In [24], the bearing degradation signal is modeled by an exponential function. Jin *et al.* [25] has shown that the summation of two exponential functions can capture the more degraded trend of bearings. The double exponential function itself is defined as follows:

$$Y = ae^{bt} + ce^{dt}, \quad (3)$$

where *Y* is the prediction result of IndRNN (HI); *t* is the time step; *a*, *b*, *c*, and *d* are the parameters.

Once the prediction of IndRNN is completed, the double exponential function is utilized to fit the prediction result. The parameters in the double exponential function are updated by the gradient descent technique. Lastly, this updated function is used to predict the time when the HI reaches the failure threshold.

3.2 Objective Function

The main purpose of this study is to improve the average accuracy of the RUL prediction results for all the testing sets. Therefore, a score in the IEEE PHM 2012 challenge [26] is deployed to evaluate the performance of the prediction method. It is defined as follows:

$$\text{Score} = \frac{1}{11}\sum_{i=1}^{11} A_i, \quad (4)$$

where:

$$A_i = \begin{cases} \exp\left(-\ln(0.5) * \left(\frac{Er_i}{5}\right)\right) & if\ Er_i \le 0 \\ \exp\left(-\ln(0.5) * \left(\frac{Er_i}{20}\right)\right) & if\ Er_i > 0 \end{cases} \quad (5)$$

and Er_i is the percentage error of prediction result for the *i*-th case. It is defined as follows:

$$Er_i = \frac{ActRUL_i - RUL_i}{ActRUL_i} \times 100\%, \quad (6)$$

where $ActRUL_i$ and RUL_i are the actual RUL and the predicted RUL of the i-th testing set, respectively.

3.3 Feature Extraction

The vibration signals are a time-series data. Due to the enormous number of the original data, it is necessary to perform the feature extraction beforehand. In this study, the feature set includes 11 features in time domain, 1 related-similarity (RS) in time domain, 5 RS features in frequency domain and 8 classical features in time-frequency domain.

Firstly, in time domain, 12 statistical features are considered, including mean, RMS, kurtosis, skewness, peak-to-peak, variance, entropy, crest factor, wave factor, impulse factor, margin factor, and RS feature from all the time domain features. Secondly, in the frequency domain, the sample frequency is 25.6 kHz. The frequency spectrum are located in 0−12.8 kHz, 0−3.2 kHz, 3.2−6.4 kHz, 6.4−9.6 kHz and 9.6−12.8 kHz. Thirdly, the time-frequency domain includes the energy ratios of eight frequency sub-bands, which are generated by performing haar wavelet package transform with a three-level decomposition on vibration signals. These three-domain features are extracted from vertically and horizontally vibration signals.

The RS features are calculated through the similarity measurement of data sequences between the current and initial times [22]. If the data sequence at time t is denoted as f_t and the data sequence at an initial operation time is denoted as f_0, then the RS features can be calculated by:

$$RS_t = \frac{\left|\sum_{i=1}^{k}(f_0^i - \tilde{f}_0)(f_t^i - \tilde{f}_t)\right|}{\sqrt{\sum_{i=1}^{k}(f_0^i - \tilde{f}_0)^2 \sum_{i=1}^{k}(f_t^i - \tilde{f}_t)^2}}, \quad (7)$$

where k is the length of the data sequence, $\tilde{f}_0$ and $\tilde{f}_t$ are the mean values of $\{f_0^i\}_{i=1:k}$ and $\{f_t^i\}_{i=1:k}$. However, after the feature extraction is implemented, there are still a lot of features left. Thus, this study will employ GA to obtain the best feature subset.

3.4 Feature Selection

In the area of data sciences, the idiom "garbage in, garbage out" describes that low-quality input data will produce a low-quality output. In order to avoid this situation, choosing sensitive features is obviously needed. Liu and Motoda [27] indicated that the influences of feature selection are as follows:

(1) Improve performance (accuracy, speed of learning, simplicity of rules),
(2) Visualize the data for model selection, and
(3) Reduce dimensionality and remove noise.

Feature selection algorithms can be categorized into two types: filter and wrapper algorithms [28]. The main difference between these two is that filter algorithms select features by using statistical indicator of features before any application is performed. On the other hand, wrapper algorithms select features by considering the training result of the data. The performance of the current feature subset is computed, then according to the performance and the searching criterian, the next feature subset is identified.

Guo *et al*. [22] utilized correlation and monotonicity techniques to calculate the criteria and the criteria with normalized values above a 0.5 threshold chosen as the feature subset.

4. RESULTS

This section presents the computational results for the proposed IndRNN. In this study, all of the proposed modified IndRNN were coded by python programming language. The experiments were implemented on a Windows 10 desktop computer with 3.6 GHz CPU and 32GB RAM. The detailed experimental result will be described in the following sections.

4.1 Datasets

This experimental dataset is collected from PRONOSTIA platform. PRONOSTIA is an experimentation platform contribute to provide real data of the degradation trend of ball bearings along their whole operational life [26]. The vibration signals are collected in horizontal and vertical directions by two accelerometers. Two accelerometers sampled the signals at 10 seconds intervals in 25.6kHz sampling rate and 0.1 second duration. Thus, each observation contained 2560 points. The detailed description of the platform and experimental setup can be found in [26].

The dataset was derived in three different operating conditions. First condition had seven ball bearings operated at 1800 rpm and 4000 N radial. The second condition featured seven ball bearings operated at 1650 rpm and 4200 N radial. The third condition presented three ball bearings operated at 1500 rpm and 5000 N radial. In each condition, first two of the datasets were provided for training, other were provided for testing. Table1 shows the operation conditions.

Table 1. Operation conditions of bearing dataset.

Condition / Dataset	Condition 1	Condition 2	Condition 3
Training set	Bearing1_1	Bearing2_1	Bearing3_1
	Bearing1_2	Bearing2_2	Bearing3_2
Testing set	Bearing1_3	Bearing2_3	Bearing3_3
	Bearing1_4	Bearing2_4	
	Bearing1_5	Bearing2_5	
	Bearing1_6	Bearing2_6	
	Bearing1_7	Bearing2_7	

4.2 Parameter Setting

In IndRNN, the number of epochs, the number of RNN layers, the number of hidden layer nodes, activation function, loss function, optimizer, and output size need to be pre-determined as well. Table2 shows the details of parameters in IndRNN model. Basically, these settings are based on the literatures.

Adam is the gradient descent based algorithm. The updating rule is based on the following equations:

$$m_t = \beta_1 m_{t-1} + (1-\beta_1) g_t \quad (8)$$

$$v_t = \beta_2 v_{t-1} + (1-\beta_2)(g_t)^2 \quad (9)$$

$$\hat{m}_t = \frac{m_t}{1-\beta_1^t} \quad (10)$$

$$\hat{v}_t = \frac{v_t}{1-\beta_2^t} \quad (11)$$

$$\theta_t = \theta_{t-1} - \eta \frac{\hat{m}_t}{\sqrt{\hat{v}_t} + \epsilon}, \quad (12)$$

where η is learning rate, β_1 and β_2 are the exponential decay rates for the moment estimates, m_t is the 1st moment vector and v_t is the 2nd moment vector. Besides, g_t is the derivation calculated by

the loss function and t is the iteration. Basically, η can be set in the interval of [0.001, 0.1] and $\beta_1,\ \beta_2 \in [0, 1)$.

Table 2. The parameters of IndRNN.

Parameter	Value
Number of epochs	50
Number of RNN layers	10
Hidden layer nodes	60
Activation function (RNN cell)	Leaky ReLU
Activation function (output)	Sigmoid function
Loss function	MSE
Optimizer	Adaptive moment estimation (Adam)
Learning rate (Adam)	0.0015
Beta1 (Adam)	0.5
Beta2 (Adam)	0.999
Epsilon (Adam)	1e-08
Number of output	1

4.3 Computational Results

In this study, the proposed method is compared with original RNN. RNN and IndRNN used feature subset proposed by Guo *et al*. [22]. The result is shown in Table3, while the computational time is listed in Table 4. Table 3 showed that IndRNN has higher score than that of RNN. However, as Table 4 indicated, IndRNN needs longer training time.

5. CONCLUSIONS

This study focus on how the performance of applying deep learning to RUL problem. Two kinds of deep learning techniques which are appropriate to time series data are compared in this study. IndRNN can predict RUL more precisely and get less negative error rate. It means the company can avoid the product line shot down suddenly and also prevent the potential hazard from the broken machine.

Since deep learning neural network has a lot of parameters need to be decided, in the future research, we can use different metaheuristics to find the best parameters for deep neural network. In addition, the vibration signals of ball bearing have a cycle. After feature extraction, using the similarity between two signal patterns to predict the RUL can be tried.

Table 3. The computation results of score.

Test bearing ID	Current time (s)	Actual RUL (s)	RNN Er (%)	IndRNN Er (%)
Bearing 1_3	18010	5730	12.4	79.9302
Bearing 1_4	11380	339	67.1	19.6552
Bearing 1_5	23010	1610	-126	23.6025
Bearing 1_6	23010	1460	-713	15.7534
Bearing 1_7	15010	7570	68.8	84.4122
Bearing 2_3	12010	7530	-0.538	-298.2736
Bearing 2_4	6110	1390	-132	-212.9496
Bearing 2_5	20010	3090	-306	-870.5502
Bearing 2_6	5710	1290	-119	-330.2326
Bearing 2_7	1710	580	-93.1	-5070.6897
Bearing 3_1	3510	820	16.3	-1.5936
Score			0.2125	0.2222

*the best prediction for the predicting method

Table 4. Computational time (in second).

Method	Computational time
RNN	37.36
IndRNN	406.44

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AI-based Automatic Optical Inspection of Glass Bubble Defects

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ABSTRACT
Automatic Optical Inspection (AOI) offers a range of solutions to meet the requirements of every production facility, attracting significant interest of manufacturers of various industries. One important AOI application in the glass industry is to detect bubble defects in spherical glass, especially those used for making high-end lenses. Nevertheless, the AOI process must make the inspection decision in a reliable manner. Another challenge is that glass bubble defects are nearly transparent and can be captured by cameras only from certain viewing angles and with the aid of a specially engineered lighting mechanism. In this paper, an Artificial Intelligence method based on AOI (AI-AOI) is proposed to address the need of the glass industry as aforementioned. In specifics, our proposed method employs (1) a specially designed back-lighting mechanism to illuminate the hardly visible glass bubble defects, (2) Otsu thresholding image-segmentation method to obtain the distortion part and the core part of the defects and eliminate the fake defects caused by dust particles, and (3) a novel AI-based bubble-defect detection method capable of capturing the bubble defects as small as a few millimeters in diameter. The initial experimental results validate the feasibility of the proposed AOI method with an accuracy of 95%. If we exclude factors such as scratches by humans or the presence of dust particles in the inspection room, our method can achieve a recognition rate of 100%.

CCS Concepts
• Information systems → Information systems applications → Decision support systems → Online analytical processing

Keywords
Automated optical inspection; artificial intelligence; glass bubbles

1. INTRODUCTION
Automatic Optical Inspection (AOI) offers a range of solutions to meet the requirements of every production facility, attracting significant interest of manufacturers of various industries. In the field of AOI research, the problems to be solved are usually divided into two categories, namely *image acquisition system design* and *detection system design*. The former aims at obtaining high-quality images of the target under inspection that can be used for image processing. The latter is associated with extracting information from input images to identify objects of interest in the images.

One important AOI application in the glass industry is to detect bubble defects in spherical glass, especially those used for making high-end photographic lenses. As raw materials used for the manufacture of glass are in form of oxides, melting of such raw materials, which is an essential process in glass production, naturally produces reaction gases forming bubbles in the glass melt. Today's glass manufacturers remove gaseous bubbles in the glass melt by the so-called *refining process*, which typically involves heating the glass melt to temperatures well above the raw material batch melting point. The refining process also introduces refining agents that either help dissolves the bubbles or cause them to rise to the top of the melt quicker. Nevertheless, a non-perfect glass refining or coating process occurs on occasion and by chance, inducing bubble defects in the glass products. As the forming of bubble defects is inevitable in today's glass production process, a good AOI system design for the detection of bubble defects in the glass is extremely valuable to those high-end glass manufacturers whose products are expected to be free of bubble defects in millimeter-scale at least.

A practical AOI process for detecting glass bubble defects must make the inspection decision in a reliable manner. Another challenge is that glass bubble defects are nearly transparent and can be captured by cameras only from certain viewing angles and with the aid of a specially engineered lighting mechanism. In this paper, an Artificial Intelligence method based on AOI (AI-AOI) is proposed to address the need of the glass industry as aforementioned. In specifics, our proposed method employs (1) a specially designed back-lighting mechanism to illuminate the hardly visible glass bubble defects, (2) Otsu thresholding technique to obtain the distortion part and the core part of the defects and eliminate the fake defects caused by dust particles, and (3) a novel AI-based bubble defect detection method capable of capturing the bubble defects as small as a few millimeters in diameter.

The rest of this paper is organized as follows. Section 2 surveys the existing work on the detection of glass bubble defects and relates them to our own. Section 3 introduces the design rationale and the framework of our proposal. Section 4 presents the

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performance evaluation and analysis of our proposed detection method. Finally, Section 5 concludes and considers possible directions for future research.

2. RELATED WORKS

Although AOI has attracted significant interest of manufacturers of various industries, only a few research studies have been done on the detection of glass bubble defects. In [1], to robustly detect low-contrast defect region on glass, termed Mura or blemish area, the authors proposed a detection algorithm to segment the blemish glass defects. In specifics, the proposed algorithm employed a modified model-fitting (MF) estimator to estimate the image's background model and, as a by-product, to segment the blemish defects. Compared with the conventional least-square (LS) estimator, the proposed algorithm can successfully estimate model parameters from a dataset of contaminated Gaussian mixture. It can also capture the blemish defects in images by detecting outliers during the process of estimating the background model parameters.

In [2], Peng et al. proposed an online AOI method and built a system prototype for detecting defects existing in float glass. In specifics, the inspection was done by detecting the change of image gray levels due to the differences in optical characteristics of glass and the defects. The authors also implemented a series of image processing algorithms, for instance, an image filtration algorithm based on gradient direction, to filter out the noise and retain the information of the defects. They also used the OTSU algorithm to obtain the distortion part and core part of the defects and eliminated the fake defects caused by dust or insects. Wuhan glass factory has adopted the proposed AOI method, proving that this method is effective, accurate, and reliable.

In [3], Adamo et al. studied the problem of detecting and measuring the defects in satin glass and designed and built an in-line PC-based visual inspection system to address the problem. Their prototype system consists of three modules, namely a set of CMOS cameras, a roller conveyor, and a PC computer to process images and control other modules in the system. The defect detection software was implemented based on the Canny edge detection method with thresholds chosen according to statistics collected from previous runs of image processing. Furthermore, the authors presented evaluation methods and experimental results to validate the proposed solution. They also cooperated with the local electronic industry to further the research development of their visual inspection system.

In [4], Zhao et al. presented a method for detection and recognition of glass defects in low-resolution images. In this work, they employed the method of Canny edge detection to locate the defect region with the smallest possible connected rectangle region and then obtained the binary information of the core region based on a specific filter. They developed a new method named Binary Feature Histogram (BFH) to describe the characteristics of the glass defects and adopted BFH-based classifiers and the AdaBoost method for classification.

In [5], Ryu et al. used the two-wavelength methods of projection moiré topography to measure the 3D shape of an object with 2π-ambiguity problems. Furthermore, their proposal could achieve rapid measurement by synchronizing the CCD camera and the projector. Their experimental results proved that the proposed method can effectively overcome the 2π-ambiguity problems of 3D measurement because of its high measuring speed and high sensitivity.

In [6],[7], nonlinear algorithms based on deep learning techniques have been developed to extract nonlinear features, which can be stacked in the construction of deep networks, although they simply insert a nonlinearity between learned single-layer linear projections.

3. DESIGN RATIONALE WITH FRAMEWORK

In this section, we firstly elaborate on the design of our image acquisition system, then how we employed Otsu thresholding and Kanade's interchangeable projection technique to perform image segmentation, and finally an AI-based method for detecting bubble defects in the spherical glass.

3.1 Image Acquistion

Figure 1 illustrates the design of our image acquisition system used for defecting bubble defects in the spherical glass. The system includes a projector serving as the light source, spherical glass as the target object under inspection, a charge-coupled-device (CCD) camera to acquire the target's images, and a PC-based computer to process images acquired by the camera.

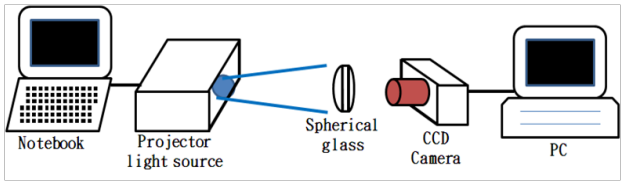


Figure 1. Design of our image acquisition system.

A key component in our image acquisition system is the design of its lighting mechanism. The lighting mechanism must be designed properly with respect to the target object under inspection, its surrounding environment as well as the relative positions of the target object, the light source and the camera used for the image acquisition. A well-design lighting mechanism, used alone with a high-end CCD camera, assists greatly in capturing the target's image with all the details of interest. In this work, the target under inspection is spherical glass, and it has three physical properties that affect our image acquisition design, namely its transparent body, its smooth surface with varying curvature, and the body with varying thickness.

Firstly, because the spherical glass under inspection has a body of varying thickness, it was necessary for us to hold the glass and the camera in some fix positions and then tune the camera's focus accordingly until the camera can capture clear images of bubble defects in the glass. Secondly, we found that during the image acquisition phase, if the light source and the camera were positioned on the same side with respect to the location of the target under inspection, then the images acquired by the camera would contain the shape of the light source's outlook. And even worse, this undesired shape pattern could appear anywhere in the acquired images, depending on the curvature of the target's surface which faced the camera. By the aforementioned analysis, we realized that since the spherical glass is transparent and has varying curvature and thickness, the back-lighting mechanism works better than the front-lighting mechanism in case of detecting bubble defects in the spherical glass.

The next step is to choose a suitable light source for the image acquisition system. Based on Ryu's measurement approach in [5], we employed a structured light projection method to project

parallel stripes of light onto the spherical glass, which not only illuminated the glass body but also allowed three advantages. Firstly, the displacement of the light strips on the glass enables an exact retrieval of the 3D coordinates of any defects in the glass. Secondly, the projector emits light beams from its internal direct-current bulbs, whose strong beam convergence property helps avoid the noise interference problem that commonly occurs to those using ordinary alternating-current light sources. The third advantage is that we can easily adjust the brightness and the color of the light beams produced by the projector.

Table 1. Summary of distance and lighting settings

	Distance from the light source to the glass		Distance from the glass to the camera
Distance	1.85 meters		0.25 meters
	R Channel	G Channel	B Channel
Color	0	0	24

Finally, we manually adjusted the distance between the projector and the spherical glass and the distance between the glass and the CCD camera, as shown in Table 1, so that the camera could clearly detect the bubble defects intercepting the light stripes emitted from the projector. If the adjustment is done properly, such interference would cause the light stripes to be refracted outward and form a uniformly expanded dark pattern on the glass surface, which looks like an enlarged black dot. Since the bubble defects in the acquired images appear like black dots, using certain light colors results in high contrast between the defect regions and the rest background image, which makes the later task of bubble-defect detection much easier. After an exhaustive search for the most suitable light color, we found that it worked best when adopting the light-color settings as specified in Table 1.

3.2 Otsu Thresholding for Image Segmentation

In the acquired images, only regions that contain the bubble defects are considered the region of interest (ROI), while the rest should be dismissed from the AOI process. To detect the ROI of the acquired images as well as to separate them from the rest, we employed Otsu's thresholding method to perform the following image segmentation process, and we refer the readers to reference [2] for details. One thing worth mentioning is that since the light refracted out of the glass bubble appears blue, we performed Otsu's thresholding based on the blue channel. Figure 2 shows a sample result after applying Otsu's method, in which a small black dot at the left upper corner is the bubble defect to be detected. Furthermore, the inspectable area of an acquired image in this study is determined by the size of the projector's light bulb, so the next step is to further refine the ROI.

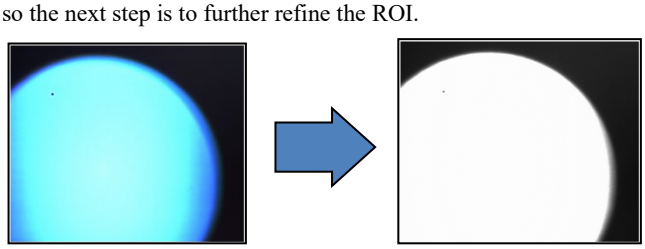


Figure 2. A sample result after applying Otsu's method.

After applying Otsu's method to the acquired images to obtain clear foreground boundaries of the ROI, we then segmented the four corner regions by used the Kanade's interchangeable projection technique [8] with the following formulas:

$$V(x) = \sum_{y=0}^{h-1} B(x, y), \tag{1}$$

$$H(y) = \sum_{x=0}^{w-1} B(x, y), \tag{2}$$

where $V(x)$ and $H(y)$ denote the vertical projection and the horizontal projection, respectively, $B(x,y)$ denotes the pixel value of the Otsu thresholded image, h and w denote the height and the width of the image, respectively. Based on the projection values computed by Equation (1) and (2), we could refine ROI by removing the four corner regions from the Otsu thresholded image.

3.3 Bubble Defect Detection

For this research, a smaller and customized architecture has been implemented with VGG. The architecture is based on the architecture similar to VGG-net by Simonyan and Zisserman [9]. The batch normalization process is a powerful technique for improving the performance, speed, and stability of artificial neural networks. The adopted model for this customized network is presented. The number of channels per layer is 16, 32, 64, and 128, respectively. The number of channels begins with three input channels and then follows from 16 to 128 in increasing order. Two dropout and five batch normalization layers are added into the network to reduce the overfitting. At last, a three-class softmax function based on TensorFlow is added to classify the defects.

Algorithm 1: Batch Normalized Transformation

Requirement: Values of i over a batch: $B = \{i_0, i_1, \dots, i_{M-1}\}$

Parameters to be learned: γ, β

Batch normalization: BN

$\mu\beta \leftarrow \frac{1}{M}\sum_{m=0}^{M-1} i_m$ (batch mean)

$\sigma^2 \leftarrow \frac{1}{M}\sum_{m=0}^{M-1}(im - \mu\beta)$ (batch variance)

$\hat{i}_m \leftarrow (im - \mu\beta)/\sqrt{\sigma^2 + \varepsilon}$

$yi \leftarrow \gamma \times \hat{i}_m + \beta \equiv BN\gamma, \beta(im)$ (scale, shift)

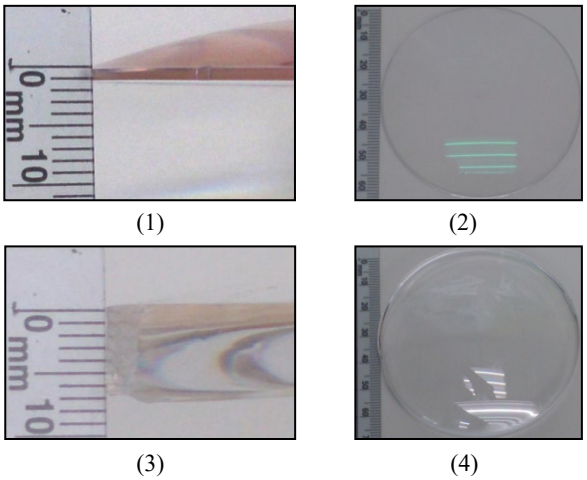
return $y = BN\gamma, \beta(im)$ (Result)

This algorithm calculates the mean and variance for each batch, normalizes and performs a shift and scaling. Parameters γ and β are learned during training, along with the original parameters of the network. In the algorithm, ε is a constant which is added to the mini-batch variance for numerical stability. Batch Normalization (BN) of parameters γ,β is performed with a higher learning rate without adopting vanishing moments or exploding gradients. It can reduce overfitting because it is with a slight regularization effect, similar to dropout.

4. EVALUATION

4.1 Experiment Setup

The spherical glass samples used for the performance evaluation have diameters ranging from 64 mm to 70 mm. The thickness of their body ranges from 1 mm to 7 mm, while the surface curvature varies, as shown in Figure 3.



(1) (2)

(3) (4)

Figure 3. Two spherical glass samples measured against a standard scale: (1) Sample A has a thickness of about 1mm and (2) a diameter of about 64 mm; (3) Sample B has a thickness of about 7 mm and (4) a diameter about 70 mm.

In regard to the experimental setup, we mounted a spherical glass sample and the CCD camera in two separate housings that are attached to an optics rail and adjusted their positions according to the distance settings specified in Table 1. Then we started the projector to project structured light onto the spherical glass sample as described in Section 3.1, fetched the images acquired by the camera to the PC computer, and finally executed our bubble-defect detection software, which was implemented in Borland C++ according to Section 3.3, to process the acquired images. The relevant details regarding the hardware and the software used in our experiment are summarized in Tables 2 and 3.

Table 2. Summary of hardware for experimental setup

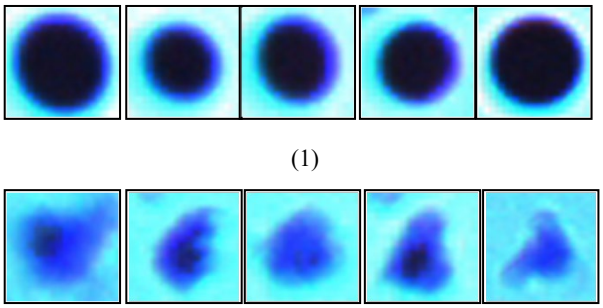
	Hardware	Standard
Host	Acer	V193W
CPU	Intel(R) Core(TM)2 Quad	Q8400 2.66G Hz
Memory	Samsung	1.96GB RAM
Capture card	INTEL®	PRO/1000 GT Desktop
Camera	Basler	piA2400-12gc
Optical lens	Nikon + DG Extension Tube	AF 50mm F1.8D + 20mm
Light source	Panasonic Projector	PT-L735U

Table 3. Summary of hardware for experimental setup

	Software	Standard
Operating system	Microsoft Windows XP	Professional version SP3
Image capture software	Pylon Viewer	3.2.2.3032
Programming language	Borland C++	Builder 6

4.2 Experiment Result

Our experiments were targeted at evaluating the accuracy of the proposed AOI method. The glass samples used here are 50 pieces of spherical glass supplied from a local glass manufacturer in Taiwan. The inspection results of our AOI method are compared against those derived from human inspection. We also divided the experiments into two sets. One of them was performed in a clean-room environment, while the other was performed in an ordinary computer lab (non-clean-room). The results are summarized as follows:



(1)

(2)

Figure 4. A few samples of the detection result: (1) glass bubble defect, (2) dust particle.

Table 4. Experimental result: accuracy

	Clean-room environment	Non-clean-room environment
Accuracy	100%	95%

5. CONCLUSION

We have shown in the work that for the detection of bubble defects in spherical glass, the lighting mechanism, the image acquisition method, as well as the detection algorithm, must be designed together to achieve a high accuracy performance. The initial experimental results validate the feasibility of the proposed AOI method with an accuracy of 95%. If we exclude factors such as scratches by humans or the presence of dust particles in the inspection room, our method can achieve recognition rates of 100%. Exploiting other advanced defect defection algorithms will be part of our future work. We also intend to improve the distance settings which are required to accommodate the image acquisition system.

6. ACKNOWLEDGMENT

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Improvement of Non-oil Ethylene Propylene Diene Monomers Mixing Process

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ABSTRACT
This research aims to study the factors affecting the mixing efficiency of the case study company and to improve the non-oil EPDM mixing process by applying the Six Sigma concept. Five systematic steps are conducted to apply the Six Sigma approach, i.e., define, measure, analyze, improve and control. After applying the DMAIC steps, wastes occurred in the process are substantially reduced by shifting the Mooney viscosity mean to be near or on the target value as reflected from increased process capability index (Cp_k) from -1.25 to 3.92. In addition, the result of the response surface method reveals the appropriate process parameter setting as follows: mixing time ~ 14 (min.), Nip gap ~ 1.10 (mm.) and Number of passes ~ 9 (pass.). The result also shows that the standard deviation is decreased from 0.45 to 0.30.

CCS Concepts
• General and reference→ Evaluation • General and reference→ Performance • General and reference→ Verification • General and reference→ Experimentation

Keywords
Six Sigma; Rubber mixing process; Non-oil EPDM; Response surface method

1. INTRODUCTION
According to the current situation, the rubber industry has become more and highly competitive. The development of the mixing process is an important part ensuring the quality of the product and desired target. There are many factors that affect the efficiency of mixing and the product quality such as the attraction between particles (fillers), the EPDM rubber flow properties, the geometry of the mixer and the operating conditions [6], which makes case study research to study operating conditions (mixing time, mixing temperature, fill factor, nip gap and number of passes) and their interactions that affect the mixing quality. Poor mixing was the cause of large particles affecting the uniform distribution throughout the masterbatch and masterbatch viscosity, which is difficult for good dispersion in a high loading of fillers [5]. In the study process, the Six Sigma and DMAIC principles are used together for sustainable development and wide acceptance. In particular, the DMAIC (Define-Measure-Analyze-Improve-Control) problem-solving and improvement model of Six Sigma is followed. In this model, several statistical and quality improvement tools such as fishbone diagram, Control chart, Design of Experiments (DOE), Response Surface Design and Response Optimizer have been utilized.

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1.1 Six Sigma Concepts and Literature Review
Six Sigma is a tool and concept for quality improvement. The main goal is to reduce the defects or losses that occur in products and services, including ones from the production process. It helps reduce defects and production costs. In most cases, data analysis and various causes are identified to determine the correct problem, which relies on the DMAIC (define–measure–analysis–improve–control) principles and statistical analysis to help. Another important factor is the focus on customer satisfaction to be able to solve the problem along with improving and developing the production process appropriately. The name of Six-Sigma (6σ) refers to the standard deviation 6σ which is derived from the idea that the chance of waste occurs 3.4 times per production or operation 1 million times. Most organizations accept a 2-3 sigma level. Six-Sigma is a tool and approach that has been used to improve processes for long-term operations [1] which focuses on improving product quality and effectiveness (Productivity) of the organization [2].

1.2 Rubber Manufacturing Process (Mixing Department)
Rubber manufacturing process, especially mixing process section was, studied and improved in this paper. In company case study consists of 6 main steps, namely: (1) Raw material, (2) Mixing in Kneader, (3) Milling by Two-roll mill, (4) Cooling and Forming, (5) Quality control and (6) Folding and Keeping. These process steps are shown in the chart below.

Figure 1. Rubber mixing process section

2. METHODOLOGY

In the study using the principles of Six-Sigma DMAIC, there are a total of 5 steps as described below. In this paper, the goal is to achieve good mixing performance again. Mooney viscosity of the product (EPDM masterbatch) should be reduced to be in control again and the average Mooney viscosity of the product is approaching closer to the target. Which will result in increased process capability value.

Define – The phase of defining a problem or selecting a project to be improved or designed and emphasizing the requirement of customers. So the selected project should really be important, made worth, to get the target point and don't waste time.

Measure – It is a measuring phase such as measuring process capability, measuring waste, measuring the effectiveness, etc. for analysis of various variables that affect the process. And calculate the variation and capability of the process from sample products (EPDM masterbatch observed), the MINITAB program (version 18) is used to analyze all these results.

- Examine normal Normal Probability Plot of this data (EPDM masterbatch observed) to prove that data normal distributions by looking at P-value (P> 0.05, at $\alpha = 0.05$, the data is normal distribution) [7] and then evaluating the capability of the process at that time. The data need to be improved when Cp_k <1.33 for two-sided specifications [8].

Analyze – The purpose of analysis phase (from the measured data) is to find or prove the most important variable in the process (key process variable) that is the root cause of the problem that is defined. In this step, selected potential parameters that have an effect on the problem by scoring results of the research team and those involved are shown in Chart of Cause and Effect Matrix.

- Evaluation of Cause and Effect Matrix, all potential parameters were evaluated by the scoring method on the scale of 0 to 9. Score 9 = strong relationship, score 3 = moderate relationship, score 1 = marginal relationship and score 0 = no relationship.

Improve – This phase focuses on improvements after the variables that are very important or significant are chosen. We then proceeded to edit/improve to eliminate the root cause of the problem from analyst phase or in the design. This process was improved by Central Composite Design (CCD) - Response Surface methodology (RSM).

- Choose the most important 3 parameters with 3 levels (High, Middle and Low) for a central composite design, a way of RSM.
- Use RSM to study the effect and interaction between mixing parameters on rubber property.
- Use RSM, a tool of statistical and mathematical techniques that are utilized for the improvement, and optimization of processes. And then, the best mixing parameters can be predicted at this phase by using Response Optimizer on the Minitab program.

Control – As of last, this is the final phase in the DMAIC process, which ensures that the improvements are sustained and have continuous performance checks. Which, use X-MR Chart for the range of Mooney viscosity to check and doing the DMAIC method periodically.

2.1. A Case Study-Company Profile

The case study company is a rubber product manufacturer including rubber masterbatch, rubber compound, materials and equipment for rubber shoe manufacturers, vulcanized rubber and rubber soles for shoes. All of our rubber products are produced based on our policy to make satisfactory products to service the target group effectively.

Table 1. Mooney Viscosity (MV) specification of the product (Non-oil EPDM masterbatch)

Main specification range	100 ± 5 MU (Mooney Unit)
Average MV of EPDM masterbatch	106.03 MU
Target Specification	100 MU

2.2. Action Follows the DMAIC Approach

2.2.1. *Define phase*

In the production of non-oil EPDM masterbatch, there is an out of spec (OOS) of the Mooney viscosity (which is the value used for QC in each production lot) and the product surface is cracked. Due to incompatibility between rubber and fillers (Filler is not well dispersed in rubber matrices) as shown in Table1, Figures 2 and 3, which is expected to result from improper mixing conditions.

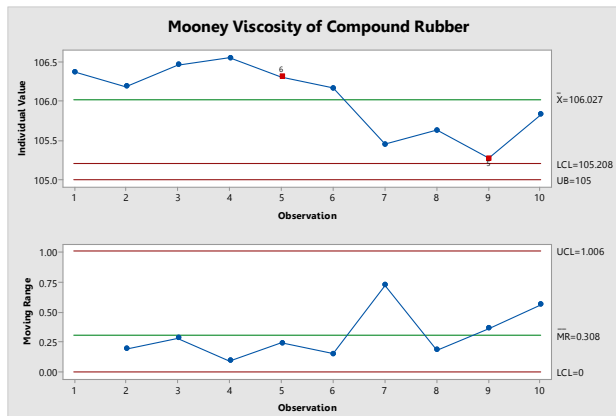


Figure 2. I and MR control chart - Mooney viscosity exceeds the threshold set by the factory.

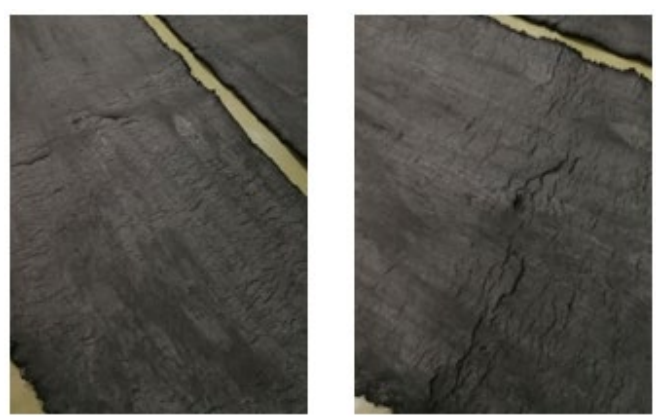


Figure 3. The defect on the surfaces of Off-spec products.

Table 2. Observation data (Before improvement)

Sample no.	Mooney viscosity (MU)
1	106.38
2	106.19
3	106.47
4	106.56
5	106.32
6	106.17
7	105.45
8	105.63
9	105.27
10	105.83

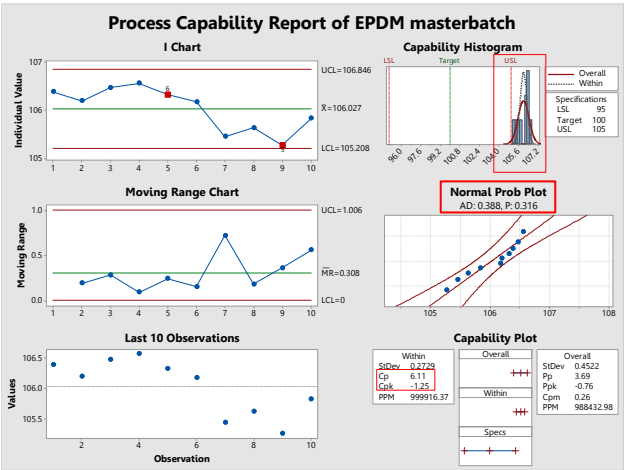


Figure 4. Process Capability Report of Mooney viscosity of EPDM masterbatch: Before the improvement

2.2.2. *Measure phase*

Initially, we collected data on the problem in the processing line and analyzed statistical values. If the collected data is less than 30 (n <30), the test data normalization (Normal Prob Plot) must be tested first to prove that data normal distributions by looking at P-value (P-Value must greater than 0.05, at α= 0.05). The means of Mooney viscosity of EPDM masterbatch is out of USL for specification product limits and the results of process capability Analysis (Cp, Cp_k) at this time are 6.11 and -1.25 respectively as shown in Figure 4 (Cp, Cp_k should be greater than 1.33 for two-sided specifications [8]).

2.2.3. *Data analysis*

Cp is greater than or equal to the specified acceptance criteria (1.33) but Cp_k is less than the specified acceptance criteria (1.33) Indicates that the level of process variation is small at an acceptable level but the process is still unacceptable because the process has a mean deviation from the target value. We should find a method to improve the average to be closer to the target.

According to the data (Before improvement, Table2), the product (EPDM masterbatch) exceeds the upper spec limit (USL) but the process variation is relatively low, which can be seen from low standard deviation (SD) and I and MR chart, which is in the UCL-LCL. This indicates that this process is in-control and ready to be improved. To find the parameters that affect the quality of the mixing process, there is no need to reduce the variation of the process before the improved in the next step.

2.2.4. *Identification of the possible cause*

Analysis of the exact cause of the problem was performed by using cause and effect diagram (see Figure 5) that is analyzed according to the principles of 5M1E at each step of the process [3]. Then, the potential factors that were screened by the Cause and Effect Matrix step, which were scored by the brainstorming of the research team and those involved were summarized (as shown in Figure 6). It was found that the factors that the research team expected to affect the quality of the mixing including 7 parameters (i.e. Mixing time, Mixing temp, Fill- factor, Rotor speed, Ram pressure, Nip gap and Number of passes) which, if the quality of mixing is poor, this will affect product quality (EPDM masterbatch) and out of specification of products.

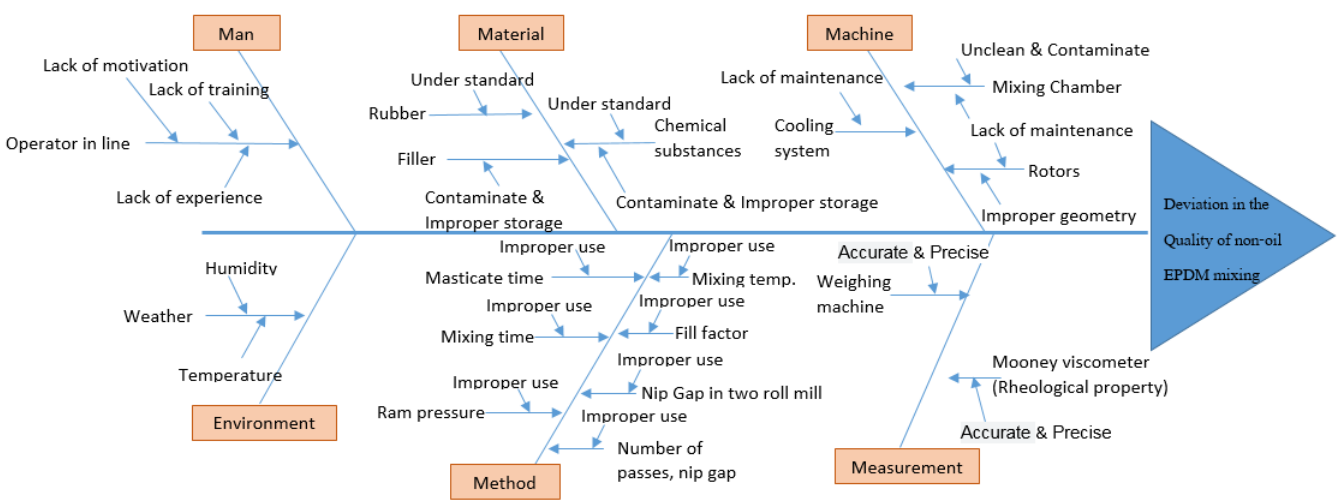


Figure 5. Cause-and-effect diagram related to EPDM mixing quality problem

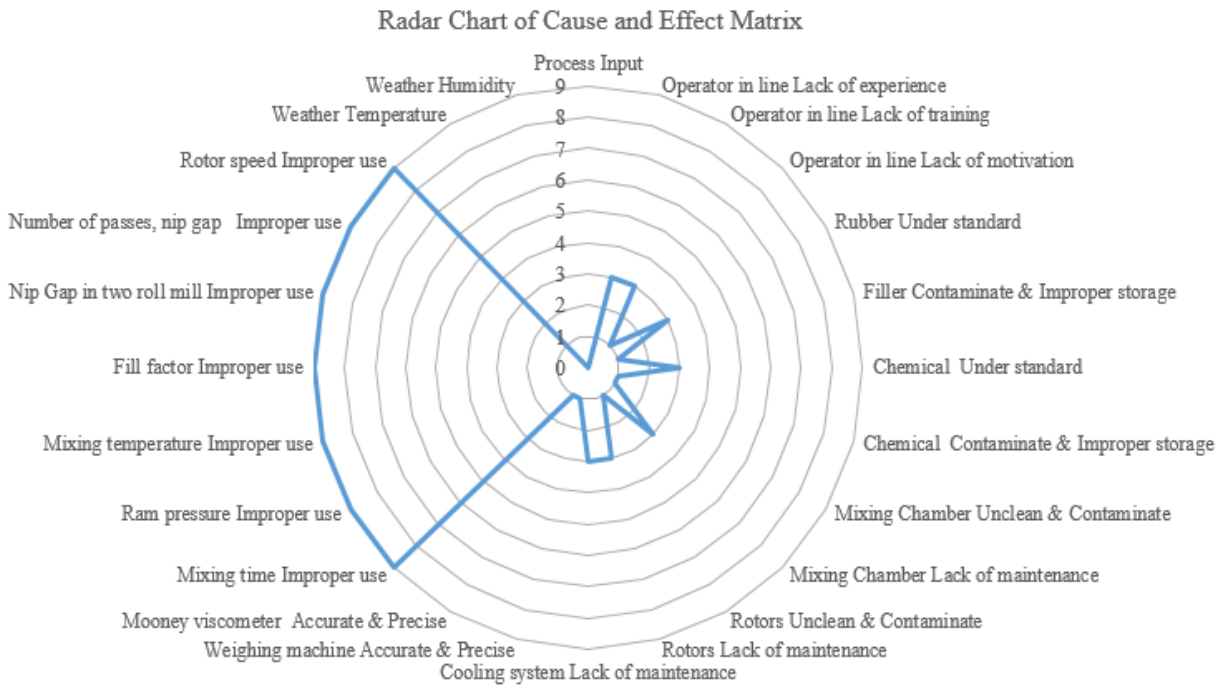


Figure 6. Radar Chart of Cause and Effect Matrix

Table 3. Central Composite full Design (40 runs) of the experiment for 3 factors , each at 3 levels

StdOrder	RunOrder	PtType	Blocks	A : Mixing time, min	B : Nip Gap, mm	C : No.of passes, pass	Mooney Viscosity (Y)
27	1	1	1	6	2.3	13	105.69
13	2	-1	1	10	1.65	3	105.34
30	3	-1	1	14	1.65	8	102.1
21	4	1	1	6	1	3	106.03
35	5	0	1	10	1.65	8	102.91
22	6	1	1	14	1	3	104.05
24	7	1	1	14	2.3	3	103.84
16	8	0	1	10	1.65	8	102.67
39	9	0	1	10	1.65	8	102.54
36	10	0	1	10	1.65	8	102.65
8	11	1	1	14	2.3	13	101.06
26	12	1	1	14	1	13	96.99
5	13	1	1	6	1	13	96.77
19	14	0	1	10	1.65	8	102.53
20	15	0	1	10	1.65	8	102.76
3	16	1	1	6	2.3	3	108.24
14	17	-1	1	10	1.65	13	100.94
17	18	0	1	10	1.65	8	102.64
9	19	-1	1	6	1.65	8	104.43
2	20	1	1	14	1	3	104.38
25	21	1	1	6	1	13	96.48
28	22	1	1	14	2.3	13	101.74
23	23	1	1	6	2.3	3	108.34
37	24	0	1	10	1.65	8	102.9
11	25	-1	1	10	1	8	100.75
32	26	-1	1	10	2.3	8	105.84
15	27	0	1	10	1.65	8	102.83
31	28	-1	1	10	1	8	100.69
6	29	1	1	14	1	13	97.46
38	30	0	1	10	1.65	8	102.66
40	31	0	1	10	1.65	8	102.67
18	32	0	1	10	1.65	8	102.75
10	33	-1	1	14	1.65	8	102.1
33	34	-1	1	10	1.65	3	104.57
1	35	1	1	6	1	3	106.01
29	36	-1	1	6	1.65	8	104.05
34	37	-1	1	10	1.65	13	100.87
12	38	-1	1	10	2.3	8	105.6
4	39	1	1	14	2.3	3	103.99
7	40	1	1	6	2.3	13	104.87

2.2.5. *Improve*

The parameters that have the highest score, will be chosen to improve the composed of a total of 7 parameters as described above. However, due to the limitations of the machine and budget, some parameters are fixed (i.e. Rotor speed, Mixing temp, Ram pressure and Fill factor), remaining only 3 parameters selected: Mixing time, Nip gap and Number of passes. The research team and those involved think that actually adjust and modify at the factory in the short term. To find the appropriate level of parameters, the research team has chosen the use of a central composite design - response surface method (RSM) which each parameter is divided into 3 levels (as shown in Table 4), evaluation result as shown in Table 3. In this paper, the author and team members focus on adjusting the parameters to make the response variable value coming close to the target value.

Table 4. Machining parameters and their levels

Control parameters	Unit	Symbol	Levels		
			-	0	+
Mixing time	min	A	6	10	14
Nip gap	mm	B	1.00	1.65	2.30
Number of passes	pass	C	3	8	13

*Fill factor (0.8), Rotor speed (30 rpm/23 rpm) and Initial mixing temperature (80°C) are fixed.

From results, ANOVA for response function of Mooney viscosity (Figure 7) can be seen that each parameter has a p-value less than 0.05, at α= 0.05 which shows that all 3 main parameters and their interactions affect Mooney viscosity of products significantly. And the equation used in the Central Composite Design (CCD) to suit the effect of the variable (X) on the response (Y) is explained by Eq 1 (the second-order model).

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \beta_{ii} X_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{ij} X_i X_j \qquad (1)$$

If there is curvature in the system, then a polynomial of higher degree must be used, such as the second-order model. In most cases, the second-order model is adequate. In this section, we will show how to use this fitted model to find the optimum set of operating conditions for parameters [4]. The Fit Regression Model for this experiment is shown in Figure 7, Eq. 2.

Analysis of Variance α to enter = 0.05

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	284.117	47.353	242.25	0.000
Linear	3	240.104	80.035	409.45	0.000
Mixing time	1	26.912	26.912	137.68	0.000
Nip Gap	1	78.408	78.408	401.12	0.000
No.of passes	1	134.784	134.784	689.54	0.000
2-Way Interaction	3	44.013	14.671	75.05	0.000
Mixing time*Nip Gap	1	12.426	12.426	63.57	0.000
Mixing time*No.of passes	1	2.102	2.102	10.76	0.002
Nip Gap*No.of passes	1	29.485	29.485	150.84	0.000
Error	33	6.451	0.195		
Lack-of-Fit	8	5.088	0.636	11.67	0.000
Pure Error	25	1.363	0.055		
Total	39	290.568			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.442121	97.78%	97.38%	96.40%

Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	102.893	0.070	1471.89	0.000	
Mixing time	-1.1600	0.0989	-11.73	0.000	1.00
Nip Gap	1.9800	0.0989	20.03	0.000	1.00
No.of passes	-2.5960	0.0989	-26.26	0.000	1.00
Mixing time*Nip Gap	-0.881	0.111	-7.97	0.000	1.00
Mixing time*No.of passes	0.362	0.111	3.28	0.002	1.00
Nip Gap*No.of passes	1.358	0.111	12.28	0.000	1.00

Regression Equation in Uncoded Units

Mooney Viscosity (Y) = 106.29 + 0.1243 Mixing time + 3.094 Nip Gap - 1.3896 No.of passes - 0.3389 Mixing time*Nip Gap + 0.01812 Mixing time*No.of passes + 0.4177 Nip Gap*No.of passes (2)

Figure 7. Results of ANOVA for response function of Mooney viscosity

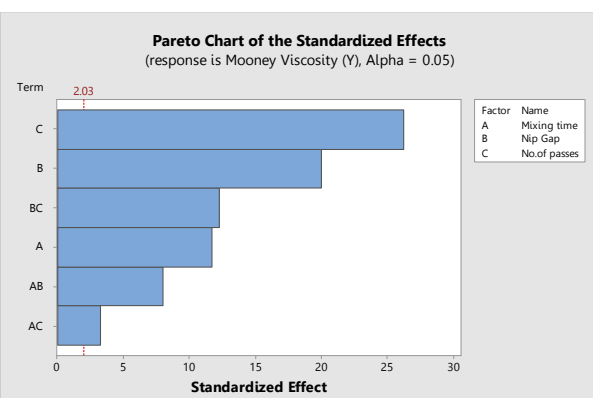
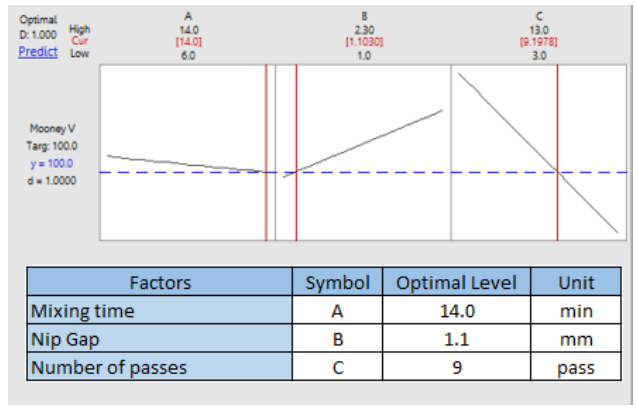


Figure 8. Pareto Chart of the Standardized Effects

According to (Figure8), it is found that the most influential factor on response Y (Mooney viscosity) are C (Number of passes, nip gap), B (Nip gap), Interaction BC, A (Mixing time), Interaction AB and Interaction AC respectively. From this knowledge, it made us know which factors we should focus on first to improve in order to get good mixing quality in the future.

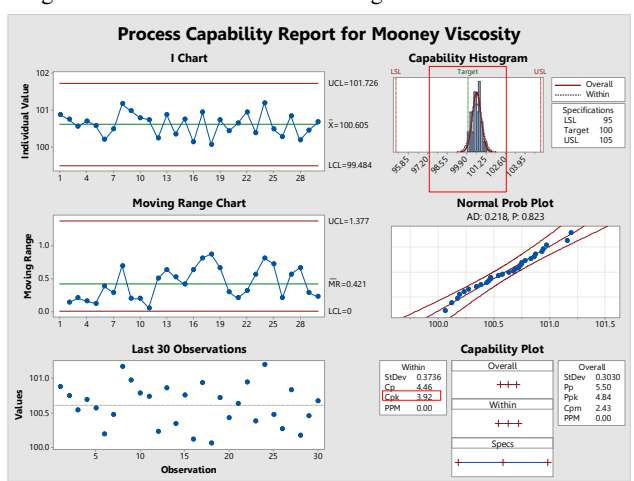


Factors	Symbol	Optimal Level	Unit
Mixing time	A	14.0	min
Nip Gap	B	1.1	mm
Number of passes	C	9	pass

Figure 9. Response optimization plot

After getting the optimal parameter condition by using the Minitab program (Response Optimizer) with the Target setting 100 MU (Figure 9), the prediction results are Mixing time ~ 14 (min.), Nip gap ~ 1.10 (mm.) And Number of passes ~ 9 (pass.). Moreover, it will be used as a guideline to determine a value for each parameter of the mixing process (After improvement). Which the results as shown in Table 5.

By setting the parameter level according to the above values and collecting data (after set new parameter), make to calculate statistical values and process capability report (Cp_k) again, which found that the standard deviation value (SD) is decreased. Process capability value (Cp_k) is increased and the mean of the output close to target value increased as shown in Figure 10.



Response	Before improvement			After improvement		
	Average	SD	C_{pk}	Average	SD	C_{pk}
Mooney viscosity value	106.03	0.45	-1.25	100.61	0.30	3.92

Figure 10. Process Capability Report of Mooney viscosity of EPDM masterbatch: After improvement

2.2.6. *Control*

The goal of the control phase is to maintain the efficiency of the developed process to be sustainable, which has checked and doing the DMAIC method periodically.

Table 5. Final observation data (After improvement)

Sample no.	Mooney viscosity (MU)
1	100.87
2	100.74
3	100.54
4	100.69
5	100.57
6	100.19
7	100.47
8	101.16
9	100.97
10	100.78
11	100.73
12	100.23
13	100.86
14	100.34
15	100.75
16	100.12
17	100.93
18	100.06
19	100.72
20	100.43
21	100.63
22	100.94
23	100.38
24	101.19
25	100.47
26	100.27
27	100.83
28	100.17
29	100.45
30	100.67

3. DISCUSSION AND CONCLUSION

This paper utilizes the DMAIC method, which is one of the Six-Sigma principles in examining and developing a case study company in the rubber mixing process section. Results are shown as follows: First, it can help the product (EPDM masterbatch) to be in spec range and on target particularly the Mooney viscosity, which is an important parameter that can be used to predict the processibility for the next process. The low viscosity masterbatch is easy for mixing (no need to masticate for a long time, reduced cycle time, lowered mixing time and energy). In the injection molding process, it can easily flow in a complex mold. Second, process capability value (Cp_k) is highly improved from -1.25 to 3.29 due to the mean of process move closer to target significantly and less variation.

4. ACKNOWLEDGEMENT

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Blockchain Technology Adoption: Examining the Fundamental Drivers

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ABSTRACT
Identifying and quantifying the drivers for adopting blockchain technologies are important for developing effective launch plan. Technology Acceptance Model (TAM) and its derivatives have been used for this purpose. However, some of these models only use a few standardized, predetermined independent variables to collectively represent the drivers. Low predictive power of TAM leads to questions on whether this restriction may detrimentally constrain the exploration of other driving factors. Some other extended models with higher R^2 are considered impractical and lack of theoretical foundations. This paper demonstrates that reasonable predictive power can be achieved even with simple, practically implementable model when research targets are sampled and segmented properly. By employing a more fundamental theory, this study has also included additional variable that would normally not be considered in TAM.

CCS Concepts
• Social and professional topics→ Professional topics

Keywords
Blockchain; Technology Acceptance; Reasoned Action; Planned Behavior

1. INTRODUCTION
Numerous researchers and consultants have analyzed and predicted the path of blockchain technology adoption based on technical advantages and values. Business strategies are hence derived [1-6]. However, fewer works have been done to understand the adoption from user behavior perspectives. Among the available studies, most of them use Technology Acceptance Model (TAM) to investigate the adoption behavior [7-9]. While TAM has been widely used for analyzing technology adoption, its predictive power has also been widely criticized [10-19]. To improve predictive power, extensions of TAM such as Unified Theory of Acceptance and Use of Technology (UTAUT) have been proposed [20]. These models give higher R^2 but being challenged for artificially introducing numerous moderators to achieve the results [21,22]. The excessive number of variables would also make UTAUT impractical for real-life researches. This study briefly examines the cause of apparent low R^2 in TAM and, by properly defining scope and sampling, demonstrates that reasonably high R^2 can be achieved with simple and implementable model under practical business environment.

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2. RELEVANT THEORIES
It is a common belief that attitude towards a certain behavior determines the actual action to perform or not perform that behavior. Theory of Reasoned Action (TRA) points out that human performing a particular behavior is influenced not only by his or her attitude towards that behavior, but also a subjective norm about that behavior [23]. Subjective norm refers to the subject's belief of what other relevant people think about the behavior. The theory explains many apparently inconsistent behaviors found in social science research [24]. As a further refinement, the Theory of Planned Behavior (TPB) has been developed to account for the subject's volition control. This is achieved by adding a component known as perceived behavioral control to TRA [25, 26].

The importance of TRA / TPB is that effect or strength of each driver for a particular behavior can be verified and quantified. This would be very useful for understanding barriers to a desirable behavior, and hence developing appropriate strategies to encourage it. Quit smoking, avoid drug use, treat illicit alcohol consumption are well-known applications of TRA / TPB in health sector [27-29]. In early smoking cessation campaigns, health hazards were emphasized. However, effectiveness was low. By using TPB, researchers identified that many smokers already had very high awareness about these negative health impacts and wanted to quit (i.e. a positive attitude towards quit smoking), but would not able to control their own behavior to stop smoking due to influences of subjective norm (e.g. what would their smoking friends think if he or she quit) and perceived behavioral control (e.g. low self-efficacy). Surprisingly, the behavior of "attempt to quit smoking" correlates much heavier to subjective norm and perceived behavioral control than to attitude [27, 30]. With these discoveries, later campaigns put more attentions to change subjective norm (e.g. emphasize supports from family and friends) and enhance perceived behavioral control (e.g. reinforce self-confidence), and subsequently achieved better results [27, 30]. The theory is equally applicable to behavioral investigation in technology sector. Adoption of energy services company in heavy industry, for example, has been analyzed and policy recommendations have been made accordingly [31].

Derived from TRA, Technology Acceptance Model (TAM) assumes the perceived usefulness of a technology and perceived ease of use can predict the actual use via attitude towards using [32]. This assumption is questionable because the connection between attitude towards using a technology and the actual use can be affected by factors not controllable by the potential user. If the user cannot make the final decision to adopt a certain technology, his attitude towards using this technology is obviously not a reliable predictor of adoption. In fact, researchers have pointed out that while TAM may reasonably predict user's

intention, predictive power for actual use is low [10-19]. Effect of decision autonomy is illustrated in Section V.

A further problem is the effects of subjective norm in TRA model had been ignored in early TAM, although the construct has been added back in later versions of TAM [33]. It is worth pointing out that TRA concerns about decision of an individual and, as discussed above, subjective norm has an important role in many cases. Without this construct, it is expected that the model's predictive power will be reduced. This inference is consistent with most observations in [10-19].

To account for user's inability to make final adoption decision, moderators are introduced [20,33]. However, this approach has been criticized for being artificially increasing the R^2 without solid theoretical foundation [22]. Furthermore, adding numerous variables to the model has made it rather impractical in many real-life business settings.

As an alternative, the perceived behavioral control construct in TPB could possibly account for user's inability to make final adoption decision. Some studies [34-36] compared the predictive power of TPB and TAM on actual use but results are not conclusive.

To provide reliable insights for business strategy development, user's inability to make final adoption decision must be accounted. On the other hand, model construction must be based on researches that can be practically implemented under real-life business constraints. As discussed in Section IV, this study collects data from seminar participants and therefore, in the interest of time, only modest number of Likert scale questions are asked. Instead of introducing moderators to improve R^2, an early segmentation is applied, followed by analyses that include some and all of the segments.

In this paper, adoption of blockchain technologies among small and medium size enterprises (SME) in Hong Kong is analyzed. Data was collected via questionnaire and has been segmented by the respondent's industry, company revenue, and ability to make decision for blockchain technology adoption. Through segmentation, user's ability/inability to make final adoption decision has been accounted and the initial model is built based on responses from those decision makers. Details are explained in section IV.

Given the issue of decision making has been addressed, simple TRA model is chosen for model development under practical data collection restrictions.

3. THE MODEL

3.1 Model Construction

A proposed TRA model is shown in Figure 1.

In this model, three constructs drive the behavior of blockchain technology adoption. They are:

USF = perceived usefulness

EOU = perceived ease of use

TRD = perceived trend

Other constructs, as defined in standard TRA, are:

ATT = attitude towards adoption

NOR = subjective norm of adoption

INT = behavioral intention to adopt

BHV = behavior to adopt

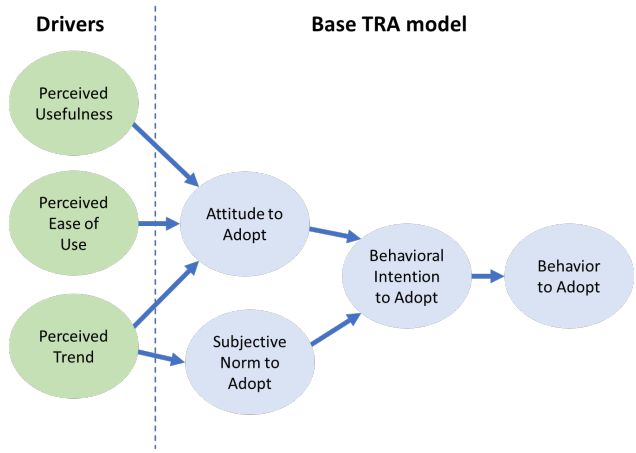

Figure 1. TRA model for blockchain technology adoption

3.2 Model Validation

Based on the model structure, mediation analysis is used to validate the model. Hypotheses in Table 1 are being verified.

Table 1. Hypotheses for TRA blockchain adoption model

Hypothesis		Description
H1	H1a	USF and INT are positively correlated.
	H1b	ATT and INT are positively correlated.
	H1c	The relationship between USF and INT is mediated by ATT.
H2	H2a	EOU and INT are positively correlated.
	H2b	ATT and INT are positively correlated.
	H2c	The relationship between EOU and INT is mediated by ATT.
H3	H3a	TRD and INT are positively correlated.
	H3b	ATT and INT are positively correlated.
	H3c	The relationship between TRD and INT is mediated by ATT.
H4	H4a	TRD and INT are positively correlated.
	H4b	NOR and INT are positively correlated.
	H4c	The relationship between TRD and INT is mediated by NOR.
H5	H5a	ATT and BHV are positively correlated.
	H5b	INT and BHV are positively correlated.
	H5c	The relationship between ATT and BHV is mediated by INT.
H6	H6a	NOR and BHV are positively correlated.
	H6b	INT and BHV are positively correlated.
	H6c	The relationship between NOR and BHV is mediated by INT.

To obtain numerical values for validation, these constructs are measured via 20 variables listed in Table 2. Each variable is corresponding to a question on the questionnaire designed for this research. Respondents provide their answers by indicating whether they Strongly Agree (score=5), Agree (score=4), being Neutral (score=3), Disagree (score=2), or Strongly Disagree (score=1) to the statement of the question. Numerical averages of variables associated with each construct would be, subjected to Cronbach's Alpha test, used to represent the respondent's view about that construct.

Table 2. Variables / questions for measuring the constructs

Construct	Variable	Description
USF	USF_1	In our business, some process improvements CANNOT be made without blockchain technologies.
	USF_2	Adopting blockchain technologies will enable our company to offer new products / services that CANNOT be provided in the past.
	USF_3	Blockchain technologies can provide a justifiable return on investment in a reasonable period of time.
	USF_4	In our sector, companies who have implemented blockchain technologies have gained competitive advantages.
EOU	EOU_1	Blockchain technologies are safe and reliable.
	EOU_2	For our business, there is no major operational barrier for adopting blockchain technologies.
	EOU_3	Our employees can quickly cope with changes due to deploying blockchain technologies.
	EOU_4	If needed, external implementation consultants are readily available at a reasonable fee.
TRD	TRD_1	At a regional / country level, authorities are encouraging companies to adopt blockchain technologies.
	TRD_2	Adopting blockchain technologies is becoming a trend in many business sectors.
	TRD_3	More companies in OUR sector will adopt blockchain technologies in the NEAR future.
NOR	NOR_1	Our customers would expect our company to use blockchain technologies.
	NOR_2	Our suppliers would expect our company to use blockchain technologies.
	NOR_3	Our employees would expect our company to use blockchain technologies.
ATT	ATT_1	Blockchain technologies can improve our operation
	ATT_2	In an overall sense, blockchain technologies are good for our company.
INT	INT_1	I believe our company should implement blockchain technologies in NEAR future.
	INT_2	I am actively cultivating agreement among other relevant members in the company to adopt blockchain technologies.
BHV	BHV_1	We are working out / already have a implementing plan with budget for blockchain technologies.
	BHV_2	We have spent / scheduled to spend remarkably on implementing blockchain technologies.

Upon finishing data collection, the following analyses are performed in order to formally validate the model:

(i) Cronbach's Alpha – to verify if using numerical average of the variables to represent the construct is vital.

(ii) Correlation and Discriminant Validity – to verify the theoretically uncorrelated constructs are actually uncorrelated.

(iii) Mediation Test – to verify the hypotheses in Table 1 in order to valid the proposed TRA model.

(iv) Exploratory Analyses – to explore alternative model structure.

(v) Predictive Power – to illustrate changes in model predictive power when different segments of respondents are included

4. DATA COLLECTION

4.1 Tools for data collection

Starting February 2019, an anonymous questionnaire designed for this research had been distributed to audiences of a number of commercial seminars on information technology for SMEs in Hong Kong. The survey officially closed in July 2019. There are 23 questions on the questionnaire, with 20 questions directly corresponding to the variables on Table 2, and 3 questions for understanding the essential background of the respondent. These three questions are shown in Table 3. At the end of each seminar, a short briefing about this survey is provided. Then, the audiences are asked to spare about 10 minutes to fill out and return the questionnaire.

Table 3. Additional questions about respondent's background

Which of the followings best describe your business nature? __ Manufacturing __ Trading __ Services __ Retail __ Others
You company's annual revenue is: __ Under USD 5M __ USD 5 - 25M __ USD 25-50M __ Over USD 50M
Concerning about evaluating and /or investing in blockchain technologies, you are: __ the final decision maker __ taking major responsibilities __ regularly involved __ occasionally involved __ not involved

While attaching survey to commercial seminars is helpful for securing a satisfactory respond rate, there are a few limitations that could affect the research quality.

(a) Length of the questionnaire – it is impractical to request respondent to answer many questions under this setting. Spending 10 minutes is probably the threshold. For TRA survey, using only 20 questions to valid a general model is challenging [37].

(b) Appropriateness of sample – this survey is about decision of adopting blockchain technologies. Not all seminar participants are decision makers even though they might have a keen interest to adopt blockchain technologies.

(c) Size of the respondent's company – big companies generally have more resources for evaluating new technology options and therefore could behave differently from smaller companies.

(d) Timing – data collection for this research spreads over a period of six months in order to collect sufficient samples. Respondents' views about adopting blockchain technologies may changed during this period of time.

Based on these considerations, the following remedial actions are taken.

(a) The TRA model is built based on the responses from "final decision makers" and those who are "taking major responsibility" for deciding whether to adopt blockchain technologies (see Table 3);

(b) In addition to (a), only include responses where company's annual revenue is in the range of USD 5-50M (see Table 3).

4.2 Result of Data Collection

A total of 263 valid questionnaires has been collected in the six-month period. With the criteria set-forth in Section 4.2, 117 responses satisfy the conditions and are being used for model development. In these 117 samples, 72.6% has an annual revenue between USD 5 to 25M, and the remaining 27.4% runs from USD 25 to 50M. In terms of business sector, 36.8% of the respondents come from manufacturing, 32.5% from trading, 10.3% from services sector, 15.4% from retail, and 5.1% belongs to other sectors. Regarding respondent's role, 34.2% claim to be final decision makers and 65.8% are, even though may not be the final decision maker, taking up major responsibilities for making decisions to adopt blockchain technologies.

For the remaining 146 samples not used for model development, 42 respondents have reported that they regularly involve in evaluating or investing in blockchain technologies. The rest 104 respondents mention that they are occasionally involved. This information would be used for analyzing model predictive power in section V.

5. DATA ANALYSES

Because of small sample size, it is infeasible to separately analyze data by business sector, revenue, or respondent's role. Therefore, the complete dataset is analyzed in a consolidated manner.

5.1 Cronbach' Alpha

Cronbach's Alpha test examines whether a construct can be vitally represented by the numerical average of the associated variables (i.e. respondent's answers range from 1 to 5). A Cronbach's Alpha higher than 0.7 indicate acceptable internal reliability [38]. For this survey, all Cronbach's Alphas are satisfactory (Table 4).

Table 4. Cronbach's Alpha test

	No. of variables	No. of data	α
USF	4	117	0.815
EOU	4	117	0.784
TRD	3	117	0.706
NOR	3	117	0.890
ATT	2	117	0.763
INT	2	117	0.830
BHV	2	117	0.918

5.2 Correlation and Discriminant Validity

Examining the independence of the constructs is especially important for this survey due to small sample size. In order for the model to be vital, one must determine whether the constructs are distinctive. That is, the theoretically uncorrelated constructs are actually uncorrelated. Researchers [39] have demonstrated that such discriminant validity can be claimed if

$$1 - r - SE > 0 \quad (1)$$

where r is the correlation coefficient
SE is the standard error

As shown in Table 5, discriminant validity is satisfied.

Table 5. Discriminant Validity

Construct-pair	Correlation Coefficient (r)	Standard Error (SE)	1 - r - 2*SE
USF - EOU	0.523	0.075	0.327
USF - TRD	0.753	0.051	0.145
USF - NOR	0.749	0.074	0.103
USF - ATT	0.834	0.059	0.048
USF - INT	0.778	0.087	0.048
USF - BHV	0.746	0.095	0.064
EOU - TRD	0.552	0.069	0.310
EOU - NOR	0.671	0.088	0.153
EOU - ATT	0.555	0.095	0.255
EOU - INT	0.701	0.100	0.099
EOU - BHV	0.700	0.102	0.096
TRD - NOR	0.746	0.090	0.074
TRD - ATT	0.761	0.083	0.073
TRD - INT	0.627	0.124	0.125
TRD - BHV	0.554	0.134	0.178
NOR - ATT	0.792	0.054	0.100
NOR - INT	0.860	0.056	0.028
NOR - BHV	0.773	0.071	0.085
ATT - INT	0.783	0.072	0.073
ATT - BHV	0.680	0.086	0.148
INT - BHV	0.864	0.048	0.040

5.3 Mediation Test

Mediation test (Figure 2) verifies each proposed relation in the model via testing the hypotheses in Table 1.

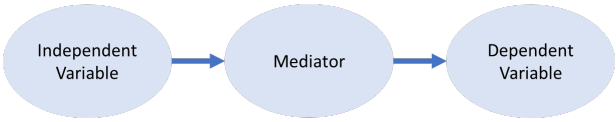

Figure 2. Mediation test

Mediation effect exists when the following three conditions are met [40, 41]:

(i) The independent variable significantly predicts the dependent variable;

(ii) The independent variable significantly predicts the mediator variable; and

(iii) When the dependent variable is regressed on both the mediator and the independent variable, the mediator significantly predicts the dependent variable while the predictive utility of the independent variable is reduced. The mediation is partial if both the mediator and the independent variable are significant. If the mediator is significant and the independent variable is becoming insignificant, this is a full mediation.

Results of mediation test (Table 6) support all the hypotheses in Table 1.

Table 6. Mediation Test

Constructs	Correlation Coefficient	p-value	Mediation
USF - INT	0.778	0.000	Partial
USF - ATT	0.834	0.000	
USF - INT	0.412	0.000	
ATT - INT	0.440	0.000	
EOU - INT	0.701	0.000	Partial
EOU - ATT	0.555	0.000	
EOU - INT	0.385	0.000	
ATT - INT	0.569	0.000	
TRD - INT	0.627	0.000	Full
TRD - ATT	0.761	0.000	
TRD - INT	0.075	0.406	
ATT - INT	0.726	0.000	
TRD - INT	0.627	0.000	Full
TRD - NOR	0.746	0.000	
TRD - INT	-0.033	0.644	
NOR - INT	0.885	0.000	
NOR - BHV	0.773	0.000	Full
NOR - INT	0.860	0.000	
NOR - BHV	0.114	0.217	
INT - BHV	0.766	0.000	
ATT - BHV	0.703	0.000	Full
ATT - INT	0.809	0.000	
ATT - BHV	0.009	0.904	
INT - BHV	0.857	0.000	

5.4 Exploratory Analyses

Exploratory analyses are performed to explore further insights about the relationships among the variables. Significance levels are denoted by: * $p < 0.01$, ** $p < 0.005$, *** $p < 0.001$

(a) BHV is regressed against INT

Table 7. BHV - INT

	Correlation Coefficient	p-value	R^2
BHV - INT	0.864	0.000	0.747

INT significantly predicts BHV, as suggested by the model.

(b) BHV is regressed against INT, ATT and NOR

Table 8. BHV – INT, ATT, NOR

	Correlation Coefficient	p-value	R^2
BHV - INT	0.778	0.000	0.751
BHV - ATT	-0.030	0.713	
BHV - NOR	0.128	0.202	

Although R^2 has increased by 0.004 when ATT and NOR are included, these constructs are non-significant predictors under the presence of INT. The observation is consistent with the proposed model.

(c) BHV is regressed against all other constructs

Table 9. BHV – all other constructs

	Correlation Coefficient	p-value	R^2
BHV - USF	0.506	0.000	0.795
BHV - EOU	0.335	0.001	
BHV - TRD	-0.286	0.039	
BHV - NOR	0.165	0.174	
BHV - ATT	-0.158	0.172	
BHV - INT	0.527	0.000	

R^2 has further increased by 0.044. Significant direct relationships BHV-USF and BHV-EOU exist.

(d) INT is regressed against ATT and NOR

Table 10. INT – ATT, NOR

	Correlation Coefficient	p-value	R^2
INT - ATT	0.272	0.000	0.768
INT - NOR	0.645	0.000	

ATT and NOR significantly predict INT, as suggested by the model.

(e) NOR is regressed against USF, EOU and TRD

Table 11. NOR – USF, EOU, TRD

	Correlation Coefficient	p-value	R^2
NOR - USF	0.424	0.000	0.705
NOR - EOU	0.408	0.000	
NOR - TRD	0.438	0.000	

In addition to the NOR-TRD relation suggested by the model, significant direct relationships NOR-USF and NOR-EOU also exist.

(f) ATT is regressed against USF, EOU and TRD

Table 12. ATT - USF, EOU, TRD

		Correlation Coefficient	p-value	R^2
ATT -	USF	0.661	0.000	0.863
	EOU	0.128	0.074	
	TRD	0.360	0.001	

Unlike the model suggests, the EOU is a non-significant predictor of ATT.

Based on the results of all the analyses and validations in this section, a revised model is proposed as in Figure 3. Besides a few additional relations have been identified, an interesting observation is perceived ease of use (EOU) does not significantly predict attitude to adopt (ATT). This contradicts the assumption of TAM. Other researchers [42-45] have also reported that EOU is not a significant predictor of ATT in their studies.

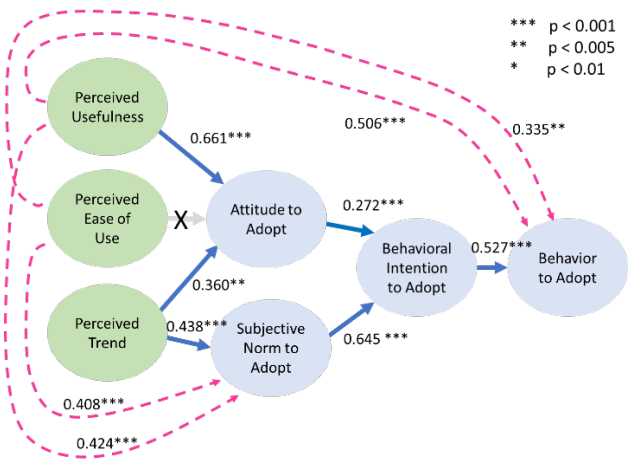

Figure 3. Revised TRA model for blockchain technology adoption

5.5 Predictive Power

The current model has been developed based on the responses from 117 decision makers who have control on whether to adopt blockchain technologies for their organization. To rigorously compare the effects of including responses from non-decision makers, additional models should be built. However, extensive efforts are required. Since USF, EOU and TRD are verified vital drivers, they are used for an indicative regression analysis.

By regressing BHV against USF, EOU and TRD, the constructs explain 70.2% variance of BHV. The high R^2 value confirms the model's predictive power on actual use of blockchain technologies.

If responses from non-decision makers are included, predictive power would be affected. With the same regression analysis, R^2 becomes 29.3% when the 42 respondents who claim to be regularly involved in evaluation / investing are included. When all responses are used for regression, R^2 becomes 18.2%. Hence, models based on non-segmented data would not be reliable for predicting actual use. The deterioration of R^2 reflects that, in an organization setting, non-decision makers may be forced to use or not to use the technologies regardless of his or her intention to use.

To further verify this view, INT is regressed against USF, EOU and TRD for the above three situations. Results are shown in Table 13.

Table 13. Indicative Predictive Power Comparison

R^2	Model 1 (N=117)	Model 2 (N=159)	Model 3 (N=263)
	Decision makers only	Decision makers and those with regular involvement	All respondents
Behavior to adopt (BHV)	70.2%	29.3%	18.2%
Behavioral intention to adopt (INT)	72.6%	73.0%	65.3%

As more responses are included, predictive power for intention remains high in all cases. Hence, user's inability to make final adoption decision would not affect the predictive power on INT but would seriously impact the predictive power on BHV. The observation reaffirms other researchers queries about the connection between attitude of using and actual use [10-19]. Results of this study is consistent with meta-analysis in [46].

6. DISCUSSIONS AND CONCLUSIONS

6.1 General Observations

The revised model in Figure 3 provides quantitative measurements about the relative importance of the drivers. As some other researches have also demonstrated, perceived ease of use (EOU) is not a significant predictor of attitude to adoption (ATT) in this study. This contradicts the assumption of TAM. It is also of interest to see that the weight of subjective norm (NOR) is considerably higher than attitude (ATT). This phenomenon is similar to the observations in smoking cessation campaigns mentioned in Section II. With the insights gained from TRA model, more focused business development strategies can be derived.

6.2 Limitations

This research has illustrated a practical and systematic way to understand the drivers for actual blockchain technology adoption. Instead of developing complex models, predictive power is enhanced by data segmentation at the outset.

The model has been kept as simple as feasible in order to suit practitioners need. Section IV has discussed some limitations of this approach. It is particular important to realize that this research is not sector specific due to practical data collection constraints. Since every sector may have remarkably different behavior, separated investigations are crucial for accurate sectoral strategy development.

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Pump Scheduling for Water Supply Production using Mathematical Programming

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ABSTRACT
This research proposes a mathematical model and a solution for a pump scheduling problem applied in a water supply production plant of the Provincial Waterworks Authority so that the minimum electricity cost is achieved. The branch and cut algorithm in OpenSolver is used to solve the problem. Five pump scheduling scenarios are studied. In the first scenario, the pump scheduling program is implemented in the present production system without production condition changes. In the other scenarios, four main factors are adjusted to analyze the effect on the electricity cost. These factors are the minimum volume of water in a clear water tank, the stock of finished water, the piping capacity, and water demand. The results of the first scenario show that the proposed pump schedules can reduce the electricity cost by 7.87%. The results of the other scenarios indicate that all main factors, except the capacity of the pipe line affect the pump schedules and the electricity cost. The experimental results of these four scenarios yield significant information in regard to production system improvement.

CCS Concepts
- **Mathematics of computing → Solvers**

Keywords
Pump scheduling; water supply production; branch and cut algorithm

1. INTRODUCTION
The case study organization is a branch of the Provincial Waterworks Authority in Thailand with a production rate of 17,935 m^3 per day to service 19,846 households. Water production includes eight main processes: raw water intake, coagulation, flocculation, sedimentation, filtration, disinfection, corrosion control, and distribution. The production process is illustrated in Figure 1.

Raw water, which is from the Maesai river, is drawn into the production process at the raw water pump station. Alum, lime and carbon dioxide are added to the raw water in the coagulation process. This process causes small particles to stick to one another and form larger particles. When the particles become heavy enough to settle at the bottom of a basin, the sediment is removed. The water is then filtered through layers of fine, granulated materials. As smaller suspended particles are removed, turbidity diminishes and clear water emerges. To protect against any bacteria, viruses and other microbes that might remain, disinfectant is added before the water flows into a clear water tank. The pH of water in the clear water tank is maintained by adding alkaline substances. The quality of water is monitored before the water flows into the distribution system and to households.

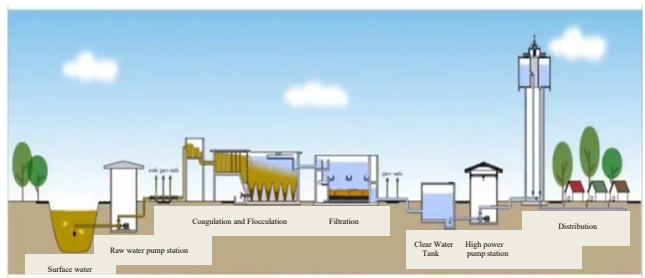

Figure 1. Water supply production process

The water supply production cost of the case study plant is 120,000 Baht per month. Sixty-eight percent of production cost comes from electricity cost and thirty-two percent comes from chemical substances. A major part of the electricity cost occurs at the raw material pump station. There are four pumps at this station. Two of them have power of 110 kW and can pump water at 500 m^3 per hour. One pump with power of 55 kW can pump water at 420 m^3. The other with power of 55 kW can pump water at 380 m^3. At present, the selection of operating pumps and the time slots for operations are assigned depending on the operators' experience. There are three parts of the electricity cost, which are service charge, energy charge and peak demand charge. The service charge is a fixed cost. The energy charge varies according to the time period, which is divided into on-peak and off-peak periods. The energy charge in an on-peak period is double that of the off-peak period. The peak demand charge depends on the daily peak power of all operating pumps. To reduce the electricity cost, a better method to determine the 24-hour operation schedule of these four pumps is required.

The pump scheduling problem is a classic problem that has been of interest to many researchers for a long time. Being one of the pioneers of the subject, [1] presented a method based on linear programming to determine a 24-hour pump schedule that yields minimum cost. A dynamic optimization algorithm was developed

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by [2] limiting the number of pump switches while minimizing the energy consumption cost. The specific constraints of water production systems and the additional operational constraints has led to various types of pump scheduling problem. In addition, the main factors affected by the constraints in the water production system are studied, such as the size of water tanks [3]. A multi-objective function is an extension of classical pump scheduling that considers more than just energy cost. Most mathematical models involve mixed integer nonlinear programming [4]. Since the problems are more complicated, most of the algorithms proposed are heuristics such as the Genetic Algorithm [4], Evolutionary Algorithms [5], the Adaptive Weighted Sum Genetic Algorithm [6] the Neural Network Algorithm [7], etc. Recently, various objectives of pump scheduling have been studied. For example, [8] proposed pump operation scheduling to minimize water loss as a result of leakages in water distribution systems by dividing the large problem into many small sub-problems and solving them by gradient method. According to the literature review, many researches have employed heuristics or meta-heuristics. Few researches have investigated the use of exact algorithms such as the branch and bound algorithm, the branch and cut algorithm, column generation, and dynamic programming. Even though exact algorithms take more computational time than heuristic and metaheuristic algorithms, exact algorithms guarantee an optimal solution. Moreover, a significant increase in the performance of computers due to new technology and computing techniques, has dramatically reduced the limitation of problem size for exact algorithms. There is much software supporting exact algorithms. Most are commercial software such as Premium Solver, MATLAB, CPLEX, etc. Some are freeware such as OpenSolver, which can be applied to medium-sized scheduling problems [9]. These reasons enhance interest in developing and improving exact algorithms.

The purpose of this research is to develop a pump operation scheduling program to apply in a water supply production plant. To solve the problem, the branch and cut algorithm in OpenSolver is employed because of the free software license and user familiarity. This program is intended to provide optimal pump operation schedules with lower electricity cost than the present pump operation schedules. Adjusting the main factors in the water production system is studied to analyze the effect on the system.

2. RESEARCH METHODOLOGY

2.1 Data Collection

The current water production is studied to understand the production process and the current pump scheduling conditions. There are three sizes of pump namely M_1, M_2, and M_3 in the raw water pump station. Let letter i be a machine index and $i \in I$; $I = \{1,2,3\}$. The general pump code is represented by M_i. Four main parameters, which are the raw water pump flow rate, the quantity of sludge blowdown water, the quantity of backwash water, and the capacity of the clear water tank, are summarized in Table 1.

The Time-of-use (TOU) tariff that the Thai metropolitan electricity authority applies to the case study plant, which is a state enterprise, is shown in Table 2. TOU is divided into three parts, which are energy charge (off-peak charge and on-peak charge), peak demand charge, and service charge. The number of working days in a month (d) is determined by the human resource department at the beginning of the year.

The data from both Table 1 and Table 2 are used as the input parameters in the mathematical model. The water production plan is provided daily. Hourly pump operation is determined in the daily production plan. Therefore, there are 24 periods represented by t = 1, 2, …, 24. The parameter t =1 means 9:00 a.m. and t = 24 means 8:00 a.m. the next day. The on-peak period (9:00 a.m. – 9:59 p.m.) is represented by a set T_{on} = {1,2, …, 13}. The off-peak period (10:00 pm. – 8:59 am) is represented by set T_{off} = {14, 15, …, 24}. Since water demand at the beginning of any period t has to be covered, then the water supplied from the production process at the beginning of that period (S_t) in cubic meters is equal to water demand. The forecasted water demand for 22 days is collected for numerical experiments.

Table 1. Data of the current water production process

Raw-water pump			
Pump code (M_i)	**Number of pumps *(NP_i)**	**Power (P_i)**	**Pump performance (V_i)**
M_1	2	110 kW	500 m^3/ hr
M_2	1	55 kW	420 m^3/ hr
M_3	1	55 kW	380 m^3/ hr
Clear water tank			
Capability	**Highest volume** (H_{high})	**Lowest volume** (H_{low})	**Safety stock volume** (H_{stock})
2,500 m^3	2,300 m^3	1,000 m^3	1,800 m^3
Quantity of sludge blowdown water (B_t)			
210 m^3			
Quantity of backwash water (L_t)			
250 m^3			

Table 2. TOU tariff for government enterprise

Voltage level	**Service charge**	**Peak demand charge**	**Energy charge**	
			On-peak 9:00 a.m. - 9:59 p.m.	Off-peak 10:00 p.m.- 8:59 a.m.
	R_s	R_d	R_{on}	R_{off}
22- 33 kV	312.24 Baht/Month	132.93 Baht/kW	4.2097 Baht/kWh	2.6295 Baht/kWh

2.2 Mathematical Model Formulation

The mathematical model representing the water production process is created by using parameters in section 2.1 and the following decision variables:

2.2.1 Decision variables

M_{it} = the number of water pump i operating in period t; $i \in I$ and $t \in T; T\{1,2,...,24\}$

D = Daily peak electrical power (kW)

C_{on} = Electricity cost during on-peak period = $R_{on} \times \sum_{t \in T_{on}} \sum_{i \in I} M_{it} P_i$

C_{off} = Electricity cost during off-peak period = $R_{off} \times \sum_{t \in T_{off}} \sum_{i \in I} M_{it} P_i$

$$C_D = \text{demand charge} = \frac{R_D}{d} \times D$$

$$C_S = \text{Service charge per working day} = \frac{R_S}{d}$$

W_t = Pumped Water Volume at the beginning of period t

TW = the total volume of pumped water

LW = the maximum capacity of pipe line

H_t = volume of clear water at the beginning of period t

2.2.2 Mathematical model

$$Minimize \quad Z = C_{on} + C_{off} + C_D + C_S \qquad (1)$$

subject to

$$H_t = H_{t-1} + W_{t-1} - S_{t-1} - B_{t-1} - L_{t-1} \quad ; \forall\, t \in T \qquad (2)$$

$$H_t \geq H_{low} \quad ; \forall\, t \in T \qquad (3)$$

$$H_t \leq H_{high} \quad ; \forall\, t \in T \qquad (4)$$

$$H_T \geq H_{stock} \qquad (5)$$

$$TW_t = \sum_{i \in I} M_{it} V_i \quad ; \forall\, t \in T \qquad (6)$$

$$W_t \leq TW_t \quad ; \forall\, t \in T \qquad (7)$$

$$W_t \leq LW \quad ; \forall\, t \in T \qquad (8)$$

$$D \geq \sum_{i \in I} M_{it} P_i \quad ; \forall\, t \in T \qquad (9)$$

$$0 \leq M_{it} \leq NP_i \quad ; \forall\, i \in I,\, t \in T \qquad (10)$$

$$M_{it} \in interger \quad ; \forall\, i \in I,\, t \in T \qquad (11)$$

The objective function in Eq. (1) minimizes the total electricity cost of the raw-water pump station, which comprises four cost elements: energy charge during on-peak period, energy charge during off-peak period, demand charge, and service charge per working day. Constraint (2) determines that the volume of clear water in the tank at the beginning of any period t is the summation of the volume of clear water in the tank at the beginning of the previous period and water pumped into the tank at the beginning of the previous period minus the volume of outflow water (water supplied to the households, sludge blowdown water, and backwash water) at the beginning of the previous period. Constraints (3) and (4) state that the volume of clear water in the tank at the beginning of any period t should not be lower than the minimum volume allowance and should be not over maximum volume allowance. Constraint (5) controls the volume of clear water in the tank in the last period of the day, which is not to be lower than the stock level. Constraint (6) states that the total volume of pumped water is the summation of water pumped from all pumps. However, the actual volume of pumped water is restricted by the capacity of the pipe line. Therefore, the actual pumped water is the minimum of two volumes that are the total volume of pumped water and the capacity of the pipe line. This condition is shown by constraint (7) and (8). Constraint (9) shows that daily peak electrical power is the maximum of the summation of electrical power of all operated pumps for all periods of time. Constraint (10) states that the number of water pumps i operating in period t cannot be over the number of available water pumps. Constraint (11) shows that the number of pumps is an integer.

2.3 Program Development

The program is developed in the Excel Spreadsheets conforming to the mathematical model in section 2.2.2. The program comprises four parts, which are parameters, decision variables, constraints, and objective cells. All of the parameters in Tables 1 and 2 are separated in the spreadsheet (Figure 2) from parameter S_t in order to avoid unintentional deletion or data being put into these cells. The formula conforming to the mathematical model is put into the cells for constraints and an objective function shown in Figure 3. After that, the problem is put into the OpenSolver add-on tool by referring to the cells shown in Figure 4. After that, the program uses the branch and cut algorithm to solve the problem. The outputs given from the program are the number of pumps operating in each period, the daily peak electrical power, and the electricity cost, which are put into the decision variable cells (Figure 5).

Input Parameter I		
Data of Pumps		
Pump Code	Power (kW) (kW)	Pumped Volume per hour (m^3)
M1	110	500
M2	110	500
M3	55	420
M4	55	380

Input Parameter II	
Volume of Clear Water (m^3)	
2.1 Capacity of tank	2,500
2.2 Volume at 9 a.m. (H_0)	= HT of previous day
2.3 Allowable Highest Level	1,000
2.4 Allowable Lowest Level	2,300
2.5 Safety Stock Level	1,800

Input Parameter III		
Electricity Charge		
Time		Energy Charge (Baht/ kWh)
On peak	9.00-22.00	4.2097
Off peak	22.00-9.00	2.6295
Peak Demand		132.93
The number of working day in a month		31
Service Charge (Baht/Month)		312.24

Figure 2. Input Parameters

Constraints			Pump Operation Schedule				Electricity Charge	
Ht	LW	TWt	Time Slot	Status			$M_1P_1 + M_2P_2 + M_3P_3$	Energy Charge
(m^3)	(m^3)	(m^3)		M_1	M_2	M_3	Power (kW)	(Baht)
=F5	580	=SUMPRODUCT(T5:T54,V5:V54)	9.00-10.00	0	0	0	=(T5*B5)+(U5*B7)+(V5*	=W5*C14
=N5+O5-K5-J5+5	580	=SUMPRODUCT(T5:T54,V6:V54)	10.00-11.00	0	0	0	=(T6*B5)+(U6*B7)+(V6*	=W6*C14
=N6+O6-K6-J6+6	580	=SUMPRODUCT(T5:T54,V7:V54)	11.00-12.00	0	0	0	=(T7*B5)+(U7*B7)+(V7*	=W7*C14
=N7+O7-K7-J7+7	580	=SUMPRODUCT(T5:T54,V8:V54)	12.00-13.00	0	0	0	=(T8*B5)+(U8*B	=W8*C14
=N8+O8-K8-J8+8	580	=SUMPRODUCT(T5:T54,V9:V54)	13.00-14.00	0	0	0	=(T9*B5)+(U9*B	=W9*C14
=N9+O9-K9-J9+9	580	=SUMPRODUCT(T5:T54,V10:V54)	14.00-15.00	0	0	0	=(T10*B5)+(U10*$	=W10*C14
=N10+O10-K10-J10+10	580	=SUMPRODUCT(T5:T54,V11:V54)	15.00-16.00	0	0	0	=(T11*B5)+(U11*$	=W11*C14
=N11+O11-K11-J11+11	580	=SUMPRODUCT(T5:T54,V12:V54)	16.00-17.00	0	0	0	=(T12*B5)+(U12*$	=W12*C14
=N12+O12-K12-J12+12	580	=SUMPRODUCT(T5:T54,V13:V54)	17.00-18.00	0	0	0	=(T13*B5)+(U13*$	=W13*C14
=N13+O13-K13-J13+13	580	=SUMPRODUCT(T5:T54,V14:V54)	18.00-19.00	0	0	0	=(T14*B5)+(U14*$	=W14*C14
=N14+O14-K14-J14+14	580	=SUMPRODUCT(T5:T54,V15:V54)	19.00-20.00	0	0	0	=(T15*B5)+(U15*$	=W15*C14
=N15+O15-K15-J15+15	580	=SUMPRODUCT(T5:T54,V16:V54)	20.00-21.00	0	0	0	=(T16*B5)+(U16*$	=W16*C14
=N16+O16-K16-J16+16	580	=SUMPRODUCT(T5:T54,V17:V54)	21.00-22.00	0	0	0	=(T17*B5)+(U17*$	=W17*C14
=N17+O17-K17-J17+17	580	=SUMPRODUCT(T5:T54,V18:V54)	22.00-23.00	0	0	0	=(T18*B5)+(U18*$	=W18*C15
=N18+O18-K18-J18+18	580	=SUMPRODUCT(T5:T54,V19:V54)	23.00-24.00	0	0	0	=(T19*B5)+(U19*$	=W19*C15
=N19+O19-K19-J19+19	580	=SUMPRODUCT(T5:T54,V20:V54)	24.00-1.00	0	0	0	=(T20*B5)+(U20*$	=W20*C15
=N20+O20-K20-J20+20	580	=SUMPRODUCT(T5:T54,V21:V54)	1.00-2.00	0	0	0	=(T21*B5)+(U21*$	=W21*C15
=N21+O21-K21-J21+21	580	=SUMPRODUCT(T5:T54,V22:V54)	2.00-3.00	0	0	0	=(T22*B5)+(U22*$	=W22*C15
=N22+O22-K22-J22+22	580	=SUMPRODUCT(T5:T54,V23:V54)	3.00-4.00	0	0	0	=(T23*B5)+(U23*$	=W23*C15
=N23+O23-K23-J23+23	580	=SUMPRODUCT(T5:T54,V24:V54)	4.00-5.00	0	0	0	=(T24*B5)+(U24*$	=W24*C15
=N24+O24-K24-J24+24	580	=SUMPRODUCT(T5:T54,V25:V54)	5.00-6.00	0	0	0	=(T25*B5)+(U25*$	=W25*C15
=N25+O25-K25-J25+25	580	=SUMPRODUCT(T5:T54,V26:V54)	6.00-7.00	0	0	0	=(T26*B5)+(U26*$	=W26*C15
=N26+O26-K26-J26+26	580	=SUMPRODUCT(T5:T54,V27:V54)	7.00-8.00	0	0	0	=(T27*B5)+(U27*$	=W27*C15
=N27+O27-K27-J27+27	580	=SUMPRODUCT(T5:T54,V28:V54)	8.00-9.00	0	0	0	=(T28*B5)+(U28*$	=W28*C15
=N28+O28-K28-J28+28	=SUM(O5:O28)	=SUM(P5:P28)	Total	=SUM(T	=SUM(U	=SUM(V	=SUM(W5:W28)	=SUM(X5:X28)
			(D) Daily peak electrical power (kW)					
			(Z) Electricity cost					=X29+((W31*C23)/C24)+C25/C24

Figure 3. Mathematical Model Worksheet

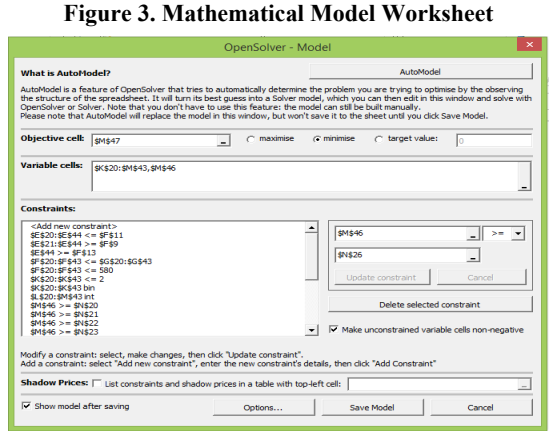

Figure 4. OpenSolver-Model Window

Pump Operation Schedule				Electricity Charge	
Time Slot	Status			$M_{1t}P_1+M_{2t}P_2+M_{3t}P_3$	Energy Charge
	M_{1t}	M_{2t}	M_{3t}	Power (kW)	
	500	420	380		(Baht)
9.00-10.00	0	1	0	55	231.53
10.00-11.00	0	1	0	55	231.53
11.00-12.00	0	1	0	55	231.53
12.00-13.00	0	0	0	0	0.00
13.00-14.00	0	1	0	55	231.53
14.00-15.00	0	1	0	55	231.53
15.00-16.00	0	1	0	55	231.53
16.00-17.00	0	1	0	55	231.53
17.00-18.00	0	1	0	55	231.53
18.00-19.00	0	1	0	55	231.53
19.00-20.00	0	0	0	0	0.00
20.00-21.00	0	1	0	55	231.53
21.00-22.00	0	1	0	55	231.53
22.00-23.00	0	1	0	55	144.623
23.00-24.00	0	1	0	55	144.623
24.00-1.00	0	0	0	0	0.000
1.00-2.00	0	1	0	55	144.623
2.00-3.00	0	0	0	0	0.000
3.00-4.00	0	0	0	0	0.000
4.00-5.00	0	1	0	55	144.623
5.00-6.00	0	1	0	55	144.623
6.00-7.00	0	1	0	55	144.623
7.00-8.00	0	1	0	55	144.623
8.00-9.00	0	1	0	55	144.623
Total	0	19	0	1045	3703.85
(D) Daily peak electrical power (kW)				55	
(Z) Electricity cost				3949.764306	

Figure 5. Answer from OpenSolver

2.4 Program Implementation and Numerical Experiments

Twenty-two sets of past daily demand forecasts for water are used as S_t in the numerical experiments. The schedules of these 22 sets of data are recorded. The electricity cost corresponding to each schedule obtained from the program is collected and compared with that of the present schedule. There are five scenarios to be studied. In the first scenario, the program is implemented under the current production conditions. It is done to test the performance of the program to generate a 24-hour operation schedule for pumps at lower electricity cost. In the other scenarios, the four main factors are adjusted to analyze their effect on the electricity cost. These factors are the minimum volume of water in the clarifier tanks (H_{low}), the stock of finished water (H_{stock}), the piping capacity (LW), and water demand (S_t). The parameter settings of these scenarios are summarized in Table 3.

Table 3. Parameter Settings

Parameter	Parameter				
	1	2	3	4	5
H_{low} (m^3)	1,000	1,000 - 2,200 (Step up by 100)	1,000	1,000	1,000
H_{stock} (m^3)	1,800	1,800	1,000 - 2,200 (Step up by 100)	1,800	1,800
LW (m^3/hr)	580	580	580	TW_t	580
S_t (m^3)	S_t	S_t	S_t	S_t	10 – 50% Additional from S_t

3. RESULTS AND DISCUSSION

The result of the program is 24-hour pump operation status. An example of the pump schedule, which is obtained from solving the problem of Day 1 for scenario 1, is shown in Figure 5. The result shows that pump M_2 with power of 420 kW should be operated during the following times 9:00 a.m.-7:00 p.m., 8:00 p.m.-12:00 a.m., 1:00 – 2:00 a.m., and 4:00 a.m. – 9:00 a.m. Daily peak demand is 55 kW The minimum electricity cost is 3,949.76 Baht. The results for the first scenario show that all pump operation schedules obtained by solving the mathematical model yield lower electricity cost than the present pump operation schedules. The average electricity cost is reduced by 7.87%. The average computational time is 1.87 seconds. The cost due to process changes in the other scenarios.

The electricity costs of scenario 2 and scenario 3 are illustrated in Figure 6 and Figure 7 respectively. Figure 6 shows that the electricity cost is 1.86% higher per each 100 m^3 of additional H_{low}. The increasing rate of electricity cost is higher when H_{low} is over 1,400 m^3. However, decreasing H_{low} to be lower than 1,000 m^3 (present volume) gives an unfeasible solution because the production system cannot cover the demand. The present H_{low} is the critical level that may not support higher demand in the future. Therefore, if the production plant needs to reserve more water to decrease the chance of raw water shortage or to cover increasing water demand in the future, the case study plant needs 1.86% additional electricity cost and needs to control H_{low} not to be over 1,400 m^3.

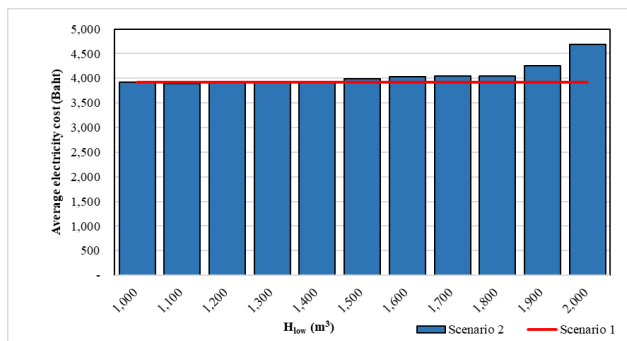

Figure 6. Average electricity cost at each H_{low} level

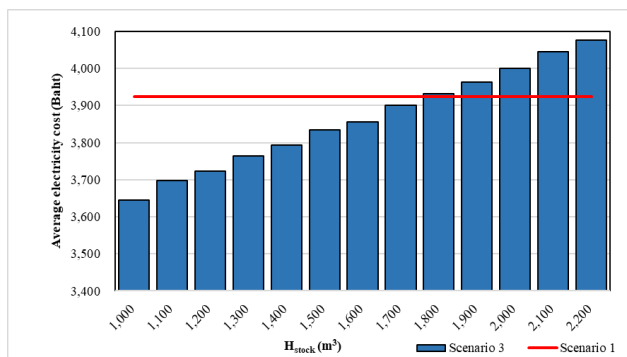

Figure 7. Average electricity cost at each H_{stock} level

Figure 7 shows that electricity cost increases when H_{stock} increases. H_{stock} is the volume of finished water that is stored to ensure that the demand during the first period of the next day will be covered. H_{stock} at 1,000 m^3 still covers the past demand. If the forecast of future demand is the same as the present demand and the plant needs to reduce electricity cost, the plant can reduce H_{stock}.

However, if the plant needs to enhance the confidence of demand coverage in the first period or to plan for demand expansion, the plant needs an additional 2.00 % of electricity cost per 100 m^3 increase in H_{stock}.

The experimental results of scenario 4 show that the pump operation status of all data sets is the same as that of scenario 1. In other words, the increase in piping capacity does not affect the electricity cost. Since the total volume of pumped water is lower than the current piping capacity, the expansion of piping capacity is not necessary at present. However, if water demand in the future increases, the expansion of piping capacity might be considered.

The experimental results of scenario 5 are summarized in Table 4. In this table, the range of demand increments is from 10% to 25% additional to the current water demand. A demand augmentation of over 25% cannot be covered by the current production process. For this case, the program reveals that there is no feasible solution. As shown in Table 4, the greater the increase in water demand, the greater the electricity cost at higher rates.

Table 4. Electricity cost increment

Demand increment (%)	10	15	20	25
Electricity cost increment (%)	9.96	15.86	19.54	52.83

4. CONCLUSION

The pump scheduling program works effectively and efficiently. It provides a 7.87% electricity cost saving schedule within 1.87 seconds. The pump operation schedule from the program can be used as a decision support tool for pump operation decisions. To solve the pump scheduling problem, OpenSolver, which is freeware, is employed. No extra cost is required. Thus, it is affordable and applicable for the case study plant and general factories.

The study of effect the four main factors on the production system yielded significant information for the case study plant to plan for expanding demand in the future or to enhance the confidence interval for a service level. To reserve additional raw water, 1.86% additional electricity cost for each 100 m^3 of additional H_{low} is required. To reserve additional finished water, 2.00% additional electricity cost for each 100 m^3 of additional H_{stock} is needed. Changing the piping capacity in the production system does not affect the production schedule or the electricity cost because the pipe capacity utilization is less than the present piping capability. The optimal pump schedules are the same as the pump schedules in scenario 1. However, this factor may impact the electricity cost when water demand increases. If the case study plant chooses to use the current process without any changes, up to 25% incremental demand can be covered. In situations where over 25% incremental demand is needed, the production system needs to be adjusted and improved.

For future research, production process improvement that may need a combination of main factor adjustments should be considered.

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Session IX

Ergonomics and applications

An Ergonomic Approach on Physical Assessment of Public Hospitals in the Philippines

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ABSTRACT

This study focused on the occupational risks experienced by healthcare workers in public hospitals. Studies have showed that factors in the physical environment such as noise, illumination, and temperature represent a significant risk among hospital staff. Ergonomic assessment was conducted to determine the risks associated with high noise level, low illumination level, and high indoor temperature. Survey questionnaires were distributed to 276 healthcare workers to obtain the RPN (risk priority number) in the selected areas in three public hospitals in Metro Manila, Philippines. Subsequently, noise, illumination, and temperature of these hospitals were measured using sound level meter, light meter, and digital LCD electronic thermometer respectively. The RPN and physical environment measurements were statistically analyzed to determine the areas with high occupational risk. Results of the study show that noise level and temperature have strong positive relationship with the occupational risks. As the measurements of these physical environment increases, the occupational risk experienced by the healthcare workers also increases. However, illumination level and the occupational risk have a moderate to strong negative relationship with each other. It can be implied that a dimmer surrounding causes problems to healthcare workers. It was also observed that the OPD, OB ward, ER, OB nurse station, pediatrics ward, and medicine ward have high occupational risk in terms of noise level. Meanwhile for illumination, areas with high occupational risks due to poor lighting are ER, OR, laboratory, pharmacy, OPD, OB nurse station, and surgical nurse station. For this reason, the researchers were able to design an ideal physical environment for the public hospitals using the principles of ergonomics.

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CCS Concepts

•General and reference → Document types → General conference proceedings

Keywords

physical environment; public hospitals; occupational risk; ergonomics

1. INTRODUCTION

Hospital is the most active healthcare facility that delivers service 24 hours per day for the whole year. Physical environment (noise, illumination, and temperature) of hospitals represent a significant risk among hospital staff [1]. In the Philippines, it is estimated that only 2.2 million Filipino workers are given with "effective Occupational Safety and Health (OSH) protection and services". Conversely, 17 out of 18 workers do not benefit from a satisfactory working condition [2]. Based on the survey conducted by PSA (2013), the healthcare industry is rank 10 out of 18 industries with high occupational risks. The occupational risks of healthcare employees accounted to 2.34% of the total employees [3]. In the Occupational Safety and Health Standards amended by the Department of Labor and Employment (DOLE), noise, illumination, and temperature are some of the physical environment that needs to be considered in establishing a safety workplace [4].

Previous studies have proved that high noise levels significantly affect not only the patients but hospital staff as well, it causes annoyance, stress and potential burnout to hospital staff [5]. Additionally, noise has an adverse impact on healthcare professionals, both physically and psychologically because it can be distracting, making communication difficult, and contribute to a perceived increase in stress. A study showed that 83% of the healthcare staff respondents thought that noise contributed to human errors, especially in the operating room [6].

On the other hand, for the illumination, studies found that factors that need to be considered in hospital design lighting are the comfort of the patients, the critical visual requirements for hospital staff, and the comfort and visual need of the visitors [7]. A study showed that only 35.8% of the respondents expressed high or very high levels of satisfaction with the illumination level at their working environment, while 56% of the respondents indicated that lighting condition at their working environment caused, to some extent (e.g. moderate to very high on the scale), eye strain [8]. The most frequent types of accidents due to insufficient lighting are

stumbling, slipping, and falling. These accidents may result to injury such as sprains, bruises, fractures, and cuts.

Thermal condition is another environmental factor in hospitals that could lead to occupational risks. Indoor air quality and thermal comfort must be controlled to significantly reduce the risk of infections [9]. Aside from infection, thermal condition also affects sleep. High temperatures could also result to skin rashes, hypothermia and heat stroke to healthcare workers.

Given these conditions, this study aims to assess the different types of occupational risks experienced by healthcare workers and to evaluate the current physical environment of public hospitals in the Philippines. The study also intends to determine the effects of physical environment to occupational risks of healthcare workers in order to propose and recommend ideal working environment of public hospitals in the Philippines.

The study was limited to the facilities of three hospitals in Metro Manila. The focus of the study was on the tasks made by healthcare workers and would not engage on the views of the patients inside the hospital. This study would be beneficial for the healthcare workers in performing their tasks safely and effectively. It also generates fresh insights in the decision making of the hospital stakeholders. The findings make an important contribution to the field of hospital interior architecture in the Philippines. Government agencies such as DOH, DOLE, OSHA, and PSA can make use of the results of this study for public use.

2. METHODOLOGY

The respondents of this study are healthcare workers in public hospitals in the Philippines. The population size of healthcare workers inside the selected areas of the three public hospitals undergone Slovin's Formula and Stratified Sampling to get the number of respondents for this study. A total of two hundred seventy-six (276) healthcare workers were selected from Medicine Ward, Medicine Nurse Station, Surgical Ward, Surgical Nurse Station, OB Ward, OB Nurse Station, Emergency Room, Operating Room, Laboratory, Specimen Room and Pharmacy. The areas selected for assessment are the common departments in public hospitals.

To gather initial data to be used in the study, survey questionnaires were administered to the respondents in order to assess the occupational risk occurring in each area in the hospitals. Respondents were asked to rate the severity and occurrence of the occupational illness associated with high noise level, poor illumination, and excessive heat exposure in the tasks to be performed on a specific area. Then, the RPN (Risk Priority Number)/survey score is computed by multiplying the severity rating and occurrence rating which is obtained in the Occupational Risk Survey responses.

Afterwards, the researchers measured the noise, illumination, and temperature in the 21 specific areas for 10 days with different time slots to obtain varying data from 8:00 am to 5:00 pm. There were 3 replicates in every measurement. In measuring the noise, illumination and temperature, the researchers used sound level meter, light meter, and digital LCD electronic thermometer respectively.

In order to determine the significant relationship of physical environment and occupational risk experienced by the healthcare workers, correlation analysis was used following the studies of [10][11]. The dependent variable considered in the study is the average RPN of all tasks performed in every area while the independent variable is the measurements of the physical environment in each area. In addition, two-way ANOVA was also performed in order to determine the significant difference among the tasks performed by the healthcare workers to the factors of physical environment identified in the study.

To evaluate the level of risk for each department in the public hospitals, Factor Checkbox Questionnaire (FCQ) were given to the respondents. This questionnaire also helps in determining the effect of physical factors identified in the study to the tasks/job being performed by the healthcare workers.

And in order design an ideal physical environment for healthcare workers, the researchers applied the principles of ergonomics. The recommended noise level was determined by computing the worker's daily exposure to occupational noise (normalized to an 8-hour day), taking into account the average levels of noise and the time spent in each area. This is the parameter that is used by the OSHA Regulations and is essential in assessing a worker's exposure and what action should be taken. Similarly, for the recommended illumination level, the researchers used the method suggested by Illuminating Engineering Society (IES) wherein it considers three factors in measuring the ideal illumination level for each department: worker age, reflectance of task/background, and speed/accuracy of task. And in order to recommend the ideal room temperature of a conditioned space for the different departments in the hospital, the researchers computed the recommended effective temperature. Effective temperature is an empirically determined index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or coolness felt by the human body.

Finally, to evaluate the different engineering controls that will be recommended for the design of public hospitals, the researchers used the Health and Work Performance Questionnaire (HPQ) and cost-benefit analysis. The HPQ was used to estimate the workplace costs of health problems in terms of reduced job performance, sickness absence, and work-related accidents-injuries. On the other hand, the cost-benefit analysis was used to show the relationship between the relative costs and benefits of a proposed engineering controls, expressed in monetary or qualitative terms.

3. RESULTS & DISCUSSION

3.1. Results of Correlation Analysis

In order to evaluate the physical environment of three public hospitals in the Philippines, the researchers initially measure the noise level, illumination level and temperature level of the hospitals. In addition, scores for occupational risks were also obtained from the respondents by computing the severity and occurrence of risk based on the duration of exposure of the respondents to the physical factors and its effect to the respondents. Afterwards, correlation analysis was made to determine the strength of relationship between the occupational risks to the physical factors identified in the study. The results are shown in the table below.

Table 1. Result of Correlation Analysis

Correlation Coefficients			
Physical Factor	Hospital A	Hospital B	Hospital C
Noise	0.960	0.940	0.948
Illumination	-0.744	-0.677	-0.595
Temperature	0.982	0.951	0.972

The result of correlation analysis indicates that temperature and noise levels have a strong positive relationship with the occupational risk while illumination level has a moderate to strong negative relationship to occupational risks.

3.2. Results of Occupational Risk Assessment

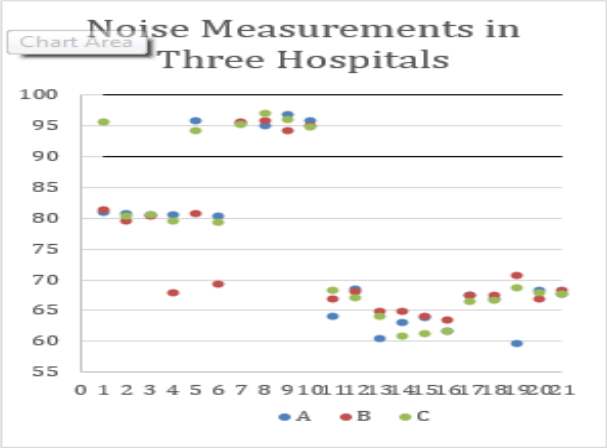

Figure 2. Result of Risk Assessment for Noise

The result revealed that for noise, areas with high occupational risks are the following: Hospital A: OPD, OB ward, ER, OB nurse station, pediatrics ward; Hospital B: OPD, ER, OB ward, OB nurse station; Hospital C: OPD, ER, OB ward, pediatrics ward, medicine ward.

For illumination, there are only two classifications in occupational risk assessment; acceptable and unacceptable. Most of the areas in three hospitals do not comply with the recommended illumination level. Thus, the researchers only considered the first 5 areas with highest discrepancy in actual and recommended illumination level. In Hospital A, the areas with the highest discrepancy are ER, OR, laboratory, pharmacy, and OB nurse station. For Hospital B: ER, OR, laboratory, pharmacy, and surgical nurse station. For Hospital C: ER, OR, laboratory, OPD, and OB nurse station.

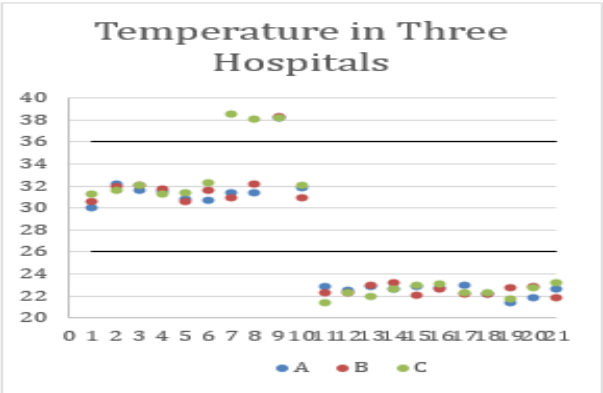

Figure 2. Result of Risk Assessment for Temperature

For temperature, areas with high occupational risks are the following: Hospital A: OPD, medicine nurse station, ER, surgical ward, and surgical nurse station; Hospital B: OPD, OB nurse station, surgical ward, medicine nurse station, and surgical nurse station; Hospital C: OB ward, OPD, OB nurse station, pediatrics nurse station, and emergency room.

3.3. Results of Analysis of Variance

The areas in each hospital that were identified to have high occupational risks were further analyzed using two-way ANOVA. Data on different tasks performed by each hospital staff in public hospitals were gathered as well as different sources of physical environment (noise, illumination, temperature) for each department in public hospital. This was done to determine significant difference between the tasks performed by hospital staff and sources that affect the physical environment (noise, illumination, temperature) among the different areas in public hospital with high occupational risks. The interaction among the factors: tasks and sources were also analyzed to determine if their interaction affects the measurement of physical environment (noise, illumination, temperature). The results are shown in the tables below.

Table 2. Result of 2-Way ANOVA for Noise

Hospital A	Tasks	Sources	Inter.
OPD	0.309	0.391	0.134
OB Ward	0.633	0.66	0.339
Emergency Room	0.457	0.466	0.461
OB Nurse Station	0.57	0.156	0.238
Pedia Ward	0.379	0.055	0.533
Hospital B	Tasks	Sources	Inter.
OPD	0.316	0.237	0.284
Emergency Room	0.434	0.493	0.106
OB Ward	0.546	0.308	0.431
OB Nurse Station	0.101	0.098	0.358
Hospital C	Tasks	Sources	Inter.
OPD	0.259	0.491	0.561
Emergency Room	0.683	0.448	0.492
OB Ward	0.493	0.067	0.619
Pediatrics Ward	0.219	0.423	0.139
Medicine Ward	0.296	0.556	0.513

Table 3. Result of 2-Way ANOVA for Illumination

Hospital A	Tasks	Sources	Inter.
Emergency Room	0.392	0.348	0.131
Operating Room	0.343	0.596	0.652
Laboratory	0.573	0.078	0.685
Pharmacy	0.449	0.427	0.072
OB Nurse Station	0.272	0.108	0.335
Hospital B	Tasks	Sources	Inter.
Emergency Room	0.152	0.128	0.221
Operating Room	0.128	0.186	0.618
Laboratory	0.07	0.25	0.252
Pharmacy	0.401	0.679	0.573
Surgical Nurse Station	0.545	0.569	0.276
Hospital C	Tasks	Sources	Inter.
Emergency Room	0.357	0.313	0.533
Operating Room	0.062	0.326	0.265
Laboratory	0.166	0.422	0.088
OPD	0.699	0.057	0.087
OB Nurse Station	0.623	0.243	0.597

Table 4. Result of 2-Way ANOVA for Temperature

Hospital A	Tasks	Sources	Inter.
OPD	0.339	0.166	0.304
Medicine Nurse Station	0.305	0.421	0.405
Emergency Room	0.565	0.59	0.545
Surgical Ward	0.095	0.206	0.158
Surgical Nurse Station	0.683	0.416	0.26
Hospital B	**Tasks**	**Sources**	**Inter.**
OPD	0.18	0.319	0.112
OB Nurse Station	0.495	0.308	0.211
Surgical Ward	0.31	0.675	0.578
Medicine Nurse Station	0.257	0.577	0.152
Surgical Nurse Station	0.463	0.439	0.409
Hospital C	**Tasks**	**Sources**	**Inter.**
OB Ward	0.204	0.458	0.491
OPD	0.292	0.472	0.083
OB Nurse Station	0.69	0.428	0.155
Pediatrics Nurse Station	0.122	0.305	0.165
Emergency Room	0.246	0.433	0.116

The results of two-way ANOVA revealed a p-value of greater than 0.05 for all the variables (tasks, sources and interaction). Therefore, we can conclude that the tasks performed by hospital staff in each department have no significant difference, as well as the sources of physical environment (noise, temperature and illumination) in each department in public hospital. Similarly, the interaction between the tasks and sources do not affect the level of noise, illumination and temperature that were measured in each department. This means that the engineering control that will be proposed in the study would be applicable to all departments in public hospitals.

3.4. Recommendation of Engineering Control

In order to determine the ideal engineering control that will be proposed on each area in the public hospital with high occupational risks, the researchers initially conducted a Heath and Work Performance Questionnaire (HPQ) to estimate the workplace costs of health problems in terms of reduced job performance, sickness absence, and work-related accidents-injuries caused by poor design of physical environment [12]. The results are shown in table 5.

3.4.1 Engineering Control for Noise

The proposed action to reduce the noise level in the different areas of public hospital is the installation of sound absorbing products. The lists of alternatives are shown in the table 6.

Table 5. Result of Cost of Inefficiency Computation

NOISE					
Hospital A	Cost of Inefficiency	Hospital B	Cost of Inefficiency	Hospital C	Cost of Inefficiency
OPD	9911.97	OPD	4350.37	OPD	3960.26
OB Ward	3730.68	ER	5678.45	ER	9586.43
ER	15069.21	OB Ward	5018.77	OB Ward	8298.72
OB Nurse Station	2497.3	OB Nurse Station	2006.47	Pediatrics Ward	2425.54
Pedia Ward	3570.77			Medicine Ward	2833.5
ILLUMINATION					
Hospital A	Cost of Inefficiency	Hospital B	Cost of Inefficiency	Hospital C	Cost of Inefficiency
ER	8975.78	ER	5786.37	ER	4259.99
OR	13643.97	OR	10729.69	OR	16878.75
Laboratory	6935.13	Laboratory	2575.91	Laboratory	5349.96
Pharmacy	2506.71	Pharmacy	1444.35	OPD	2828.23
OB Nurse Station	3708.47	Surgical Nurse Station	4690.53	OB Nurse Station	2786.71
TEMPERATURE					
Hospital A	Cost of Inefficiency	Hospital B	Cost of Inefficiency	Hospital C	Cost of Inefficiency
OPD	8822.05	OPD	3343.09	OB Ward	3851.78
Medicine Nurse Station	5165.2	OB Nurse Station	3008.01	OPD	4644.02
ER	3804.43	Surgical Ward	3205.53	OB Nurse Station	4835.84
Surgical Ward	2195.68	Medicine Nurse Station	2282.99	Pediatrics Nurse Station	2725.56
Surgical Nurse Station	4766.09	Surgical Nurse Station	3316.89	ER	3311.03

Table 6. Summary of Sound Absorption Product Alternative

Sound Absorption Products	NRC Rating	Price (Php/sqm.)	Decibel Drop dBA	Life Expectancy (years)	Cost-Beneift Ratio
Plasterboard Acoustic Panels	0.45	1,300	5.19	5	3.4
Wood Wool Acoustic Panels	0.8	1,790	13.98	7	3.22
Polyester Acoustic Panels	0.4	1,315	4.44	4	2.6
Fabric Acoustic Panels	0.6	1,730	7.96	7	3.3
Plastic Acoustic Panels	0.55	1,630	6.94	6	3.06

These products differ in NRC rating, price, and life expectancy. The NCR (Noise Reduction Coefficient) rating measures the effectiveness of a material in absorbing sound. Its value ranges from 0 to 1, which means the higher the number, the greater the absorption [13]. Decibel drop per sound absorbing product is also computed in order to decide which among the alternatives is the best option.

The Decibel drop can be calculated using the formula:

$$d = -20log_{10}(1 - C)$$

where:

d = decibel drop

C = Noise Reduction Coefficient Rating

In addition, cost-benefit ratio for each alternative was also computed using the formula:

$$Reduced\ Noise = Noise\ Measurement - Decibel\ Drop$$

$$Cost = Area * Price\ of\ Acoustic\ Panel$$

$$Benefit = Annual\ Cost\ of\ Inefficiency * Life\ Expectancy$$

$$Benefit - Cost\ Ratio = \frac{Benefit}{Cost}$$

Therefore, the recommended noise reduction for all departments in each public hospital with high occupational risks is the installation of fabric acoustic panels. For maximum use of the acoustic panels, it can be placed on walls, ceilings, or corners.

3.4.2. Engineering Control for Illumination

To determine the ideal illumination for each department with high occupational risks, the researchers computed the recommended illumination (lux) based on IES handbook [14].

First, the tasks of the healthcare workers present in each area were evaluated and categorized based on the "Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors" to create an occupational risk matrix for illumination. Then factors such as age of workers, reflectance of surrounding/background, and speed and accuracy of tasks on each area were determined. Afterwards, weights for each factor were computed to determine the recommended illumination level for each area in the public hospital. The summary is shown in the tables below.

Table 7. Summary of Recommended Illumination Level (lux)

Hospital Area	Recommended Illumination Level (lux)
ER	75
OR	75
Laboratory	30
Pharmacy	15
Surgical Nurse Station	10
OPD	15
OB Nurse Station	10

The proposed action to improve the illumination level in the different areas of public hospital is the installation of lamps. The lists of alternatives are shown in the table 8.

The different types of lamps proposed differ in terms of efficacy, consumption, life expectancy and price. And in order to determine the best alternative, cost benefit ratio was computed using the formula:

$$Cost1 = No.of\ Lamps\ to\ Replace\ or\ Intall\ x\ Price\ per\ Lamp$$

$$Cost2 = Electricity\ Rate\ x\ \ Life\ Expectancy * power\ consumption\ x\ No.of\ Lamps$$

$$Benefit = \frac{\text{life Expectancy}}{\text{24 hrsx30 days}} xTotal\ cost\ of\ Inefficiency$$

$$Benefit - Cost\ Ratio = Benefit/cost$$

The summary of cost-benefit ratio is shown in the table 9.

Table 8. Summary of Alternatives for Improvement of Illumination

Types of Lamp	Area	Luminous Efficacy (candela/Watts)	Power Consumption (watts)	Life Expectancy (hours)	Price (Php/unit)
Fluorescent Tube Lamps	Wards, Nurse Stations, Laboratory, Pharmacy, Emergency Room, and OPD	45	40	5,000	715
Compact Fluorescent Lamps		50	10	6,000	690
Light Emitting Diode		20	8	25,000	260
Halogen lamps	Operating Room	20	75	2,000	45,000

Table 9. Computation of Alternatives to Improve Illumination

Area	Action	Cost	Benefit	Benefit – Cost Ratio
HOSPITAL A				
Emergency Room	Replace 4 Fluorescent Tube Lamps	Php10,860	Php 62,331.74	5.74
Operating Room	Replace 2 Halogen Lamps	Php93,000	Php 37,899.92	0.41
Laboratory	Replace 1 Fluorescent Tube Lamp	Php2,715.00	Php 94,749.79	34.9
Pharmacy	Replace 1 Compact Fluorescent Lamp	Php1,290.00	Php 20,889.25	16.19
OB Nurse Station	Replace 1 Light Emitting Diode	Php2,260	Php 129,460.76	57.28
HOSPITAL B				
Emergency Room	Replace 2 Fluorescent Tube Lamps	Php5,430.00	Php 40,183.13	7.4
Operating Room	Replace 1 Halogen Lamps	Php46,500.00	Php 29,804.69	0.64
Laboratory	Replace 1 Fluorescent Tube Lamps	Php 2,715.00	Php 17,888.26	6.59
Pharmacy	Replace 1 Compact Fluorescent Lamps	Php 1,290.00	Php 12,036.25	9.33
Surgical Nurse Station	Replace 1 Compact Fluorescent Lamps	Php 1,290.00	Php 39,087.75	30.3
HOSPITAL C				
Emergency Room	Replace 1 Fluorescent Tube Lamps	Php2,715.00	Php 29,583.26	10.9
Operating Room	Replace 1 Halogen Lamps	Php46,500.00	Php 46,885.42	1.01
Laboratory	Replace 1 Fluorescent Tube Lamps	Php 2,715.00	Php 37,152.50	13.68
OPD	Replace 1 Compact Fluorescent Lamps	Php 1,290.00	Php 23,568.58	18.27
OB Nurse Station	Replace 1 Light Emitting Diode	Php 2,260.00	Php 23,222.58	10.28

3.4.3. Engineering Control for Temperature

The researchers initially investigated the sources of heat in each area in the hospital; with high occupational risks in order to identify the engineering control that will be proposed. The summary is shown in the table 10.

The proposed action to improve the temperature level in the different areas of public hospital is the installation of exhaust fan and ventilation fan. These alternatives differ in terms of power consumption, price, life expectancy, current and voltage.

And in order to determine the best alternative solution for each area, cost benefit ratio was computed. In addition, the number of exhaust fan or ventilation fan that will be required for each area was also determined through the following formula:

$$Work = Current * Voltage$$

$$Work = 230V * 0.7A * \left(8hrs * \frac{60mins}{hr} * \frac{60sec}{min}\right) = 4636.8kJ$$

$$No.of\ Ventilation\ Fan = \frac{Heat\ (Q)}{Work\ (W)}$$

$$Cost = (N * Price) + (PowerConsumption * LifeExpectancy * Electricty\ Rate)$$

$$Benefit = Annual\ Cost\ of\ Inefficiency * Life\ Expectancy$$

$$Benefit - Cost\ Ration = \frac{Benefit}{Cost}$$

The computation of cost-benefit ratio for each alternative is shown in the table 11.

Table 10. Sources of Heat in the Hospitals

Hospital A		Hospital B		Hospital C	
Area	Causes of Heat	Area	Causes of Heat	Area	Causes of Heat
OPD	No ventilation system	OPD	No ventilation system	OB Ward	No ventilation system
	Insufficient number of ceiling fans		Insufficient number of ceiling		Insufficient number of ceiling fans
	Sunlight coming through the		Heat from Sun		Heat from Sun
Medicine Nurse Station	No ventilation system	OB Nurse Station	No ventilation system	OPD	No ventilation system
	Insufficient number of ceiling fans		Insufficient number of ceiling		Insufficient number of ceiling fans
	Defective fans/aircon		Defective fans/aircon		Defective fans/aircon
Emergency Room	No ventilation system	Surgical Ward	No ventilation system	OB Nurse Station	No ventilation system
	Insufficient number of aircon		Insufficient number of ceiling		Insufficient number of aircon
	Defective fans/aircon		Defective fans/aircon		Defective fans/aircon
Surgical Ward	No ventilation system	Medicine Nurse Station	No ventilation system	Pediatrics Nurse Station	No ventilation system
	Insufficient number of aircon		Insufficient number of aircon		Insufficient number of ceiling fans
	Defective fans/aircon		Defective fans/aircon		Defective fans/aircon
Surgical Nurse Station	No ventilation system	Surgical Nurse Station	No ventilation system	Emergency Room	No ventilation system
	Insufficient number of ceiling fans		Insufficient number of ceiling		Insufficient number of aircon
	Defective fans/aircon		Defective fans/aircon		Defective fans/aircon

Table 11. Computation of Alternatives to Improve Temperature

Area	Alternatives	No. of Fan	Cost	Benefit	Benefit – Cost Ratio
HOSPITAL A					
OPD	Exhaust Ventilation Fan	2	Php 135,352.00	PhP 1,270,375.20	9.39
	Supply Ventilation Fan	2	Php 54280	Php 1,058,646.00	19.5
Medicine Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 743,788.80	6.62
	Supply Ventilation Fan	1	Php 40,280.00	Php 619,824.00	15.39
Emergency Room	Exhaust Ventilation Fan	1	Php 112,352.00	Php 547,837.92	4.88
	Supply Ventilation Fan	1	Php 40,280.00	Php 456,531.60	11.33
Surgical Ward	Exhaust Ventilation Fan	1	Php 112,352.00	Php 316,177.92	2.81
	Supply Ventilation Fan	1	Php 40,280.00	Php 263,481.60	6.54
Surgical Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 686,316.96	6.11
	Supply Ventilation Fan	1	Php 40,280.00	Php 571,930.80	14.2
HOSPITAL B					
OPD	Exhaust Ventilation Fan	1	Php 129,632.00	Php 481,404.96	3.71
	Supply Ventilation Fan	1	Php 40,280.00	Php 401,170.80	9.96
OB Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 433,153.44	3.86
	Supply Ventilation Fan	1	Php 40,280.00	Php 360,961.20	8.96
Surgical Ward	Exhaust Ventilation Fan	1	Php 112,352.00	Php 461,567.52	4.11
	Supply Ventilation Fan	1	Php 40,280.00	Php 384,639.60	9.55
Medicine Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 328,750.56	2.93
	Supply Ventilation Fan	1	Php 40,280.00	Php 273,958.80	6.8
Surgical Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 479,072.16	4.26
	Supply Ventilation Fan	1	Php 40,280.00	Php 399,226.80	9.91
HOSPITAL C					
OB Ward	Exhaust Ventilation Fan	1	Php 112,352.00	Php 554,656.32	4.94
	Supply Ventilation Fan	1	Php 40,280.00	Php 462,213.60	11.48
OPD	Exhaust Ventilation Fan	1	Php 112,352.00	Php 668,738.88	5.95
	Supply Ventilation Fan	1	Php 40,280.00	Php 557,282.40	13.84
OB Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 696,360.96	6.2
	Supply Ventilation Fan	1	Php 40,280.00	Php 580,300.80	14.41
Pediatrics Nurse Station	Exhaust Ventilation Fan	1	Php 112,352.00	Php 392,480.64	3.49
	Supply Ventilation Fan	1	Php 40,280.00	Php 327,067.20	8.12
Emergency Room	Exhaust Ventilation Fan	1	Php 112,352.00	Php 476,788.32	4.24
	Supply Ventilation Fan	1	Php 40,280.00	Php 397,323.60	9.86

4. CONCLUSION

The results of the study revealed that factors in physical environment of public hospital such as noise, illumination and temperature represent a significant risk among hospital staff. It was proven in the result of the RPN (risk priority number) obtained from 276 healthcare workers in the selected area in 3 public hospitals in the Philippines. The RPN and physical environment measurements were statistically analyze using correlation analysis and two-way anova in order to determine specific areas in public hospital with high occupational risks. The result revealed that for noise, areas with high occupational risks are the following: Hospital A: OPD, OB ward, ER, OB nurse station, pediatrics ward; Hospital B: OPD, ER, OB ward, OB nurse station; Hospital C: OPD, ER, OB ward, pediatrics ward, medicine ward. For illumination, there are only two classifications in occupational risk assessment; acceptable and unacceptable. Most of the areas in three hospitals do not comply with the recommended illumination level. Thus, the researchers only considered the first 5 areas with highest discrepancy in actual and recommended illumination level. In Hospital A, the areas with the highest discrepancy are ER, OR, laboratory, pharmacy, and OB nurse station. For Hospital B: ER, OR, laboratory, pharmacy, and surgical nurse station. For Hospital C: ER, OR, laboratory, OPD, and OB nurse station. For temperature, areas with high occupational risks are the following: Hospital A: OPD, medicine nurse station, ER, surgical ward, and surgical nurse station; Hospital B: OPD, OB nurse station, surgical ward, medicine nurse station, and surgical nurse station; Hospital C: OB ward, OPD, OB nurse station, pediatrics nurse station, and emergency room. Given these conditions, the researchers were able to recommend appropriate engineering controls in order to design an ideal working environment for healthcare workers. In order to evaluate each alternative, Health and Work Performance Questionnaire (HPQ) and cost-benefit analysis were used. The HPQ was employed to estimate the workplace costs of health problems in terms of reduced job performance, sickness absence, and work-related accidents-injuries. On the other hand, the cost-benefit analysis was used to show the relationship between the relative costs and benefits of a proposed engineering controls, expressed in monetary or qualitative terms.

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An Ergonomic Design of Passenger Cabin for Public Utility Jeepney

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ABSTRACT

Public Utility Jeepney (PUJ) is one of the most popular and indispensable mode of public transport, and has been providing a practical means of transportation almost everywhere in the Philippines. Recently, there has been a decline in commuter's patronage of PUJs due to the fact that the jeepneys had not received any significant innovation since its introduction in the 50s and, also the decrease of service level attributed to the worsening traffic congestion, economic, socio cultural and the rise of much more convenient alternative mode of transportation such as Asian utility vehicles, buses and railway transport have contributed to the situation.

Nowadays, it's not enough for commuters to reach their intended destinations in a cheap and quick way; there are also some other qualitative factors that can affect how passengers experience traveling. The study was conducted to improve the existing jeepney passenger cabin design using ergonomic solutions by identifying ergonomic hazards and discomfort area of the passenger while riding the jeepney cabin. The findings of the study revealed that the current jeepney passenger cabin is poorly designed or lacking proper ergonomic application. And, the passengers were likely to experience discomfort and are at risk of injury as reflected in the RULA and REBA scores of the passengers. This was also corroborated by the survey and statistical analyses that were done in the study. The existing cabin dimension do not conform and match to the anthropometric measurements of Filipino passengers and thus, they were subjected to awkward postures and movements. Because of this, the authors were able to design an ergonomic passenger cabin for public utility jeepney by applying the pinciples of anthropometry and quality function deployment.

CCS Concepts

•General and reference→ Document types→ General conference proceedings

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Keywords

Passenger cabin; jeepney; ergonomic design

1. INTRODUCTION

Innovation in technology in the last two decades led to changes in specific economic and socio-cultural values. As this happened consumer needs and expectations also shifted dramatically [1]. People expected functionality, but they are more interested in intangible product characteristics that satisfy their affective needs [2]. With the constant shift in trends of customer demands and needs, product development goes toward integration of emotional values in product design [3]. This is particularly and increasingly the case with transport vehicles [4]. Public transportation networks play an essential role in creating a more efficient mode of transportation for the public to help decrease traffic congestion that would foster social inclusion and reduce pollution [5].

The demand in public mode of transportation in the Philippines is led by jeepney with 57% followed by the bus, tricycle, LRT and PNR with 21.41%, 18.15%, 3.30% and 0.05%, respectively [6]. This indicates the popularity of jeepney as one of the most common mean of public transportation in the Philippine road.

The popularity of jeepney can be credited due to its capacity and accessibility anywhere. The easy accessibility of jeepneys can be accounted due to its low-priced acquisitions cost wherein customizations are made for the vehicle to have wider capacity that aims to increase profitability neglecting ergonomic concern, which may lead to awkward postures of passengers that increases the risk of MSDs [7]. Awkward postures also affect ride comfort of passengers [8][9]. However, ride comfort is difficult to evaluate due to various objective and subjective influencing factors. Since commuters spends a significant amount of time traveling, continuous improvement of passenger comfort has become an important criterion in terms of marketing and improving vehicles as well [10]. This led the researcher to fill the research gap by (1) identifying ergonomic hazards, discomfort area and risk factors brought by the existing design of passenger cabin of jeepney (2) grasp the affective response of passengers to the design aspects of the jeepney and utilize it in the design conceptualization. (3) close the gap between the dimensions of jeepney riding accommodation and the corresponding anthropometric measurements of jeepney passengers to accommodate all that falls within the 5th and 95th percentiles of the population. (4) design public utility jeepney's riding accommodations based on relevant ergonomic standards and necessary safety features.

2. METHODOLOGY

To achieve the objectives of the study, the study was divided into three phases. On the first phase, a focus group was conducted to determine passengers' issues with the jeepney's passenger cabin

and their needs and wants. The discussion topic covered the perceived comfort, satisfaction and preference in the existing design. For the second phase, the result of the discussion led to the creation of house of quality and development of survey questionnaires that measured the passenger's emotional response, perception, body discomfort, reason for discomfort and the level of comfort while riding the jeepney. A total of 100 commuters participated in the study, with ages of 18 years old and above who frequently use jeepneys as their main mode of transportation. And for the last phase, quantitative measurements were done, the maximum, minimum and average dimensions of different jeepney passenger cabin were measured and compared with the available data on Filipino anthropometric measurements to determine which does not adequately accommodate the passengers. In addition, to validate the discomfort that passengers experience in riding the jeepney, RULA and REBA questionnaires were administered. This measured the exposure of the passengers to ergonomic risk factors associated with upper extremity musculoskeletal disorders [11] [12] [13] [14]. And finally, based on the data gathered, Quality Function Deployment were utilized for the development of a product concept. The results were used to facilitate the conceptualization of the new design of passenger cabin of jeepney.

3. RESULTS AND DISCUSSION

The main purpose of the passenger cabin is to accommodate the passengers in a space in which they can sit without experiencing discomfort, inconvenience and danger. Therefore, anthropometry of the jeepney passengers is very essential in designing a suitable passenger cabin. The following table contains cabin dimensions and body parts that can influence it.

Table 1. Body Part Jeepney Cabin Dimension

Passenger Cabin Dimension	Consideration	Corresponding Body Part
Seat height	Reach	Lower legs
Seat width	Clearance	Hips
Seat depth	Clearance	Thighs
Backrest height	Reach	Torso
Seat-Roof height	Clearance	Torso + Neck + Head
Aisle Width	Clearance	Hip Breadth
Step board height	Reach	Tibial/ knee height
Overhead grab rail	Reach	Thumb-tip reach
Ceiling-floor height	Clearance	Standing: Standing height Seating: Seating height

The study determined that the current jeepney passenger cabin is not ergonomically designed based on the considered factors for both qualitative and quantitative measures. More than 50% in the perception survey stated that the existing design features of the passenger cabin cannot properly accommodate them. According to the respondents, the seat space provided for the passengers is not enough. While the seat dimensions such as seat height, seat depth and the seat width, the latter dimension is said to be insufficient with 68% of the respondents and the other two as "just right". The result shows that the seating capacity is one of the issues for the passenger cabin since both seat space and seat width was found to be insufficient. The other design aspects found to be insufficient by the respondents are the overhead clearance, aisle width and aisle height. The seat cushion is considered by the respondents as unsuitable, while the grab handle and overhead grab rail are suitable. The things found inadequate by the respondents are the backrest with nearly half of response, ventilation with 73% of the response and the roof insulation with almost half of the response said "inadequate". For temperature, the combined response for the "warm" and "slightly warm" is more than 3/4 of the total response, a clear sign of unfavorable temperature inside the cabin. The flooring is described as slippery and rusty by the respondents. The lighting also garnered different negative response which shows negative perception of the current lighting inside the cabin. The window got a score of response of "having not enough cover for sunlight/ rain". Lastly, the step board is found that 59% of the respondents as too high. This result is backed by the Passenger's Body Discomfort and Causes Survey Result, it revealed that nearly half of the respondents stated that the neck, mid and lower back, and buttocks are the area of their body to experience "mild" to "moderate" discomfort which are associated with certain parts of the jeepney cabin. With these results we can say that we have also partially attained another objective of the study; to identify discomfort area.

To further support this, we have to look in to more quantitative measures, such as the result of the comparison of passenger cabin dimensions and corresponding anthropometric data. The reference used for measurement of anthropometric data is presented in the figures below.

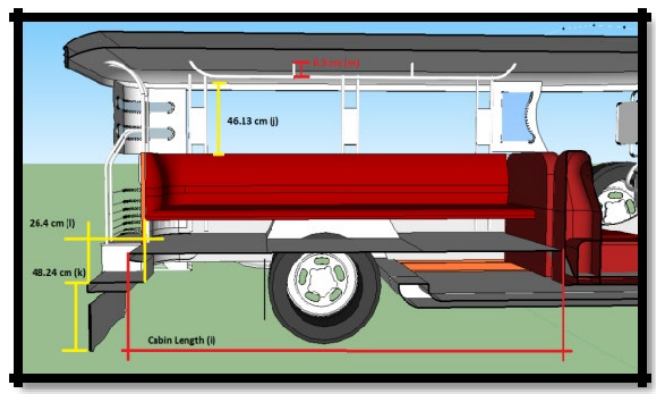

Figure 1. Passenger Cabin's Cross Sectional Length

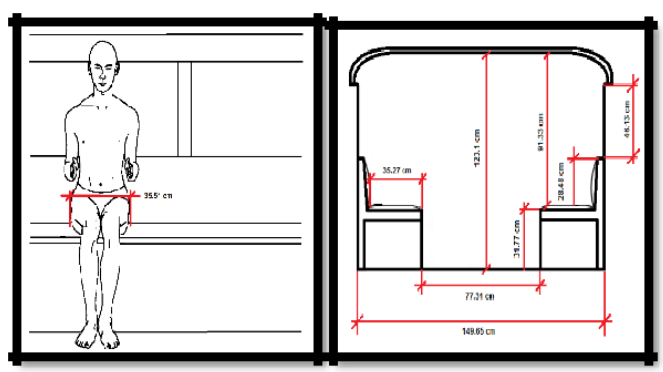

Figure 2. Dimensions to represent the existing Jeepney passenger cabin

The comparison showed that there are certain passenger cabin dimensions that does not accommodate certain anthropometric measurements such as the seat width to the 95th male percentile elbow-elbow breadth, backrest height to at least 40 cm for lumbar support, aisle width for the hip breadth of 95th female percentile. The roof-seat height to the 95th male percentile seating height. It is also noted that the average step board height and overhead grab rail height barely accommodates the 5th female percentile for reach.

The analysis is also supported by the scores of REBA and the RULA, which indicates that while inside the jeepney, the passengers are exposed to medium to high risk of MSD and discomfort. The results are shown in the table below.

Table 2. Summary of RULA Scores for Sitting Posture

RULA Score	Male		Female		Total
	Left Side	Right Side	Left Side	Right Side	
6	0	0	0	0	0
5	0	0	0	0	0
4	8	6	8	7	29
3	14	13	12	14	53
2	5	4	3	6	18
1	0	0	0	0	0

The RULA scores for sitting posture of passengers range from 2 to 4 or negligible risk to low risk, with the score 3 having the highest percentage of 53% in terms of occurrence followed by 4 and 2 with 29% and 18%, respectively. Notably the result indicates low risk, suggesting change may be required.

The results of the surveys and quantitative measures have successfully served its purpose to identify ergonomic hazards and risks factors in the design of the jeepney occupant packaging. Also identified are the parts of the body that is mostly like to be exposed of discomfort or injury based on the surveys and quantitative measures. The results of the needs analysis are shown in the table below.

Table 3. Summary of REBA Scores for Boarding and Alighting Posture

REBA Score	Male	Female	Total
7	6	11	17
6	0	0	0
5	27	21	48
4	17	18	35
			100

The REBA scores ranges from 4, 5 and 7 or medium risk, with a score of 5 having the highest percentage of 48% in terms of occurrence followed by 4 and 7 with 35%, respectively. Notably that result shows medium risk, suggesting a further study to be implemented and an action is soon to be required solving the cause of the risk.

Table 4. Needs Analysis Summary

Needs Analysis					
Cabin Dimension	Anthropometric Dimension	Percentile Group	REBA/RULA Risk Score	Discomfort/Pain Severity	
				Body Area	Reported Severity
Seat width	Hip breadth	95th Female	RULA Seating (low to moderate risk)	Lower back	Mild to severe
				Buttocks	Mild to severe
Backrest height	Sitting shoulder height	5th Female	RULA Seating (low to moderate risk)	Mid back/lower back	Mild to moderate
Ceiling-Seat height	Sitting height	95th Male	RULA Seating (low to moderate risk)	Neck	Mild to moderate
				Mid back/lower back	Mild to moderate
Aisle width	Hip breadth	95th Female	REBA Walking (moderate to high risk)	Buttocks	Mild to severe
				Upper leg	Mild to severe
				Knee	Mild to moderate
				Lower leg	Mild to moderate
Step board height	Step height	5th Female	REBA Climbing (moderate risk)	Upper leg	Mild to severe
				Knee	Mild to moderate
				Lower leg	Mild to moderate
Overhead grab rail height	Functional forward reach	5th Female	RULA Seating (low to moderate risk)	Shoulder	Mild to severe
				Upper arm	Mild to severe
				Elbow	Mild to severe
				Lower arm	Mild to severe
Ceiling-Floor height	Seat height + sitting height	95th Male	RULA Seating (low to moderate risk)	Neck	Mild to moderate
				Mid back/lower back	Mild to severe
				Upper leg	Mild to severe
				Knee	Mild to moderate
				Lower leg	Mild to moderate

The results showed the anthropometric measurement that is not accommodated by jeepney dimensions drawn in parallel with the RULA/ REBA risk score and the discomfort/ pain severity of each body parts associated with the anthropometric measurements. This simply puts forward and justifies the need for improvement of the listed jeepney dimensions. This result confirms the relationship of the several of the analysis made to determine whether the results can be correlated with each other.

Quality Function Deployment was also utilized to translate customer requirements in engineering targets and determined which are important based on the feedback of the focus group. The House of Quality proves that the top 3 design requirements are overall dimensions for the passenger cabin height, length and width.

Considering all the results from the findings of the study, the researchers have recommended new design requirements for the

improvement of the passenger cabin. The researcher also calculated the absolute and relative importance for each design requirements. This is the summation of the product of values in the relationship matrix and the customer rating. The table below shows the hierarchy of design requirements to consider in the design process.

Table 5. Passenger Cabin Design Relative Importance Table

Design Requirement	Absolute importance	Relative importance
Overall passenger cabin Height	180	10.99
Overall passenger cabin length	179	10.93
Overall Passenger cabin width	131	8.00
Padding thickness	126	7.69
Door height	99	6.04
Door width	96	5.86
Window width	75	4.58
Flooring	72	4.40
Number of window cover	69	4.21
Step board width	69	4.21
Step board height	54	3.30
Window height	47	2.87
Number of roof air vents	45	2.75
Step board depth	36	2.20
Number of light fixtures	31	1.89
Light fixtures brightness	27	1.65
Roof air vent length	15	0.92
Roof air vent width	15	0.92

The result shows that the top three design requirements are the overall dimensions for the passenger cabin such as cabin height, cabin length and cabin width. The researcher can use this when it comes to prioritizing between the design requirements while improving the passenger cabin.

Finally, in order to design an ergonomic passenger cabin for jeepney, principles of anthropometry were used. The summary of the overall design dimensions is shown in the table below.

3.1. Overall Cabin Dimension

Table 6. Relevant Measurement for Cabin Dimension

Design variable	Relevant Measurements	Proposed Specifications
Overall Cabin Length	Seat width(5th female) * Capacity	20 seater: 42.93 * 10 = 429.3 cm 22 seater: 42.93 * 11 = 472.23 cm 24 seater: 42.93 * 12 = 515.16 cm
Overall Cabin Width	2* Buttock Knee length(95th male sitting) + Hip width(95th male standing) + 2*Allowance (95th male Hand breadth)	2*(61.9) + 54.8 + 2*11 = 200.6 cm
Overall Cabin Height(Seating)	Seat height + Seating height(95th male) + Overhead clearance(95th male hand breadth)	31.77 + 92 + 11 = 134.77 cm
Overall Cabin Height(Standing aisle)	Standing hip height(95th male) + upper body vertical height(95th male standing height) 45° bent forward + Allowance(95th male Hand breadth)	[illegible] + 11 = 164.98 cm

The proposed overall cabin length is the product of seat width (5th female) and the capacity. The overall cabin width is the sum of twice the buttock-knee length (9th male sitting), hip breadth (95th male standing) + the allowance of twice the 95th male hand breadth.

The overall cabin height will have to proposed specifications one for seating and one for standing in the aisle, the seating overall cabin height is the sum of the seat height, seating height (95th male) and overhead clearance (95th male hand breadth). The standing aisle overall cabin height is the sum of the standing hip height (95th male), upper body vertical height (from 95th male standing height) bent forward 45°, the allowance of twice the 95th male hand breadth. The ceiling on the aisle will be raised higher to minimize the angle of stooping to lessen the strain on the back [15].

3.2. Seat Dimension

Table 7. Relevant Measurement for Seat Dimension

Design variable	Percentile	Anthropometric measurement	Proposed Design Specification
Seat frame height	-	-	26.37 cm
Seat cushion	-	-	5.4 cm
Seat height	5th % Female	36 cm	36 cm
Seat width	95th % Female	42.43 cm	42.43 cm
Seat depth	5th % Female	40 cm	40 cm
Backrest height	-	-	≥40 cm
Backrest angle	-	-	≥10°

The seat height proposed is the mean data 31.77 cm it is the sum of the seat frame height and the seat cushion thickness because the current mean seat height is proven to accommodate the 5th percentile of the female group. The seat cushion must be soft high density foam but not too soft, to equally spread out the pressure; the upholstery should be able to lessen the heat transfer in hot days.

The seat width is 42.93 cm with an allowance of +0.5 cm for clothing to accommodate the 95th female percentile. The seat depth proposed is the mean data 35.27 cm because the current mean seat depth is proven to accommodate the 5th percentile of the female group. According to study [16] the minimum height of the backrest required to support the lower back is 40 cm from the compressed seat surface. The backrest angle should be at least 10° inclined backwards for reduce spinal loading [17].

3.3. Door Dimension

Table 8. Relevant Measurement for Door Dimension

Design Variable	Relevant Measurements	Proposed Specifications
Door Height	Overall cabin height Standing aisle	164.98 cm
Door Width/ Aisle width	Overall cabin width – 2 * seat depth	200.6 - (2*35.27) = 130.06 cm

The proposed door height is equal to the door overall cabin height for standing aisle, 164.98 cm for ease of entry. The door width is the difference between the overall cabin width and twice the seat depth which is 121.6 cm; it is also the aisle width.

3.4. Window Dimension

Table 9. Relevant Measurement for Window Dimension

Design Variable	Relevant Measurements	Proposed Specifications
Window Height	Overall cabin height(seating) – (Seat Height + Backrest height) + Ceiling allowance	138.5 – (35.5+40) -10 = 63 cm
Window Width	2 * seat width = 85.86	20 seater: 429.3 – 85.86 = 343.44 cm 22 seater: 472.23 - 85.86 = 386.37 cm 24 seater: 515.16 - 85.86 =429.3 cm

The proposed window height is the difference of the overall cabin height for seating to the sum of the seat height and backrest height, plus the ceiling allowance of 10 cm, this would provide enough space to look over the shoulder or head of the passenger on the other side where the passenger is sitting the window width is the difference of the overall seat length minus thrice the seat length. The window width will start one seat width from the front up until the 2 seat width from the end of the cabin. The window covers are 2 independent vertical sliding fiber glass panels for each side; it will be slid hidden inside the jeepney cabin wall when not needed similar to regular vehicles.

3.5. Step Board Dimension

Table 10. Relevant Measurement for Step Board Dimension

Design variable	Relevant measurement	Proposed specification
Step board height/riser	Mean step board height (existing) = 48.24 cm	<45 cm; 24.12 cm
Step board width	Cabin aisle width/door width = 121.6 cm	121.6 cm
Step board depth	Foot length (95th male percentile) = 28cm + allowance	35 cm

The step board aids in boarding or alighting, especially into high vehicles, such as jeepney with high ground clearance. This benefits smaller passengers or the 5th female percentile. The proposed step board height should be no more than 45 from the ground [18]. The researchers decided to use half the current mean step board height. The step board width will be dependent on the cabin aisle width or the door width which to stay true with the original design of the jeepney. The proposed step board depth is 35cm to accommodate the foot length of the 95th male percentile with +7cm allowance for shoes.

The following figures are the 3D sample model of the researchers' design recommendations.

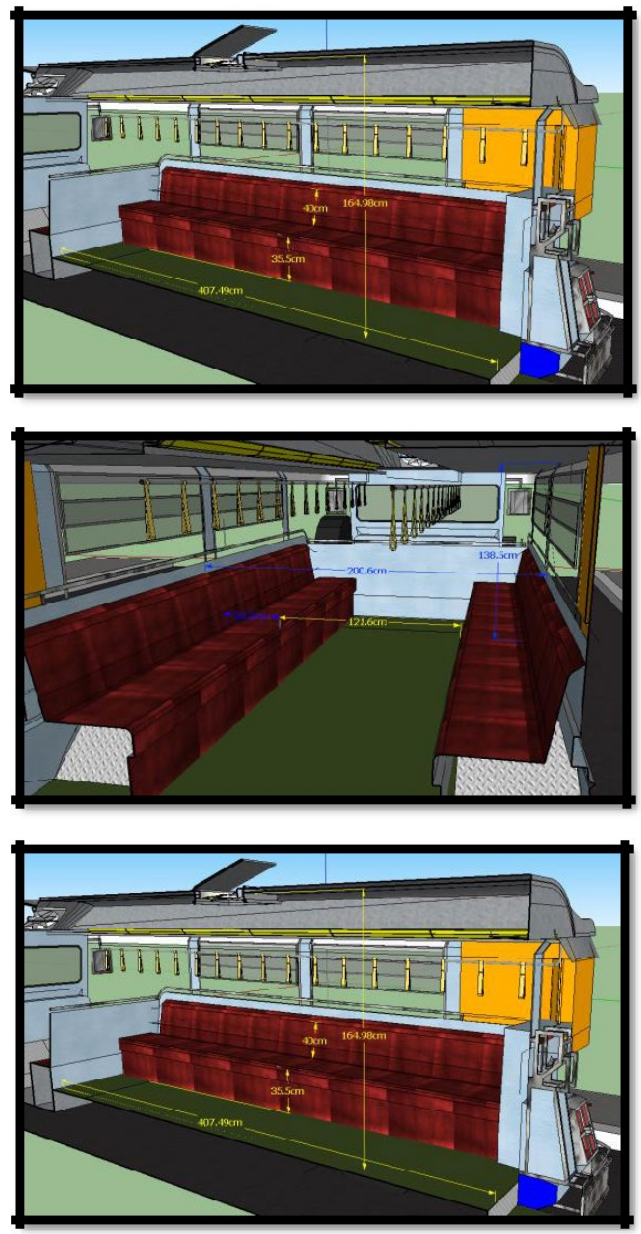

Figure 3. 3D Perspective Design of Passenger Cabin for Jeepney

4. CONCLUSION

The findings of the study showed that the current jeepney passenger cabin is poorly designed or lacking proper ergonomic application. Thus, passengers were likely to experience discomfort and are at risk of injury, this is corroborated by the survey and analysis results. The existing cabin dimensions do not conform to some of the Filipino anthropometric measurements. And, the passengers were subjected to awkward postures and movements.

With the use of ergonomic principles such as RULA, REBA and anthropometry, the ergonomic hazards were identified in this study. Anthropometry was used to determine what measurements are necessary to design the passenger cabin and if the 5th and 95th percentiles of the Filipino passengers were accommodated by the existing jeepney design. RULA and REBA were used to evaluate the effects of the existing dimensions to the passenger's posture and determined that there is a need for further investigation and require change or improvement. Because of this, the authors were able to design an ergonomic passenger cabin for public utility jeepney by applying the pinciples of ergonomics and quality function deployment.

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Understanding the Model of User Adoption and Acceptance of Technology by Thai Farmers: A Conceptual Framework

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ABSTRACT

Thailand is constantly making policy changes and implementing Industrial revolution agendas like Thailand 4.0. With the advent of Industry revolution 4.0, Thailand government is making policy initiatives and technological advancement for successful transition to industry 5.0. The initiative is focused to offer farmers an opportunities to incorporate technology in their farming and agricultural processes to produce better crops and high-quality food. The Development of Eastern Economic Corridor is a crucial step in this regard as it focused on the evolution and progression of 10 key industries in Thailand. The plan is designed to be driven through agricultural technology and innovativeness. The future benefits of the ICT based 5.0 industrial revolution in agricultural field directly depends on the user adoption and acceptance of agricultural technology. The study, therefore, investigates the acceptance and adoption of ICT based products and services by farmers by utilizing the basics of TAM. The study proposes the framework of FTAM, and identifies the internal and external factors affecting the behavior intentions and attitude of farmers. It was found out that factors like "occupation relevance", "self-efficacy" and "social influence" affect the "Perceived usefulness (PU)" and "Perceived Ease of Use (PEOU) which in return impact their behavior intention and attitude towards utilizing and accepting ICT based products and services in farming and agriculture.

CCS Concepts

• **Information systems→ Information systems applications → Computing platforms**

Keywords

Industrial Revolution; Technology Acceptance Model; Internet of Things; Information Communication Technology; innovativeness; Perceived Usefulness; Perceived Ease of Use

1. INTRODUCTION

Since the launch of Thailand 1.0, the government had been focusing extensively on improving the quality and quantity of agricultural production as it account for 8.4% of the country's total GPD. Agriculture also occupies almost 40% of the total labor working in the country. In addition, it also constitutes a major portion in Thailand's exports, contributing almost $US 25.5 billion. The agricultural trade majorly consists of items like rice (17.1%), chicken (7.8%), sugar (8.6%) and Tuna (7.5%) [26].

Under Thailand 4.0 and transition towards Industry 5.0, the current focus of the Thai government is to improve the quality of life of farmers. The Thailand 5.0 is a progression of Thailand 4.0 emphasizing more on the wellbeing of Thai farmers. It is the continuing agenda for upgrading the Small & Medium enterprises and small startups to cultivate a society of smart farmers so they can improve and develop their career paths to earn more incomes and raise their quality of life [22]. Moreover, the Thailand's transition to industry 5.0 is a great initiative to offer laborers and farmers with opportunities to incorporate technology in their farming and agricultural processes to yield better crops and high-quality food. The foundation of The Eastern Economic Corridor (EECO) Development Plan under scheme of Thailand 4.0 is another robust initiative to promote the industrial production of Thailand. The major development areas under EECO are the development of modern infrastructure, supporting local industries promoting research and training, community development and promotion of tourism. This plan has been designed carefully to drive the economy towards industrial evolution through uplifting advanced technology and innovativeness in the social and physical infrastructure of the country especially in agricultural business [8].

In addition to upgrading farmers to "smart farmers", who can use technology for their plantations and sell products on the market for better prices, the Ministry of Agriculture and Cooperatives has been working to promote a change of farming patterns. General Prayut stated that people must learn and adapt to live with technology and make use of it. Thailand 4.0 worked on the principle "will not leave anyone behind" or "all walks of life go together". The implication of industry 5.0 will be more aggressive approach towards the deployment of ICT based programs in the agricultural field. The agenda promotes and implies the means that will assist laborers to develop advanced labor skills with the ability to speak foreign languages. The government has a view that they should improve the capabilities of their workforce instead of just replacing them with robots. Research and training in agriculture field provides the latest information and necessary knowledge regarding current trends and technological advancements in agriculture worldwide. In addition, such development will lead the government in addressing issues in agriculture and farming to develop and design the policies accordingly. Furthermore, the EECO will provide the necessary support to implement all these technological based plans in industrial area focusing majorly on agriculture, farming and

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housing. They all need to adapt and develop to be "smart people". The Finance Ministry is currently proposing to establish a US$ 283.8 million fund to support the Food Innopolis Project at the Thailand Science Park (TSP). This reflects that the Thai government recognizes the importance of food innovation and how they can play a part in boosting the country's economy. As Ministry of Science and Technology coordination plans to use the Food, this project aims to position Thailand as a global food innovation hub [7].

However, despite the efforts of Thai government to transform the agriculture sector through ICT, the effectiveness of the ICT based programs in improving agricultural production are entirely dependent on adoption and acceptance levels of the farmers. Acceptance and adoption of a technology system is the starting stage of any future development, and the resulting performance of the agriculture sector in terms of production. The current research study is focused on proposing a theoretical framework to determine the factors that can positively or negatively impact the intentions and attitude of farmers in accepting ICT based systems, products and services.

1.1 Research Implications

This research has implications to the various sectors. The proposed model is useful to the governments programs such as Thailand 4.0 and Industry 5.0 and the associated initiatives to improve agricultural productions and farmers lives. The model is useful in determining the factors that influence the acceptance and adoption of a technology by farmers. The government could use the framework to increase the chances of adoption and acceptance in its deployment of ICT based programs in the agricultural field. The outcomes are equally useful to the administrators and managers, who could apply such results to create mechanisms that could attract more users to adopt technology.

2. LITERATURE

All After fourth industrial revolution (Industry 4.0), Fifth industry revolution "Industry 5.0" is a new step towards complete digitalization of industries. The European Economic and Social Science Committee defined Industry 5.0 as "a revolution focused on developing a workforce that is equipped with craftsmanship, productivity, creativity and consistency by incorporating technology and innovativeness" [19]. The invention and implications of Big data research has forced the communities worldwide to shift towards the adoption and implications of innovative products and implications. However, the truth is that reality differs from the theory and this transformation towards complete digitalization is a major threat for many countries. Similarly, Thailand government after Thailand 4.0 is preparing towards shifting to Thailand 5.0 with major focus on strengthening and development of 10 core industries. The Industry 4.0 in Thailand has been aimed to liberate Thais from the middle-income trap and shifting towards automation/robotics. The Thailand 5.0 is now emphasizing extensively to introduce technology-based revolution in farming and agricultural industry. The revolution which is a world-wide phenomenon allows the production of an atmosphere wherein all components of modern farming are easily linked together. All gadgets (e.g., CPS, digital physical frameworks) and functionalities are tended to as administrations, which always communicate with one another, accordingly, accomplishing an increased level of coordination. Along these lines, the capacity to arrange exercises is fundamental for improved supply chain management, where development typically requires the examination of numerous components in consistent challenge with one another.

In this inventive foundation, regardless of the benefits of industry 5.0 for enormous ventures, little and medium-sized endeavors, which are known as Small and Medium Enterprises (SMEs) frequently face intricacies in innovative procedures due to the persistent changes in advancements and innovations. Such condition makes it hard to screen events, expanding additionally the complexity of which these procedures can be implemented. SMEs, for example, industrial players, must deal with improving their operations management (e.g., production control, arranging and execution, operational performance measurement, and appraisal) in order to meet progressively complex client needs. Nevertheless, SMEs are firms known for their adaptability and proximity to clients [18].

SME's size simplicity correspondence and changes among employees, this empowers quicker reconfiguration in case of any alteration. However, SMEs for the most part have momentary systems, which don't support long term investments; subsequently they end up powerless on venture limit and working execution with significant expenses regarding enormous firms. These developments additionally influence little and medium farms, which put resources into cutting, must edge innovation to stay aware of the new technologies. In order to compare between conventional industry and agribusiness, there are as of now some basic and different viewpoints about it. For instance, agriculture supply chains veer in various angles from the modern division.

In agribusiness, the industry 5.0 focuses on the progression of items, information, and, knowledge among farming partners (producers and customers) at each phase of the agrarian procedures and emphasize the significance of utilization of communication. Such relations in the modern division take place just within the sight of industrial regions. In any case, industry deals with its supply chains dependent on quantitative strategies contrasted with agribusiness. Experience-based heuristic techniques assume a key job in agribusiness where natural introduction and stochastic occasions contribute a high level of store network vulnerability and an absence of consistency in rustic exercises (e.g., soil and supplement elements, photosynthesis movement or pest pervasion) [18].

With existing methodologies in agrarian supply chains and introducing new concepts and technologies Thai government is trying to take advantage of modern innovations for expanding the yield and improving the value of farming methods [10].

These include identification of digital methods for example, precision farming, which utilizes positioning technologies joined with the utilization of additional sensors and the gathered data Innovative arrangements convey critical impacts towards changing the difficulties of agrarian supply chain management into opportunities. By the way, to digitalize the farming business, new technologies and programming can't illuminate all preliminaries of the computerized change along the production network. Framework, preparing and capabilities, a satisfactory basic and authoritative working condition, and eagerness to actualize new technology are additionally unequivocal. For Agriculture 5.0, a cutting-edge broadcast communications framework in rural regions is essential. Besides, the capacity to apply information along the agriculture supply chain will demonstrate fundamental for a productive upset of existing agriculture procedures towards cultivating during the Industry 5.0 period [18].

Considering Thailand 5.0 industrial revolution and the fact that agricultural industry possesses the key position in the Thailand's economy, the reality is, it is still struggling with many economic and social issues. Despite having the major contribution in GPD and labor possession it is a fact that agricultural sector of Thailand is demonstrating low labor productivity. This led the government to adopt significant promotional strategies to enrich and enlarge the working capacity of different sub industries of agriculture along with equipping and educating their key components that "farmers". These enrichments focus on incorporating advanced and contemporary technologies such as advanced data analytics, usage of sensors and automated systems. Further, it is required that investment must be made in biotechnology research such as plant and animal breeding along with in businesses that utilize advance technologies to ensure quality in storing and maintaining fruits, vegetables and flowers.

2.1 Collecting Information: Internet of Things (IoT):

In agricultural context, the Internet of things refers the utilization of modern devices and sensors to control the actions and elements involved in farming into digital data. Almost 10 to 15 % farmers in US are utilizing IoT over 1200 million hectors and over 250000 farms [2]. This is the basic driver of Agriculture 4.0 [2]. It is a fact that because of Internet of Things, agricultural industry is able to generate massive amount of valuable information and also that the agricultural industry has been considered to be influenced and impacted positively by the technological advances [9]. With the advent of new technologies, it is estimated that IoT has the potential to maximize the agricultural productivity by 70% in the next few decades [14] which is a positive sign as it is already mentioned that because of growing population the world need to increase its food production by 60% [21]. IoT not only results in better and increased crop yield but also save cost. Studies conducted by On Farm, indicated that the utilization of IoT can increase the yield by 1.75% for an average farm. In addition, it was also found out that the energy cost also decreases by 17-32 dollars and the use of water for irrigation also falls by 8% [2].

2.2 Agriculture 5.0

The key scientific knowledge that help in successful transition towards a 5.0 society were always being and will be the center focus of IT and Science researchers in the near and distant future. Along with technology the focus of the researchers is also on developing multi-agent systems, energetics and ontological data analysis. These technologies and multi-system have been introduced by more than 25 years now [21]. Initially, they were developed to come up with new tools and methods based on principles of evolution and self-organization to solve complex problems. These systems were also referred to "intelligence emergent". The most common successful example of such multi-agent systems are the NO networks that is the network of needs and opportunities [16]. Another example is the method for the conjugate interactions for the management of resources. This approach was developed by Vittikh and Skobelev. In this approach of creating NO networks, there will be agents (roles) of opportunities and needs, which will determine the representative entities with opposite interests and then they will work in the virtual environment of systems and then cooperate and compete within that virtual market [17]. Similarly, the role of needs addresses the knowledge of future the role of opportunity deals with the knowledge of the past. This approach enables the user to get the perspective of knowledge from different point of views and solve the complex tasks.

Engineering challenges results in bringing immense solutions with the utilization of disruptive technologies and agricultural 5.0 is the biggest innovative initiative in this regard in the 21st Century [30]. The concept of 5.0 implies that farms should use precise principles for agriculture and use equipment that are built on autonomous decision making support systems and operations. Basically, the Agriculture 5.0 stresses upon the use of Artificial intelligence in which human labor force is suggested to be replaced by robots. Although, agriculture field requires a lot of manpower to harvest and keep farms productive from season to season but the fact is also there that the current society has been driven away of being part of agrarian society as majority of the rural population have moved to cities or villages have now developed into modernized environment [3]. Lack of interest in traditional farming methods in the young and upcoming generation results in farms facing shortage of skilled workforce. The concept has come into being after the crop yields and agricultural production falls in 2015. The concept has raised to overcome the problem of over demand and to satisfy the customers.

Agricultural robots with integrated Artificial Intelligence was presented as one of the solution to overcome this workforce shortage. According to a study published in Forbes, farm robots can easily replace human workforce and can be more efficient in terms of performance and speed [32]. The agriculture industry has been working towards developing robots and robotic systems that can operate in farms and agriculture fields and help the producers in completing complex and difficult tasks. The startups for agricultural techs has significantly increased in last 5 years reaching over 800 million dollars [4]. Since 2014 the use of machine learning and robotics have been used increasing along with the increased interest of industries in Artificial Intelligence.

All these efforts are made to successfully transform the agriculture industry into the concept of Agriculture 5.0 [5]. Reddy et al. stated that the integration of Artificial intelligence and use of robots in agriculture has bring drastic effects in the productivity of agriculture in many countries and has significantly reduced the operating costs of farming. Despite the fact that the exponential growth of robotic agriculture has significantly increased the profitability and production in agricultural industry however, like most the innovative initiatives this change also brings some limitations in terms of coping with new systems at early stages of adoption [23]. For most of the farmers these technologies are still too expensive to buy especially with small farms as scale economies make these small farms yield less profit. However, the fact that the technology cost decreases with time and the option of using agricultural robots will be a useful future alternative for human workforce to increase production. Today robotic innovations are boosting the agriculture globally along with the market of crop production [20]. However, what required is to create a young and new workforce through education, research and development that is capable of accepting, adopting and implementing these Artificial intelligence technologies effectively in the agricultural industry.

2.3 Advanced Farming: Principle stages for data driven management

In advance farming procedures the raw measurements of main parameters obtained from the crops have to be efficiently administered so that the ambiguous images or data will become valuable information [13]. Thirty years ago, the crop management done on the basis of field data have already brought precision to the agriculture but the digital information era has transformed it greatly. The traditional practice still involves the visual inspection

of the crops development in areas where technology has not reached yet. Farmers diagnosed the potential damages based on their experience and then make decide the treatment for different crop problems. This approach solely based on farmer's experience and their field experience [25]. In addition, the associate farmers or growers seek help from the recommendations made by engineers hired by the society they live in or cooperative technicians. In agricultural areas where the advance technologies have reached and implemented the field management principles vary according to the operation cycle of farms. This type of management system works on the data obtained from objective field data which helps in smart decision making to manage the crops and enable the farmers to take advantages from their inner variability both in terms of time and spatial wise. These types of platforms provide physical means like sensors for specific elements to the farmers to acquire the objective data and desired information [6].

This data includes the information collected directly from the parameters measured from soil, ambient and crops. The retrieving process of data from the sensors is done in different ways like using a software application or by inserting a USB port to get the data files [28]. All this is done online with an internet connection. The relationship among the data collection and decision stages determine the AI algorithm and filtering routines to get only the useful data that help them to make better decisions [29]. Furthermore, actuation is another process which refers to the conduction of physical execution of an action determined by the decision system and is implemented with the help of using advance equipment which receive their instructions from a computerized control unit [16]. As all the actions are taken place on the crops so the whole processing cycle starts and close at the crop level. The crop responses are then registered through special sensors and the management system loo continue to work since the harvesting time until the crop lifecycle ends [30].

3. PROPOSED FRAMEWORK

Authors had developed number of theoretical models to facilitate the understanding of different factors that can impact the acceptance of Information technologies. Among these models the Technology Acceptance Model is the most robust and influential in determining the technology adoption behavior of a user. Originally developed by Davis in 1986, the TAM is used with the key purpose to provide the base for exploring the internal beliefs, external variables, intentions and attitudes that impact technology acceptance [15].

3.1 Basic TAM Framework

The purpose of TAM is to predict the acceptability of a system, and identify the modifications that could be implemented in the system to make acceptable to the users. TAM is based on two main constructs; perceived usefulness (PE) and perceived ease of use (PEOU) of the system. Perceived usefulness implies the degree to which a concerned person believed the system will improve his/her performance. Perceived ease of use implies the degree to which an individual feels the system will be easy to use [15]. In addition, TAM also proposed that the existence of external factors affect the behavioral intention and the actual use of system as mediate effect on the Perceived ease of use and perceived usefulness. However, the behavioral intention is influenced an individual's attitude towards the system use, as well as his/her system utility perception (Figure 1).

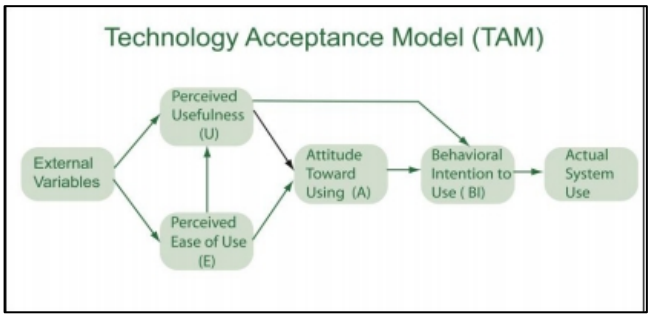

Figure 1. Original TAM Framework [1]

This implies that even if an individual may not welcome the technological system, the probability of its use is high if he/she perceived that the system will enhance the performance. As a result, there is a perceived direct link between the perceived ease of use and perceived usefulness. In this study, TAM has theoretically been applied as a basic model. For application in the context of Thai Farmers, the current study authors have utilized the Farmer Technology Acceptance model developed by Amin and Li [1].

3.2 Proposed FTAM Framework

FTAM is considered as one of the most effective models to measure the Farmer' technology acceptance. Other than the basic TAM constructs, this model also include additional variables to make it more comprehensive (Figure 2).

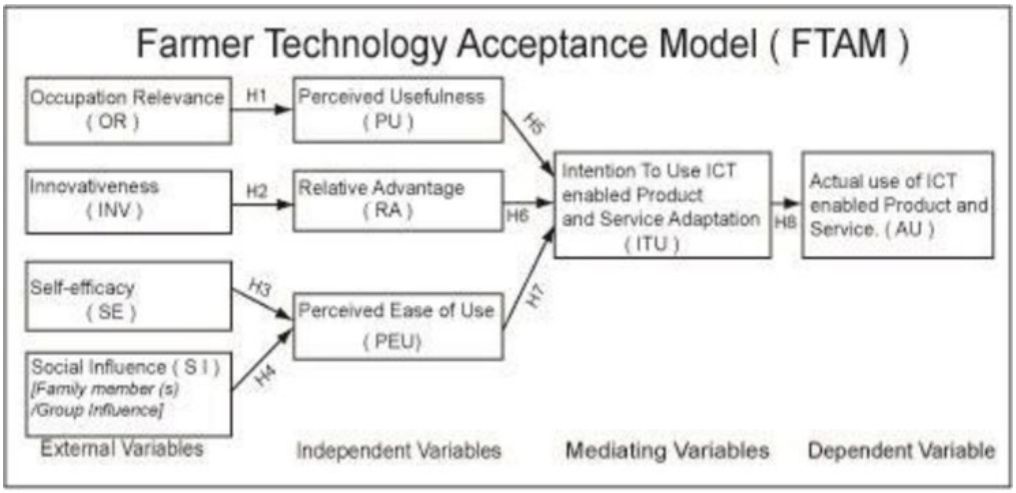

Figure 2. Farmer Technology Acceptance Model [1]

The FTAM framework postulates that perceived ease of use significantly influence the attitude of an individual to use a system through two major mechanism; self-efficacy and social influence. Self-efficacy concept advocates that the more a system easy to use, the greater the sense of efficacy by the user. The user has a feeling of control of the system and activity undertaken, a major aspect of the intrinsic motivation [24]. Social influence is built on the self-identity subjective norm perspective, with the idea that the influence of others such as family members and association groups have influence to ones behaviors. These constructs determine the extent to which an individual could adopt or use technology.

In addition to the constructs of perceived usefulness and perceived ease of use, FTAM incorporates a third construct referred to as the relative advantage (RA). The intention to use a system by an individual is directly influenced by its associated relative advantage [6]. Innovativeness has an influential capacity in building the users' continuance intention in the context of new technology. From the perspective of the diffusions of innovations theory, the continuance of intention of a user to apply, and its associated relative advantage is directly related to the perceived value of innovativeness.

In FTAM, perceived usefulness is built around the occupational relevance of the concerned system. Occupational relevance imply how useful the system is, in completing user's current task [15]. The occupational relevance is also assessed by several constructs: how difficult would it be to perform the job without the system; the control the system gives user to his/her job; the improvement of job performance by the system; and ability of the system to address the job related needs, as well as save time. A system which possesses all or some of these occupational relevance constructs increases its perceived usefulness, and the user's intention to use.

3.3 Hypotheses

H1: Farmer's specific occupation relevance is positively related to perceived usefulness of an ICT based products and services. Occupational relevance implies the usefulness of an ICT based product or service, in accomplishing a particular task. Some important constructs defining occupational relevance is enhancing the effectiveness of performance of the job, and the increase of productivity through the technological system. If the user perceives that the technology may increase his/her performance or productivity, then its perceived usefulness is considered to be high [24].

H2: Innovativeness of ICT enabled products and services has a positive relationship with their relative advantage. According to the study conducted by Saura, Molina and Contrí in 2014, in the current highly competitive market environment, innovativeness of ICT products and services is their source of sustainable competitive advantage in relation to other products. The concept of continuous innovation and developmental improvement is a strategic activity by the technological products, to maintain their relevance in the market, as well as their usefulness through relative advantage [26].

H3: Self-efficacy of a farmer is positively related to its perception of ease of use of an ICT based products and services. Self-efficacy implies the extent to which the user feels confident, and their capability to use the ICT product. Their users' ease of use of a technology is directly related to their volitional control or controllability and the fact that barriers are removed and sufficient support offered through the necessary facilitation conditions [24].

H4a: Social Influence of farmers related to an ICT based specific system is significantly related to determine its perceived ease of use

H4b: Social Influence (Family member Influence or Group influence) of a specific system has a significant role in determining the perceived ease of use, provided the farmer has no direct hand experience with the system. The social influence plays a critical role human decision making and behavior. Subjective norm could be a better predictor of the intention of a user who has no previous experience with a technology. Under mandatory situations, social influence determines the intention to use [31]

H5: Higher perceived usefulness of an ICT based system and its products is positively related with positive Behavior intention of user towards such systems. The behavioral intention (BI) is a TAM variable, which is measured using various aspects such as amount of time in using a technology, the actual number of usages, the frequency of usages and the usage diversity. A positive behavioral aspects has a significant influence on the perceived usefulness of a technology. This is through the concept that there is a general willingness to use a technology, which is considered to have useful and friendly functionality.

H6: Higher perceived relative advantage of an ICT based products and services is significantly related to positive behavioral intention of user towards such systems. Relative advantage implies the degree to which a system is considered more useful or advantageous to the user, as compared to other related systems. The stronger the system in terms of its application, as compared to its competitors, the higher the behavioral intention to use it by the user [31].

H7: Higher perceived ease of use of an ICT based system and its products is positively related with positive Behavior intention of user towards such systems. TAM framework postulates the use of a technology depends directly on the associated behavioral intention by the user. On the other hand, the behavioral intention is directly influenced by the individuals' attitude towards the use of the concerned system, as well as the perceived utility of the system. These aspects determines the degree to which an individual regards that the use of the system will be effortless [12].

H8: Positive Behavioral intention towards utilization of an ICT enabled product and services is positively related to the actual use of ICT enabled Product and services. The actual technology use is the end point where every person should do with the system at hand. However, to have a system actual use, the behavioral intention have to be formed, which is a factor that ignites the technology use. The TAM indicates that the aspects that influence behavioral intention include attitude which is the technology general impression [24]. A positive attitude leads to positive behavioral intention and the resulting actual use of the system.

4. CONCLUSION

The current research provides valuable basis regarding information and facts related to technology acceptance and adoption in agricultural in Thailand. The literature and proposed framework both can be utilized by the government in reshaping and remodeling their policies regarding the adoption of technology and innovations in agricultural industry. Due to time constraints only, conceptual framework has been established to determine the study implications towards farmer's acceptance of ICT based products and services. However, an in-depth study followed by collecting quantitative data will be conducted to further ascertain the research relevance and significance backing with the secondary data. The extend TAM utilized in this research serves as a significant source to identify, measure and address internal and external factors that can impact farmer's attitude and behavior towards using ICT based systems in agriculture. It is recommended that the attributes provided in this

research should be studied extensively through analyzing the implementation of such systems in developed countries. Future studies can incorporate the proposed framework or extend its variables to make new framework to provide a more comprehensive and in-depth review on factors that affect the user behavior, attitude as well as their performance outcomes.

5. CONTRIBUTIONS TO FURTHER STUDY

It is evident from the discussions of this study that there are several gaps and aspects around the application of technological system in agriculture that require further research. The first gap that needs statistical research is the impact of the government initiatives such as Thailand 1.0 and Thailand 4.0 on the agriculture production and well as its associated technological advancement in agriculture. Understanding the economic benefits of the past initiatives through empirical evidence would offer better suggestion for implementation of the current Thailand 5.0. Second, this study evaluated and proposed a model of user acceptance and adoption of technology on Thailand farmers. The FTAM framework was proposed on the basis of TAM. A follow up empirical investigation using quantitative techniques is suggested. The empirical investigation may use primary or secondary data and apply descriptive or inferential statistics to verify the suitability of the suggested model. This would provide empirical evidence of the acceptance and adoption of technology by Thai farmers, and the associated agricultural production.

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Effects of Chair Rise Strategies on Joint Loads

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ABSTRACT
The ability to rise from a sitting position is considered as a key determinant of independence. An ergonomic analysis of sit-to-stand (STS) is needed for people to improve the daily activity, avoid the re-injury and be a reference by documenting the influences on human musculoskeletal system. The goal is to investigate the effects of arm postures and leg positions on joint motion and joint loads during sit to stand period. The twelve young college students without any musculoskeletal disorder were recruited. Three contexts of the sit-to-stand experiment were a normal sit posture with 90 degree of knee joint (N), a normal sit with feet backward 10 cm from sitting with 90 degree of knee joint (FB) and a normal sit posture with arms forward (AF). The height of the chair was adjusted with their leg length from ground to knee joint. The six-camera motion analysis capture system with two force plates were used to collect the segmental movement and ground reaction force. The movement time, kinematics and kinetics of joint were then analyzed. The results were found the range of motion of the hip, knee and ankle were significantly affected by chair raising strategies ($p<0.05$). FB groups had lower peak moments of the hip than N and AF groups. The largest peak knee moment occurred in FB groups. The peak knee moments among three groups are significantly different ($p<0.05$). The results of this research would be a reference for strategy use for older people or people who are difficult to rise from sit.

CCS Concepts
• **Applied computing→ Life and medical sciences→ Customer health •Applied computing→ Physical sciences and engineering→ Physics**

Keywords
ergonomics; sit-to-stand; kinetics; joint loads

1. INTRODUCTION
The movement of standing up from a chair is very common activities in our daily life. It's about 60 times for a healthy adult to perform such a movement in a day[1]. The ability to rise from a sitting position is considered as a key determinant of independence.

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Generally, the moments across lower limb joints during this movement are as high as 4.7 times of the body weight, and high level strength of lower limbs is needed to perform such a multi-joint task [2]. Therefore, the sit-to-stand (STS) was referred as a test for an indicator of postural control, fall risk, lower-extremity strength, and proprioception and as a measure of disability. The sit-to-stand test also has been related to standing and postural control and to falls in older adults [3]. Deterioration of joints and weakness of muscle strength of lower limbs are the two problems suffering older people, which make the sit-to-stand movement difficult [1, 3]. These physical limitations will affect their daily activities and quality of life. Therefore, an ergonomic analysis of the assistive strategies is needed for old people to improve their daily activity, avoid the re-injury and be a reference by documenting the influences of human musculoskeletal system.

Previous studies have investigated strategies performing STS. A higher chair seat can decrease the generation of momentum of hip and knee. Using armrest will make the moments needed at the knee down by 50% [4]. The strategy that changing the foot position results in decreasing the peak moments at the hip and knee [5]. Kawagoe et al. found that the hip extension moment significantly decreased when placing the feet 10cm behind the neutral position. Shepherd note a forward foot placement would adversely affect the ease of standing up for individuals with leg muscle weakness and poor motor control [6]. Segal et al.[7] has found that adults with symptomatic knee osteoarthritis rising from a chair better through increasing hip flexed angle. Similar result was found in Parkinson's disease patients, who generate greater trunk flexion at higher angular velocity to compensate for their difficulties rising from a chair. The arm position also affects the STS task. Carr et al. [8] suggested that the extended arms generate the horizontal and vertical propulsion of the total body.

Arm forward posture, the position of two hands gripping together with the shoulders flexed at 90° and the elbows fully extended, was commonly used in clinical setting to facilitate sit-to-stand movement in subject with stroke[5]. However the effect of different arm positions on STS has not yet been investigated for joint demand. The aim of this research is to investigate the effect of arm forward and foot position on joint motion and joint loads during STS.

2. METHOD
2.1 Subject and Experimental Protocol
Twelve college students were volunteered to participate in this study performing STS transition from an armless chair. The participants ranged from 20 to 27 years (22±3.2, mean±SD) of age, from 50 to 75 kg (54.2±6.2, mean±SD) in body weight, and from 151 to 184 cm (162.2±7.7, mean±SD) in body height. None of the participants had ever suffered upper extremity injuries or disorders. The ExpertVision motion system (Motion Analysis Corp., Santa Rosa, CA, USA) with six 60 Hz cameras and one 1000 Hz Kistler force-

plate (Type 9281B, Kistler Instrument Corp., Winterhur, Switzerland) were used to measure relative joint positions and ground reaction forces. A total of 21 retroreflective spherical markers, 2.5 cm in diameter, were applied on anatomical landmarks that determined embedded axes for the body segments under consideration. The markers were attached on the skin surface for right and left sides, one each at the space between the second and third metatarsal bones, medial and lateral malleolus, sides of shank and thigh, medial and lateral epicondyle, anterior superior ischial spine and the acromion process, and one center markers, sacral (Figure 1). An adjustable-height stool without armrests or backrests was used for this task. Subjects were also asked to fold the arms across the chest and to stand from the chair at their self-selected pace. Three contexts of the sit-to-stand experiment were a normal sit posture with 90 degree of knee joint (N), a normal sit posture with feet backward 10 cm from sitting with 90 degree of knee joint (FB) and a normal sit posture with arms forward (AF), parallel ground (Figure 2). Each subject was observed rising from 100% of her knee-heel height (length from knee joint center to heel) at preferred or natural speed without the use of arm rests. The kinematic and the kinetic data were collected simultaneously at a 60 Hz sample rate, sampling period beginning as the subject was asked to begin to rise from the chair. All of the participants provided informed consent prior to the tests. Moreover, the test procedure was approved by the Institutional Review Board of Chung Shan Medical University.

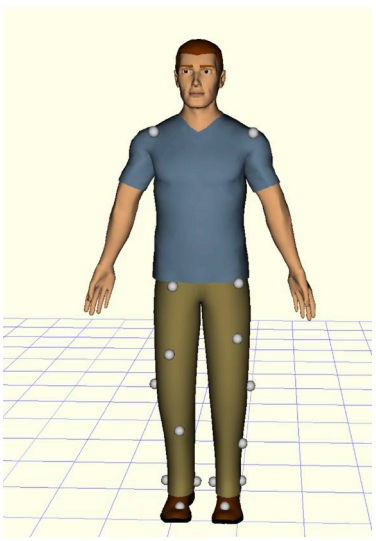

Figure 1. Markers set-up for the sit to stand task

2.2 Data Analysis

Laboratory-developed kinematics and kinetics software with matlab (2018a, The Mathworks Inc., Natick, MA, USA) was used to calculate the joint angles, resultant forces, and moments of ankle, knee and hip joints in the sagittal plane. Each segment was assumed to be a rigid body, and the ankle, knee and hip joints were treated as spherical joints. A four-segment model, including the foot, shank, thigh and trunk, was employed in the analysis. Joint angles were calculated using vector operation in the sagittal plane, based on the attached markers [9]. A piezoelectric force platform was used to measure horizontal forces as well as the location of the center of pressure on the foot during STS with the kinematic data of the low-extremity simultaneously measured. The segment mass and inertia data were estimated by anthropometry[10]. The angular velocity and acceleration were calculated with the first and second derivatives of joint angle[11]. The resultant loading of ankle, knee and hip joints then were determined using an inverse dynamic procedure with the Newton-Euler equation as equation (1) and (2)[9]. A generalized cross-validation spline smoothing (GCVSPL) routine at a cutoff frequency of 6 Hz was used for data smoothing[10]. Joint moments were expressed as external moments normalized to body mass times height (Nm/kg).The start and end of the STS task were defined as follows: the start–stand event occurred when the velocity of the left acromion process marker exceeded a threshold of 0.1 m/s in the anterior direction and end-stand occurred when the left acromion process marker reached the highest position in the vertical direction [12]. Mean and standard deviations for discrete biomechanical variables for both limbs were computed for subjects.

$$F_p = ma - F_d - F_w \quad \cdots\cdots (1)$$

$$M_p = I\dot{\omega}' + \omega' \times I\omega' - [M_d + r_d \times F_d + r_p \times F_p] \cdots\cdots (2)$$

where F_p is the proximal end joint force; F_d is the distal end joint force; F_w is the gravity force; M_p is the proximal end joint moment; M_d is the distal end joint moment; r_p is the proximal end moment arm; r_d is the distal end moment arm; ω' is the angular of the segment.

2.3 Statistical Analysis

SPSS 8.0 software was used for statistical analysis. The three kind of chair rise strategies were regarded as independent variables and the total duration of the sit-to-stand movement, the angles and moments at ankle, knee and hip as dependent variables for statistical analysis. Each measurement was performed three times. The one-way ANOVA with repeated measures procedure was conducted to evaluate the differences among chair rise strategies. A *P* value of .05 was used to determine statistical significance for all analyses

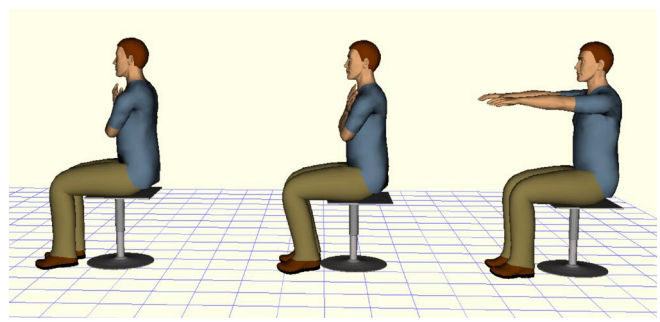

Figure 2. Experiment set-up for the sit to stand task, normal (N), foot backward (FB) and arm forward (AF)

3. RESULTS

3.1 Total Duration of the Sit-to-Stand Movement

The total duration for the rising maneuver in FB was less significant than that of N and AF groups. ($p<0.05$, Figure 3). The maximal total duration was 1.92 seconds in N group. The minimal total duration was 1.70 seconds in FB group. The total duration was decreased significantly 11% from N group to FB groups.

3.2 Peak Vertical Ground Reaction Force

The peak vertical ground reaction forces were significantly affected by chair raising strategies ($p<0.05$, Figure 4). The peak vertical ground reaction forces in normal group was the largest, 63.5%BW

(Figure 4). The lowest peak vertical ground reaction force in three groups was 58%BW in FB groups. There was not significant difference in peak vertical ground reaction force between left and right feet

3.3 Range of Motion

The range of motion of the hip, knee and ankle were significantly affected by chair raising strategies ($p<0.05$, Figure 5). The hip joint reached the maximal flexion angle at the end of the forward leaning phase. The range of motion of the hip was the largest, 97.8 degrees, for the normal group (Figure 5). The maximal flexion angle of the knee also occurred at the end of the forward leaning phase. The maximal range of motion of the knee and ankle for three groups was 89 degrees and 20 degrees in FB groups.

3.4 Peak Joint Forces

Peak forces of the hip and the knee were significantly affected by chair raising strategies. In peak hip, knee and ankle joint force ($p<0.05$, Figure 6). FB groups had lowest peak forces compared with N and AF groups (Figure 6). The largest peak joint force was 63%BW in N groups of ankle joint and the lowest peak joint force was 45%BW in BF groups of hip joint. There was not significant difference in peak joint force between left and right feet.

3.5 Peak Joint Moments

Peak moments of the hip and the knee were significantly affected by chair raising strategies. In peak hip joint moment, FB groups had lowest peak moments of the hip than N and AF groups (Figure 7). The largest peak hip moment occurred in FB groups, 1.19 Nm/Kg, (Figure 7). The lowest peak hip moment occurred in AF groups, 0.86Nm/Kg. The peak hip moments among three groups are significantly different ($p<0.05$). The peak hip moment was decreased significantly 17 % from N group to FB groups. In peak knee joint moment, FB groups had largest peak moments of the hip than N and AF groups (Figure 7). The largest peak knee moment occurred in FB groups, 0.73 Nm/Kg, (Figure 7). The lowest peak knee moment occurred in AF groups, 0.46Nm/Kg. The peak knee moment in N group was 0.56 Nm/Kg. The peak knee moments among three groups are significantly different ($p<0.05$). The peak knee moment was increased significantly 30% from N group to FB groups. There was not significant difference in peak joint moment between left and right feet.

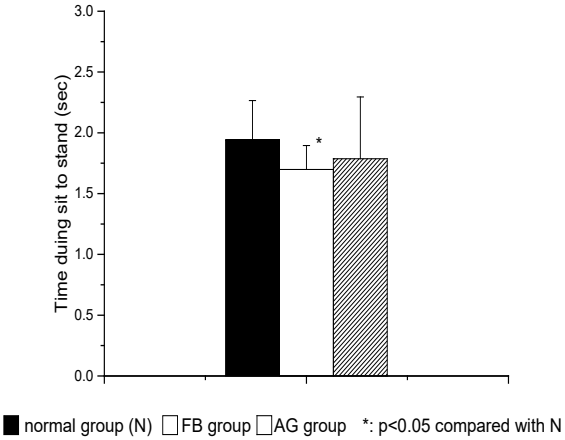

Figure 3. Mean and standard deviation of the total duration of the sit-to-stand movement while rising from the chair at 100% of the subject's knee height at preferred or natural speed without the use of arm rests. (* value significantly greater, *p<0.05*, than that of normal group.)

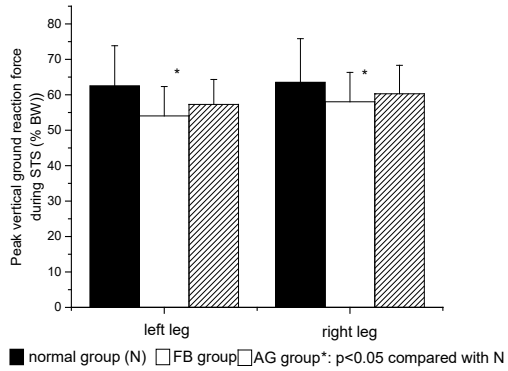

Figure 4. Mean and standard deviation of the peak vertical ground reaction force while rising from the chair at 100% of the subject's knee height at preferred or natural speed without the use of arm rests. (* value significantly greater, *p<0.05*, than that of normal group.)

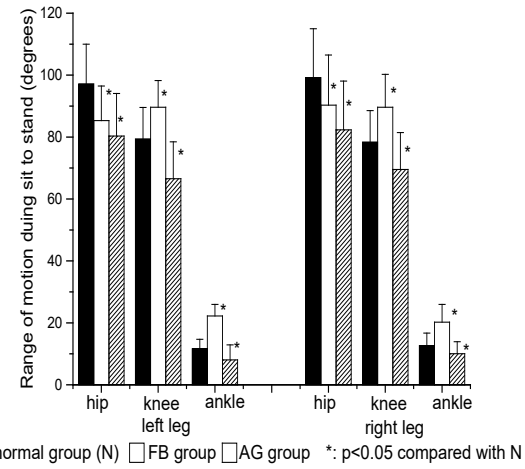

Figure 5. Mean and standard deviation of the range of motion of the lower extremity while rising from the chair at 100% of the subject's knee height at preferred or natural speed without the use of arm rests. (* value significantly greater, *p<0.05*, than that of normal group.)

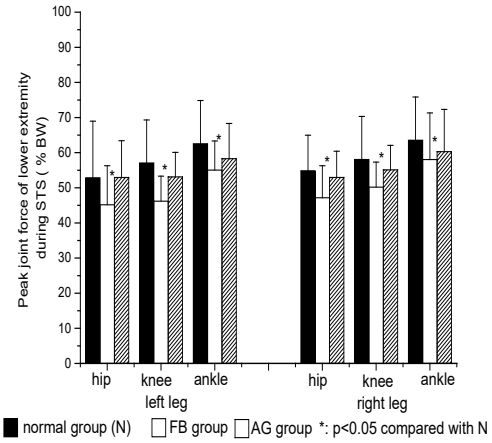

Figure 6. Mean and standard deviation of the peak joint force of the lower extremity while rising from the chair at 100% of the subject's knee height at preferred or natural speed without the use of arm rests. (* value significantly greater, *p<0.05*, than that of normal group.)

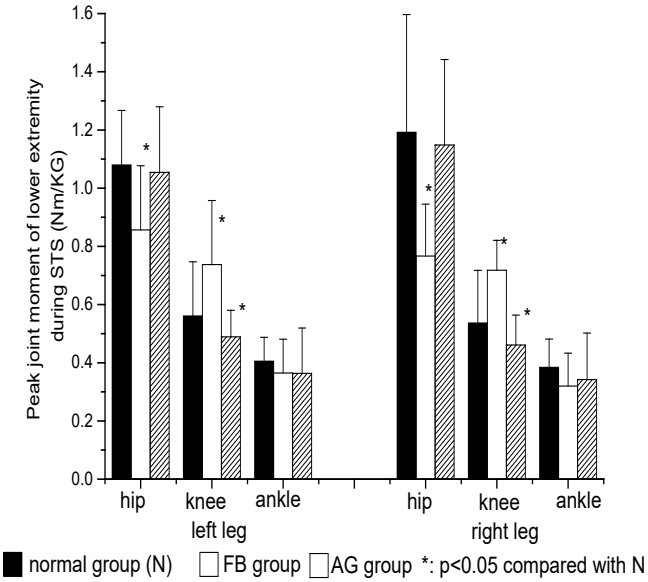

Figure 7. Mean and standard deviation of the peak joint moment of the lower extremity while rising from the chair at 100% of the subject's knee height at preferred or natural speed without the use of arm rests. (* value significantly greater, *p<0.05*, than that of normal group.)

4. DISCUSSION AND CONCLUSION

In this study, it was postulated that there are differences in kinematic and kinetic data among chair rising strategies for STS. In FB group, subjects had shorter completion times and joint loads compared to N and AF groups. However, FB had higher knee joint angles and moments. This was evident in the significant differences observed among three chair rise strategies.

In Pai's study[13], increasing the torque-generating capacity of hip flexors, knee extensors and ankle dorsiflexors could use the muscle strengthening protocols with different rising speeds. In Lou's study, pregnant women at different pregnant period will affect the strategies use during STS. In this study, the protocol was performed at preferred or natural speed, without the use of arm rests, for purposes of detailed research into the timing of STS, range of motion and peak torque of lower extremities.

Using the same method to study different ages and groups during STS, Alexander found that the time interval for elderly subjects to rise from all heights of a chair was longer than that of younger subjects[14]. Rutherford[15] noted that seat device effects were similar between age groups. Older adults used higher relative muscle activation. In Lou's study, the time interval for third period pregnancy subjects was longer than that for second period and first period pregnancy subjects[16]. This time increase became more significant for shorter chair heights, presumably meaning that third period pregnant women had greater difficulty rising from lower chairs. In this study, the FB group has less total duration than that of N and AF groups.

By comparing different normal groups during STS, Rodosky [17] and Su [18] found hip and knee moment increased as chair height decreased, the challenge increasing. In this study, similar trends are found in the FB group for knee moment by comparison with N groups. Hip moment, by contrast, was found to decrease.

By comparing different foot position during STS, Kwong showed the shorter STS completion in FB than N for patient with stroke in five times STS [5]. Khemlani noted posterior foot placement resulted in a significantly smaller hip flexion angle in the preextension phase of sit-to-stand and maximum hip extension moment (32.7 ± 12.1 Nm) was found to be reduced compared with N group[19]. In this study, the similar trends are found in FB and AF. However the maximum hip extension moment in FB was reduced 17% or 17.9 Nm for an averaged 54.2 Kg subject. That error could come from the subjects' weight, 54.2 vs 71.2 kg, and gender, man and woman vs all man.

By comparing different arm position during STS, Kwong showed the longer STS completion time in AF than N for patient with stroke [5]. The AF position might help to shift the CoG forward more efficiently, which could explain its association with STS times [5]. Carr conducted a kinematic and kinetic analysis of arm position on sit-to-stand movements with motion analysis system found that AF generate greater propulsive force during a sit-to-stand maneuver. Their results were shown to induce larger peak CoG momentum in both the horizontal and vertical directions than the restricted arm position. [20]. As there is rare study examining the effects of arm positions on sit-to-stand maneuver, further biomechanical studies are warranted[20].

This study is not without limitations. First, the population studied was limited to healthy college student; these results could not be generalized to other populations. Second, only one foot placements and one arm positions were studied for normal young subjects. Previous studies has shown that different foot placement would significantly affect the electromyographic activities of lower limb muscles and completion time. Whether other foot placements or arm positions could induce a greater effect on joint loads during STS further study of the actual kinetics and kinematics of STS with different arm positions and foot position are warranted.

In conclusion, it is experimentally confirmed that the chair rising strategies could affect the joint loads during STS. People with knee arthritis or diseases should take AF strategies to decrease the knee moment. However, the hip moment will increase as well. They are further advised to use armrests to decrease joint force and moment, thereby avoiding or minimizing loading damage to the joints.

Through the findings of this study, future research is suggested to focus on the effectiveness of strategy use in STS for old people or people with disability. In addition, other assistive equipment need to be constructed for people going through STS and for those not. It is the hope of this paper that all people can live independently and with good quality in the future.

5. ACKNOWLEDGMENTS

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6. CONFLICT OF INTERESTS

No commercial party having a direct financial interest in the results of the research supporting this paper has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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Effects of Glovebox Glove Properties on Hand Strength

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ABSTRACT
Glovebox glove usage has been known to impair hand strength such as maximum voluntary grip and key pinch strength. This study assesses the effects of three material properties of glovebox glove on hand strength to offer design/selection recommendations to provide effective prevention for Musculoskeletal disorders (MSDs) in the hand and wrist during glovebox operations. Three commercially available glovebox gloves, namely butyl, hypalon, and neoprene in 0.015" and 0.03" thickness were included for evaluation. The correlation matrix indicates that the grip strength is the only dependent variable that shows statistically significant correlations with most of the independent variables except friction, and quadratic and cubic components of friction variable. Thickness and pliability are inversely correlated to the maximum grip strength. Stepwise regression shows that the interaction of thickness and pliability is the only variable included in the final equation. To minimize effects of glove usage when performing glovebox tasks involving a gripping hand, material thickness and pliability parameters could be included for glove design and selection purposes to improve worker health and safety.

CCS Concepts
• Human-centered computing → Interaction design → Empirical studies in interaction design • Mathematics of computing → Probability and statistic → Nonparametric statistics • Applied computing→ Life and medical sciences→ Consumer health

Keywords
Glovebox; Glove thickness; Friction; Pliability; Grip strength; Key pinch strength

1. INTRODUCTION
Glovebox workers are required to wear gloves to perform glovebox operations [1]. However, glovebox glove usage has been known to impair hand strength such as maximum voluntary contraction (MVC) grip and key pinch strength [2]. Dianat et al.'s [3] review article also indicated that gloves worn show negative effects on various hand performances including hand grip and pinch strength. Grip and pinch strength reduction are associated with risk factors such as forceful exertions and awkward hand/wrist postures which may cause hand/wrist musculoskeletal disorders (MSDs)[4]. Bureau of Labour Insurance (BLI) of Taiwan also showed that the ratios of Workers' Compensation (WC) claims for work-related Musculoskeletal disorders (MSDs) on "arm, neck and shoulder (upper extremity)" regions accounted for 73.5%, 75.3%, 75.9%, 78.9, and 74.8% % of all MSDs claims for the years 2015 to 2019 (Jan.-Aug.) [5]. Previously, Sung [2] and Sung and Chiu [6] had objectively and subjectively evaluated the effects of glovebox gloves on hand strength, on contact forces for manual operations with three hand tools, and on hand tactility and discomfort to provide glove design/selection recommendations for glovebox operations. In this study, the effects of three glove properties (glove thickness, coefficient of friction, and pliability) and their interactions on grip and key pinch strength were assessed to offer extra design/selection suggestions for glovebox glove to further improve safety and health work environments for glovebox tasks.

In terms of the effects of glove properties on hand strength, published literature has shown that material thickness increased the effective handle size that reduces the maximum force capability [3, 7, 8, 9]. Batra et al. [10], Chang and Shih [11], and Dianat et al.'s [3] also showed that the extent of reduction in grip strength was correlated significantly with glove thickness. In addition, Sung [2] indicated that thinner glove generated significantly higher grip and key pinch strength than thicker glove. However, Dianat et al.'s [3] stated that the effects of glove on pinch strength required further investigated. Low static coefficient of friction of glove surface increased grasp force required [8, 9, 12, 13]. Batra et al. [10] also indicated that the grip strength and coefficient of static friction are significantly correlated. Tsaousidis and Freivalds [14] stated that higher glove pliability decreased tactile information and increased force exertions. The glove properties that change hand performance should be understood and can also serve as selection/design guidelines for currently available and potential glove materials.

To provide effective prevention for MSDs in the hand and wrist for glovebox glove usage, this study first evaluated the effects of glovebox gloves on hand performances (in terms of grip and key pinch strength). Then, this study measured the coefficient of static friction and pliability of glove materials and conducted a correlation analysis to evaluate the significance of these glove characteristics (glove thickness, coefficient of friction, and pliability) on grip and key pinch strength. Recommendation for design/selection guidelines of glovebox gloves based on the results

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were also provided to minimize glovebox gloves effects on hand performances.

2. METHODS

2.1 Subjects

Eleven volunteered Taiwanese females free of musculoskeletal disorders/injuries (MSDs) in the upper extremities (identified through interviewing process) were recruited to participate in this study. All these subjects are right handed. The mean values of age, height, hand length and maximum breadth of hand are 32 ± 5 years (23 to 40 years), 159.7 ± 5.0 cm (152.0 to 169.0 cm), 167.0 ± 5.1 mm (156.5 to 174.6 mm), and 87.2 ± 3.8 mm (79.4 to 93.4 mm), respectively. The Institutional Review Board for Ergonomics Experiment of Chao Yang University of Technology has approved this study.

2.2 Gloves

Three commercially available glovebox gloves in two different thicknesses (0.015" and 0.03") made by butyl, hypalon and neoprene materials (Figure 1) were selected for evaluation. The cuff diameter and length of the gloves are 8" and 32". Two smallest hand sizes, 8.5"and 9.75", were provided for the subject to pick the best fit glove for maximum voluntary grip and key pinch strength testing.

Figure 1. Butyl, hypalon, and neoprene glovebox gloves from left to right

2.3 Grip and Key Pinch Strength

Maximum grip and key pinch strength for gloved hands were measured for each subject using a Jamar dynamometer and Jamar pinch gauge (Figure 2). Caldwell's regimen [15] was followed for the estimations of the maximum grip and key pinch strength. The subjects were seated with their shoulder adducted and neutrally rotated, elbow flexed at 90^0, forearm in neutral position, and wrist between 0^0 and 30^0 extended and between 0^0 and 15^0 ulnar deviations to maintain neutral posture [16]. The investigator held the Jamar dynamometer or Jamar pinch gauge and asked the subject to build up maximum voluntary contraction (MVC) for force exertions. Three replicates of maximum grip and key pinch strength within 10% tolerance of the mean score were recorded. A 5-minute break was given to each subject after 25-minutes test.

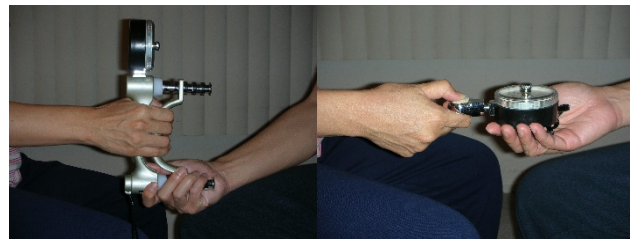

Figure 2. Grip strength testing (left) and key pinch strength testing (right)

2.4 Glove Properties Measurement

The intrinsic properties used to characterize glovebox gloves are thickness, coefficients of static friction (μ_s) and pliability. The nominal thicknesses of the gloves were provided by the vendor which had also been measured in the laboratory to fall within the acceptable variations specified in guidelines for gloveboxes (AGS-G001) by American Glovebox Society [1]. The inclined plane method (ASTM G115-93) [17] was used to measure the coefficient of static friction of glovebox gloves on aluminum surface of a 15.5 cm * 7.0 cm * 1.2 cm aluminum plate and a folding force meter designed in the laboratory was used to measure the pliability (in Kg force). Both methods were used by Batra et al. [10] and can be easily adopted in the field for glove properties measurements at low cost.

Coefficients of Static Friction

The coefficient of static friction is the ratio of tangential force and the normal force just prior to the moment of slip. A piece of glove material was mounted to a polycarbonate plate (dimensions 4.1 cm * 3.5 cm * 0.6 cm) and a 200 gram weight was attached on top of the plate. The polycarbonate plate was placed on an inclined plane with aluminum plate attached to it (Figure 3). Then, the plane was raised slowly until the plate began to slide and the sliding angle was measured using a protractor attached onto the inclined plane. The tangent of the sliding angle was recorded as coefficient of static friction of that glove material.

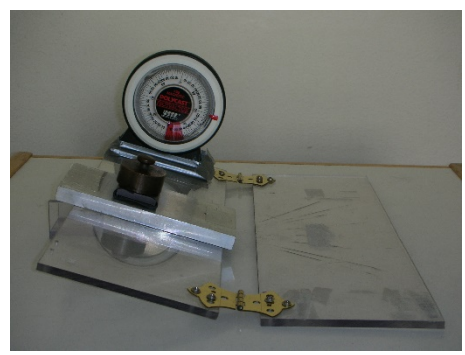

Figure 3. An inclined plane for measuring coefficients of static friction of glove materials

Pliability

Pliability is the property of being easily bent without breaking or cracking [14]. A fabricated folding force meter was used to measure the pliability. This force meter included an Accu force gauge with a piece of 4.1 cm (1.6") * 3.5 cm (1.4") * 0.6 cm (0.2") polycarbonate plate attached on the bottom. A handle was used to press the meter on top of a 4.1 cm (1.6") * 6.9 cm (2.7") piece of glove material until this piece of material was folded into a 4.1 cm (1.6") * 3.5 (1.4") cm piece with double thickness. This piece of glove material was taped on the inside bottom of a 4.1 cm (1.6") *

3.5 cm (1.4") * 3.5 cm (1.4") container made of polycarbonate plates where two sides of the walls were left open. The weight of the force required for folding the glove material to double thickness was recorded as pliability of that glove material.

2.5 Experimental Design and Statistical Analysis

This study first evaluated the effects of glove material and thickness on MVC grip strength and key pinch strength. Glove material had three levels: butyl, hypalon, and neoprene. Thickness had two levels, 0.015" and 0.03". Separate analyses of variance (ANOVAs) with repeated measures were used to determine whether there were significant differences between independent variables on dependent variables. Prior to the use of the repeated-measures ANOVA, the Kolmogorov-Smirnov (K-S) and Levene tests were used to check the normality and homogeneity of variance of the data. If either (or both) of the tests was found statistically significantly at $p<0.05$ (rejecting null hypothesis of normal distribution and/or equal error variance), data transformation was performed using logarithmic base 10 (log10) and square root functions. The transformed data were then subjected to the Kolmogorov-Smirnov and Levene tests. If both tests were passed, a repeated-measured ANOVA was carried on the transformed data. If either (or both) of the tests was found statistically significant on the transformed data, then, the nonparametric Wilcoxon signed-rank test was used for 2 related sample test and the Friedman test was used for 3 or more related samples test on the original data (without transformation). Bonferroni post hoc analyses were performed to determine which pairs of means were significantly different. Please refer to Sung and Chiu [6] for the Statistical Analysis Testing Procedure

Correlation analyses were also performed to measure the strength of the linear associations between the independent and dependent variables. The independent variables were coefficient of static friction, thickness, pliability, and the interaction, quadratic, and cubic relationships of the three glove properties. The dependent variables were maximum grip and key pinch strength. In addition, multiple regression analysis was performed to develop equations to predict hand performance over the range of glove properties measured with the found significant factors. All data were analyzed for statistical significance at $p\leq0.05$ using the SPSS 18.0 (SPSS Inc, Chicago, Illinois) statistical software.

3. RESULTS

3.1 Effects of Thickness on Hand Strength

The results of the repeated-measured ANOVA (Table 1) show that there are significant differences between glove material ($F=8.84$, $p<0.005$) and thickness ($F=104.35$, $p<0.0001$) on MVC grip strength. In addition, there is a statistically significant interaction effect ($F=8.99$, $p<0.005$) between glove material and thickness on the maximum grip strength.

Table 1. ANOVA with repeated measures results for effects of glove material, thickness, and their interactions on maximum grip strength for eleven female subjects

Source	SS	Df	MS	F	Sig
Glove material (G)	32.04	2	16.02	8.84	0.0018
Thickness (TH)	270.90	1	270.75	104.35	0.0000
G * TH	22.28	2	11.14	8.99	0.0016

Bonferroni pairwise comparisons in glove material effect show that there were statistically significant differences ($p<0.05$) for butyl vs. neoprene and hypalon vs. neoprene. This indicates that the butyl and hypalon gloves can retain significantly higher maximum grip strength than the neoprene gloves. In addition, the thinner (0.015") gloves retain significantly higher maximum grip strength (2.3 kg in mean differences) than the thicker (0.03") glove. Figure 4 shows the plot of Glove Material * Thickness interaction. For thin gloves, the grip strength seems the same for different glove materials. For thick gloves, neoprene material seems to reduce grip strength compared to butyl and hypalon materials.

No significant effect of glove on the maximum key pinch strength was found. To evaluate the effects of glove material and thickness on maximum key pinch strength, all the original data and transformation (log10 and square root) data did not pass the K-S normality tests (Asymptotic Significance < 0.05). The nonparametric Wilcoxon signed-rank test was used for 2 related samples (thickness) test and the Friedman test was used for 3 or more related samples (glove material) test on the original data. The Friedman tests show no significant differences between glove materials in maximum key pinch strength (Asymptotic Significance>0.05). However, Wilcoxon signed-rank test shows significant differences in thickness ($Z=-5.12$, Asymptotic Significance<0.05) where 0.015" thickness gloves yielded higher maximum key pinch strength than the 0.03" thickness gloves (Figure 5).

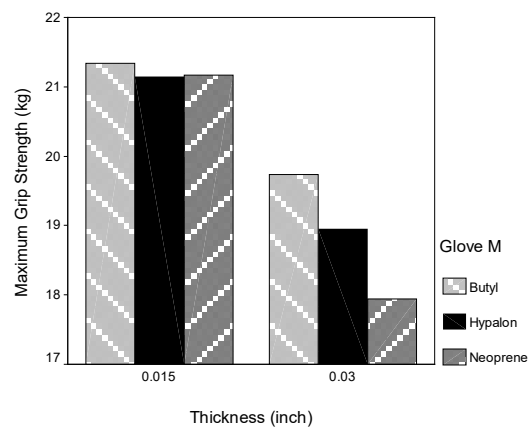

Figure 4. Interaction of Glove Material * Thickness on maximum grip strength

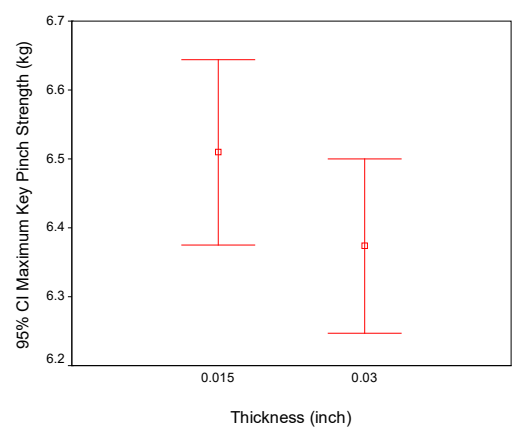

Figure 5. Effect of thickness on maximum key pinch strength for eleven female subjects

3.2 Correlation Analyses

Table 2 shows the determined values of coefficients of static friction and pliability for the glovebox gloves used in this study. The correlation matrix (Table 3) indicates that the grip strength is the only dependent variable that significantly correlated ($p<0.05$) with most of the independent variables except friction, and quadratic and cubic components of friction variable. The results indicated the following conclusions:

(1) Thickness and pliability are inversely correlated to the maximum grip strength.
(2) No linear associations were found between coefficients of static friction and maximum grip strength.
(3) No linear associations are found between glove properties and maximum pinch strength.

Table 2. Static coefficients of friction and pliability of glovebox gloves

Property/Glove	B15	B30	H15	H30	N15	N30
Friction	0.65	0.64	0.71	0.7	0.7	0.69
Pliability (kg)	0.42	0.71	0.53	0.88	0.42	0.98

Table 3. The correlation matrix between MVC grip / key pinch and dependent variables

	Th	Fr	Pl	Th*Pl	Th*Fr	Pl*Fr	Q_Th	Q_Fr	Q_Pl	C_Th	C_Fr	C_Pl
Grip	*	ns	*	*	*	*	*	ns	*	*	ns	*
Pinch	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Th: Thickness; Fr: Friction; Pl: Pliability; Q: Quadratic; C: Cubic; *: significant at p<0.05; ns: not significant.

Stepwise regression was then performed for automatically selecting significant variables to predict maximum grip strength. The result shows that the interaction of thickness and pliability (t=-7.693, p<0.001) is the only variable included in the equation and the final model is:

MVC Grip Strength (Kgf) = 24.6 – 145.6 * Thickness * Pliability (R^2 = 0.49, F=62.01, $p<0.0001$)

Batra et al. [10] attributed their low R^2 value for predicting grip strength to the variations of glove-hand fit for the subjects, however, the authors also stated that the volumetric differences between the hand and the glove may not be a good measure of glove-hand fit. In this study, the low R^2 value of the equations may have been due to narrow range of thickness and pliability measured in this study. The fitted regression model for the maximum grip strength is found to be significant (F=62.01, $p<0.0001$). The results indicate that the interaction of thickness and pliability is the best independent variable examined to predict the maximum grip strength measured in this study.

4. DISCUSSIONS AND CONCLUSIONS

To provide effective prevention for MSDs in the hand and wrist for glovebox glove usage, this study recommended the design/selection guidelines of glovebox gloves based on the results to minimize glovebox gloves effects on hand performances.

4.1 Guidelines Based on Grip Strength

For the effects of glove material and thickness on maximum grip strength, the findings of the present investigation are:

(1) Glove material affects the maximum grip strength where the butyl and hypalon gloves facilitated the highest grip strength values and the neoprene gloves recorded the lowest.

(2) Thickness affects the maximum grip strength as the thinner (0.015") gloves performed better than thicker (0.03") gloves.

To minimize effects of glovebox gloves on maximum grip strength based upon the observations made in this experiment, thinner gloves should be used as selection and design considerations for glovebox gloves. In addition, butyl and hypalon gloves should be picked over neoprene gloves to minimize the reduction of grip strength if other criteria (chemical, physical, biological etc.) were met.

4.2 Guidelines Based on Key Pinch Strength

The results of this study show that glove material included in this study did not affect the subjects' maximum key pinch strength capabilities. Thickness affects the maximum key pinch strength as the thinner (0.015") gloves performed better than thicker (0.03") gloves.

To minimize effects of glovebox gloves on maximum pinch strength, thinner gloves should be used as selection and design considerations for glovebox gloves.

4.3 Guidelines Based on Properties of Glove Materials

Batra et al. [10] indicated that thickness, coefficients of static friction and pliability of glove materials are all significantly correlated to the grip strength measurements and the best two properties to link to grip strength are thickness and coefficients of static friction. For thickness and pliability properties, the present study did show significant correlation with grip strength. However, no correlation was found between coefficients of static friction and grip strength. This may be due to similar coefficients of static friction between different types of glove materials and between the same types of glove materials with different thickness used in this study.

When performing tasks involving a gripping hand, material thickness and pliability parameters could be included for glove design and selection purposes since the interaction of thickness and pliability is a significant variable to predict maximum grip strength. The data collected from different studies could be further combined together to broaden the range of thickness and pliability values to increase the R^2 values for the grip strength predictive equations to better the design and selection of gloves to improve worker health and safety.

4.4 Selection and Design Guidelines in General

Based on the results of this study, the thickness of the gloves to be donned is recommended as 0.015" to minimize grip and key pinch strength degradation. Butyl and hypalon materials could be selected because of their smallest grip strength degradation if other criteria (chemical, physical, biological etc) are met. In terms of properties of glove materials, material thickness and pliability parameters could be included for glove design and selection purposes to predict maximum grip strength. In general, 0.015" butyl or hypalon glove is recommended to minimize the effects on MVC grip and key pinch strength.

When gloves are a necessity for glovebox operations, wearing the most appropriate glove will retain better hand strength and reduce the risks of developing MSDs and increase a worker's capability.

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The Prevalence of Musculoskeletal Disorders among Workers in Outlets and Warehouses of Courier Service Industry

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ABSTRACT
Most of the courier companies offer both courier service and cargo delivery/shipping. Thus, the courier service industry is classified under Warehousing and Support Activities for Transportation (WSAT) and Postal and Courier Activities (PCA) of the Philippine Standard Industrial Classification (PSIC). The musculoskeletal disorder (MSD) under WSAT and PCA on 2013 totals to 1075 or 56.76% of occupational diseases. The researchers aimed to conduct ergonomic assessment in the outlets and hubs of one of the largest courier companies in the Philippines. The researchers gathered information about the demographics, work methods, workplace design and working conditions of the workers through survey questionnaires, interviews and observations. The prevalence of the MSD of workers in hubs is more serious compared to those in outlets. The most affected body part of workers is lower back. Factors affecting outlet customer service representatives are the setup, table height, frequency of exercise, proper lifting, years working, weekly working days, sitting hours, postures, workplace design and transaction rates. For the workers in hubs, the significant factors that affect them are the frequency of exercise, standing time, workplace design, weekly overtime, age, transaction rates, and whether they know about proper lifting. This paper proposes an ergonomically designed workplace and recommends strategies to reduce the worker's MSD in courier service industry.

CCS Concepts
•General and reference→ Document types→ General conference proceedings

Keywords
Musculoskeletal disorder; Ergonomics; Workplace design; Courier service industry

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1. INTRODUCTION
Transportation is the process of transferring or moving objects or people from one place to another. It may be through land, water or air. Storage, on the other hand, is the process of keeping and protecting something for future use [15]. Transportation and storage are interrelated since transferring of goods requires an area of destination and place for transfer.

According to Philippine Business and Industry's 2017 census report, there were 2,804 establishments under the Transport and Storage Sector. The income to expense ratio of the sector was estimated to be 1.14 [12]. Courier activity is a vital part of Transportation and Storage industry of the Philippines. The good economic performance and the high consumer confidence of the Philippines in 2017 cause the growth on many businesses in the Philippines. This contributed to the increase of small and medium sized enterprises (SMEs). Transportation and courier industry of the Philippines rapidly emerges. Well-established courier service companies like LBC, 2Go, FedEx and DHL continue to expand their area of services [2]. According to "Philippines Logistics Market Outlook to 2019", the logistics in the Philippines has grown in 5 years due to the increasing number of international trade and increasing of e-commerce activities. With the progress in economy that enabled the growth in trade, the country expects to attain more than 6% GDP growth rate in the succeeding years. Factors such as service sector, manufacturing industry, imports and exports have influenced the logistics market in the Philippines. LBC Express, 2GO Group and others rule the domestic market. The logistics market in the Philippines is expects to grow 12.4% exceeding over USD 30 billion by the year 2019 because of the increase in importation and exportation [8].

Different studies showed that there is existing musculoskeletal disorder (MSD)/risk in the Transportation and Storage sector. Musculoskeletal Disorders are injuries affecting the muscles, tendons, nerves, and others [13]. Workers having MSD may not only cause them health threat, but also inflict large loss. This loss is due to the medical compensation for the MSD and loss due to absences in work. In Switzerland, the work- related accidents and diseases contributes to an annual 4% loss in global gross domestic product, or about US$2.8 trillion of direct and indirect costs of injuries and diseases [4]. Transportation and Warehousing sectors in United States had the occupational illnesses and injuries with days away from work of 2.7 per 100 workers [8]. Based on a study of [14], one out of three adult Americans are living with joint pain, swelling or limitation of the movement. MSD occurs due to incorrect habits of people in performing their work. There was near indication that there were correlations between MSDs and the

work-related ergonomic stressors like jobs with recurring motions, strong actions, awkward postures, and vibration.

According to [10], the greatest mistake towards musculoskeletal disorders or risk is ignoring them. It is unreasonable to wait people be injured or experience MSD before taking action. This attitude towards MSD may generate cost due to the injury. Furthermore, in the study of [6] on the prevalence of MSD among the manual handling workers in courier service industry in Selangor, the most common body part with musculoskeletal problems was the lower back part (60.8 %), followed by upper back (39.2 %), neck (21.5 %), knees (16.5 %), hip/thigh (11.4 %), ankles (11.4 %), and wrist (7.6 %). In addition to this, in the study of [9], the result showed that the highest prevalence of MSD among automotive workers was lower back pain, followed by pain at feet/ankle and pain at upper back regions. Almost one third of the study populations claimed to feel uncomfortable to their upper back and lower back. The study concluded that the back pain the workers are experiencing might be a result of their ignorance in the correct and ergonomic techniques in materials handling.

This research focused in determining the prevalence of MSD among the workers in both outlet and hub of a courier service company. Factors affecting MSD were also determined. Lastly, the paper provides recommendations on the ergonomic intervention and contingency plans in order to address the presence of musculoskeletal disorders.

2. METHODS

2.1 Data Collection

The researchers administered survey questionnaires on personal background and body parts discomfort to 75 workers in outlet and warehouse in one branch of one of the biggest courier service companies in the Philippines. Moreover, the researchers made actual observations and conducted interviews to respondents to determine the various activities involved in each process and conducted physical ergonomic assessment of the workplace.

Survey questionnaire about body part discomfort makes use of the Cornell Musculoskeletal Disorder Questionnaires (CMDQ). With this, the CMDQ score represents the body part discomfort of workers.

The researchers used National Institute for Occupational Safety and Health (NIOSH) lifting equation and Rapid Upper Limb Assessment (RULA) in order to assess the different tasks.

2.2 Statistical Analyses

Statistical tests were administered using the t–test, Analysis of Variance (ANOVA), Tukey's Pairwise Test and the regression analysis based on the gathered data using the CMDQ scores. These factors considered and tested consist of the worker's background, working conditions, workplace design and work methods. Based on the results of the significant factors, this paper developed proposed ergonomic interventions.

The ergonomic interventions comprised of an ergonomically designed workplace for courier workers and recommend strategies that will reduce or eliminate MSD in the courier service industry. Furthermore, the researchers used Anthropometry and Quality Function Deployment (QFD) to implement the design. Lastly, the proposed contingency plans were developed for the ergonomic intervention using Failure Modes and Effects Analysis (FMEA).

3. RESULTS

The 75 respondents of this study comprised of 29 Outlet Customer Service Representatives (OCSRs) from the outlets and 46 workers from the hubs. The current physical environment in outlets and hubs were assessed. They consist of the noise level, illumination level, and temperature level.

Table 1. Current Physical Environment in Outlets and Hubs

Factors	Outlets	Hubs		
		Sea Hub	Hangar Hub	Ave-rage
Noise (dB)	**74**	**107**	**109**	**108**
Light (fc)	**19**	**16**	**15**	**15**
Temperature (oC)	**24**	**31**	**33**	**32**

Aside from the physical environment of the workplace, the workplace dimensions were also assessed for the outlets. Table 2 shows the details of the current workplace dimensions in outlets.

Table 2. Current Workplace Dimensions in Outlets

Particulars	Current Dimensions (in cm.)	Recommended Dimensions (in cm.)
Table Height	80.77 cm	74 cm
Counter Height	113.36 cm	89 cm
Keyboard Height	71.18 cm	70 cm
Weighing Scale Height	29.64 cm	62 cm
Seat Height (max)	51 cm	59 cm
Seat Height (min)	39 cm	47 cm
Back Rest Height (from seat)	44 cm	42 cm
Foot Rest Height (max)	0 cm	23 cm
Foot Rest Height (min)	0 cm	0 cm
Arm Rest Height (from seat)	21 cm	17 cm
Head Rest Height (from seat)	44 cm	92 cm

Moreover, the manpower complement of the outlets and hubs, together with their working hours, average number of packages, and average number of packages per person were also determined as presented in Table 3.

Table 3. Manpower and Daily Transactions in Outlets and Hubs

Factors	Outlets	Hubs		
		Sea Hub	Hangar Hub	Total
Number of Staff	50	45	35	80
Working Hours	8	8	9	8.5
Average Number of Packages	1293	2300	2007	2154
Average number of Packages per Person	38	436	227	332

In order to determine the extent of discomfort experienced by the workers in the outlets, the researchers administered the RULA to the workers. The results of the RULA is presented in Table 4.

Table 4. RULA Scores of OCSRs Using Different Weighing Scales in Outlets

Factors	Corresponding RULA Scores		
	Big Weighing Scale (20 cm high)	Small Weighing Scale (36 cm high)	Elevated Weighing Scale (72 cm high)
Final Upper Arm Score	2	2	2
Final Lower Arm Score	1	1	1
Final Wrist Score	2	2	2
Final Wrist & Arm Score	3	3	3
Final Neck Score	2	3	3
Final Trunk Score	4	3	1
Final Leg Score	1	1	1
Final Neck, Trunk & Leg Score	6	5	3
Final RULA Score	5	4	3

In addition of assessing workers on discomfort level in the outlets, the lifting activities of the workers were also analyzed using the NIOSH Lifting Index as shown in Table 5.

Table 5. NIOSH Lifting Index of Workers in Outlets and Hubs

	Average Weight of Package (Kg.)	Recommended Weight Limit	Lifting Index
Outlets			
Big Weighing Scale	55.76	15.69	3.55
Small Weighing Scale		15.70	3.55
Elevated Weighing Scale		15.06	3.70
Sea Hub			
Loading and Unloading of Items on Container Van	42.75	16.95	2.52
Hangar Hub			
Loading and Unloading of Items on Truck	26.65	17.10	1.56

Furthermore, the CMDQ was also administered to workers in the outlets and hubs. The top 5 body parts that were affected by discomfort in outlets and hubs using the CMDQ scores by percentage are presented in Table 6.

Table 6. Top 5 CMDQ Scores of Workers in Outlets and Hubs by Percentage

Outlets		
Body Parts	**Percentage**	**Rank**
Lower Bank	24.18%	1
Upper Back	19.15%	2
Neck	13.14%	3
Forearm, Right	10.29%	4
Forearm, Left	10.29%	4
Wrist, Right	6.96%	5
Wrist, Left	6.96%	5
Hubs		
Body Parts	**Percentage**	**Rank**
Lower Back	15.55%	1
Foot, Right	11.22%	2.
Foot, Left	11.22%	2
Upper Back	7.66%	3
Shoulder, Right	7.02%	4
Shoulder, Left	7.02%	4
Knee, Right	6.56%	5

The paper also presented the body parts of workers in outlets and hubs affected by MSDs based on their activities. These activities comprised of sitting, typing, material handling, writing, and packing. The discomfort level was based on the CMDQ score of workers on their body parts in percentage. Table 7 presents the results.

Table 7. Body Parts Affected by MSDs of Workers in Outlets By Activity Based on CDMQ Scores (in Percentage)

Activity					
Sitting		Typing		Material Handling	
Body Parts	**%**	**Body Parts**	**%**	**Body Parts**	**%**
Lower Back	41.3	Forearm, Right	48.9	Lower Back	48.9
Upper Back	16.9	Forearm, Left	48.9	Upper Back	39.3
Wrist, Right	11.1	Wrist, Right	21.5	Upper Arm, Right	5.9
Wrist, Left	11.1	Wrist, Left	21.5	Upper Arm, Left	5.9
Hip/Buttocks	8.0	Shoulder, Right	4.5		
Neck	5.9	Shoulder, Left	4.5		
Shoulder, Right	2.9	Neck	3.4		
Shoulder, Left	2.9				

Activity			
Writing		Packing	
Body Parts	**%**	**Body Parts**	**%**
Neck	24.9	Upper Back	51.1
Forearm Right	20.4	Lower Back	48.9
Forearm Left	20.4		
Wrist Right	10.8		
Wrist Left	10.8		
Shoulder Right	6.4		
Shoulder Right	6.4		

Moreover, the job positions of workers in hubs were also assessed using the CMDQ scores in percentage. These job positions were evaluated as which of them was affected by MSD the most. Table 8 shows the details.

Table 8. Job Position Affected by MSDs of Workers in Hubs Based on CDMQ Scores (in Percentage)

Location of Warehouse	Position	Percentage
Sea Hub	Stuffing Crew	43.3
Hangar Hub	Warehouseman	27.4
Sea Hub	Transferer	15.1
Sea Hub	Acceptance Checker	14.3

4. DISCUSSION

The workplace of the outlets have different setups. These are the stand-alone outlets located in different areas, outlets along the driveway of mall and outlets inside mall. These outlets generally received packages that were categorize as weighing less than 10 kilograms, between 10 kilograms and 50 kilograms, and between 50 kilograms and 150 kilograms. The activities of workers in the outlets consist of sitting, typing, materials handling, writing, packing, measuring of dimensions, and standing. On the other hand, the warehouses comprised of the sea hub and the hangar hub. The workers in the hubs usually performed the loading and unloading of items on container van (for sea hub) and loading and unloading of items on truck (for hangar hub).

The workplace of workers in outlets is much better than the workplace in hubs as shown in Table 1. The noise level of 74 dB in outlets is acceptable, however, workers in the hub experienced an average of 108 dB which is above the acceptable noise level of 90 dB. Moreover, the illumination and temperature levels in the outlets are much better than the hubs, respectively.

Aside from assessing the physical environments of the workplace, the current dimension of the workplace was also assessed, As shown in Table 2, the current dimensions is not in accordance with the recommended dimensions The Filipino anthropometric standards [1] were used to provide recommended dimensions.

In addition to this, there are approximately equal number of staff working in the outlets and hubs with an average working hours of 8 hours. However, the workers from the hubs showed more work activities undertaken compared to the OCSRs in the outlets as presented in Table 3.

An assessment on the postures of the OCSRs in the outlets were undertaken while doing the weighing, measuring and packing of cargoes and parcels. Using the three types of weighing scales in determining their RULA scores, the final wrist and arm score was 3 which indicated that further investigation is needed and changes may be required as shown in Table 4. On the other hand, the final neck, trunk and leg score was 6 using the big weighing scale and followed by a score of 5 using the small weighing scale which indicated that further investigation and changes are required soon, and a score of 3 using the elevated weighing scale. Overall, the RULA score of using the big weighing score was 5 which indicated that further investigation and changes are required soon. Moreover, the RULA scores of using small and elevated weighing scales were 4 and 3, respectively which indicate further investigation and changes may be required. The difference in RULA score of using the three different weighing scales was mainly due to the differences in the height elevation of the equipment from the floor.

Aside from the RULA, The NIOSH lifting equation was used to assess the manual material handling risks associated with lifting and lowering tasks in the workplace of the OCSRs in the outlets and workers in the hubs. As presented in Table 5, the

average weight of the packages handled by them exceeded the recommended weight limit (RWL). Hence, the lifting index values were all above 1.0 indicating that their lifting tasks were hazardous. The OCSRs in the outlets have a higher lifting index compared to the workers in the hubs.

Furthermore, the respondents' discomfort levels were also assessed using the CMDQ [3], [4]. [5]. The OCSRs in the outlets experienced body discomforts in the lower back, upper back, neck, forearm, and wrist as presented in Table 6. These body parts are the frequently used by OCSRs in undertaking their tasks in the outlets. They have to bend and use their arms and hand to perform their activities in the outlets. On the other hand, the workers in the hubs experienced body discomforts in lower back, foot, upper back, shoulder, and right knee.

In terms of the activities performed by the OCSRs, they experienced body discomfort in their upper body parts from buttocks/hip up to neck while performing activities in sitting, typing, material handling, writing, and packing as shown in Table 7. These body parts were the lower back, upper back, wrist, hip/buttock, neck, shoulder, forearm, and upper arm, Moreover, for the hub, the stuffing crews are the most prevalent in terms of MSD (43.3%). This is then followed by the warehouseman (27.4%), the transferer (15.1%) and acceptance checker (14,3%) who are less prevalent in terms of MSD compared to the stuffing crew and warehouseman who are third and fourth, respectively. The reason behind this is that the stuffing crew focussed on loading/unloading of packages. Warehousemen are multitasking and they are not limited to loading/unloading of items. The transferers and acceptance checker are both performing non-lifting activities. The transferrer transfers packages to the sorted area while the acceptance cheker receives the packages on the hub.

A statistical test was performed to determine significant differences of different setups in the outlets that resulted to the prevalence of MSDs of OCSRs. The results showed that there is significant difference in the setups ($p = 0.006$) using t- test. This indicates that the difference in setups affect the OCSRs in acquiring MSDs.

With regard to their workplace, the current workplace dimensions were significantly different from the recommended workplace dimensions for outlets ($p = 0.006$) using t-test for the difference of workplace dimensions. This suggests that there is a need to redesign the workplace. Furthermore, the different setups of outlets were significantly different from each other ($p = 0.000$) with respect to the CMDQ scores of OCSRs using ANOVA. The CMDQ score of OCSRs in the stand-alone outlets located in different areas showed the highest CMDQ score which indicates that they have the highest prevalence of MSDs after using the Tukey's Post Hoc test. The outlets along the driveway of the mall followed and the least affected is the outlet inside the mall.

Regression analysis was used to determine which factor contribute to the increase in CMDQ score. The factors used to develop a regression model are the personal information gathered from respondents, the workplace, physical environment, average transactions of packages, work methods in the operations, RULA scores per activity, and RWL score.

The regression equation, using stepwise method, for the OCSRs in the outlets is:

CMDQ score (OCSRs) = 35.86 +7.270*Set-ups + 0.1810*Table height + 0.7954*Small Pouch + 1.1854*Medium Pouch + 0.212.*Box C + 0.197*Box D + 1.6107*Budget Box + 1.7203*Own Box(via air) + 2.4582*Own Box(via Sea) + 0.11381*Total transaction – 4.4634*Exercise – 14.153*Proper lifting – 0.2351*Year working – 0.743*Weekly working days + 3.2917*Sitting hours – 0.4121* Standing hours + 5.2783*Typing RULA + 1.5014*Writing RULA + 32.286*Weighing/ Measuring/ Packing RULA – 2.1163*RWL

Based on the above regression equation for OCSRs, exercise, proper lifting, years working, weekly working days, standing time and RWL showed negative coefficients that indicate that increasing these variables lead to the decrease of the CMDQ score. Exercise strengthens the body of people and this lead to the decrease of musculoskeletal discomfort. If OCSRs observe proper lifting of objects, improper postures will not happen and this will decrease the musculoskeletal disorder symptoms. On the other hand, the longer the number of years of OCSRs in the current position, they become more cautious on their actions and are aware of the problems of MSDs in their activities. In the practice, OCSRs with more than 8 working hours per day usually have less than 6 working days per week. However, they may be working the same time with others, but they have the more stressed working days than those who have 8 hours per day with 6 working days per week. This explains why increasing the number of working days per week while reducing their daily working hours will lead to the lesser musculoskeletal discomfort. Continuously sitting in a very long time will lead to the discomfort primarily on the lower and upper back of the body, as proven from the regression analysis. With this, allotting time for standing will reduce the discomfort on the said body parts. The same is true for increasing the RWL will result to a lower lifting index that make them non-hazardous.

On the other hand, the coefficients of setup, table height, small pouch, medium pouch, box C, box D, budget box, own box (via air and sea), total transactions, sitting time, typing RULA, writing RULA, and measuring/packing RULA result to an increase in CMDQ score. It is logical that the number of transactions is directly proportional to the CMDQ score since more transactions means more loads to carry and more work to be done. Sitting time causes CMDQ score to increase because continuously sitting for a long period of time will lead to the discomfort on the lower and upper back. For the typing, writing, measuring and packing RULA scores, the higher the scores represent the higher the risk in performing the activities due to the poor postures.

On the other hand, the regression equation for the non-lifting positions such as the transferer and acceptance checker in the hub is:

CMDQ score (Non-lifters) = ***23.8 + 2.670*Age – 2.88*Exercise – 11.76*Sitting time***

Only 3 factors were considered in the regression equation for the non-lifting workers in the hub as shown above. The age is directly proportional to the CMDQ score while the frequency of exercise and sitting time are inversely proportional to the CMDQ score. As the age increases, the worker's body becomes vulnerable to musculoskeletal disorder symptoms. However, exercise and related activities may lead to the more healthy body. Which will results to a decrease the musculoskeletal disorder symptoms. Both the transferer and acceptance checker spend most of the time standing. This lead to their discomfort to their feet and knees. If they will have the longer time to rest or to sit, it will decrease the severity of their discomfort on feet and knees.

Lastly, the regression equation for the lifting positions such as stuffing crew and warehouseman in the hub is:

CMDQ score (Lifters) = ***11821 + 0.1551*Packages (> 10 kg but less than 50 kg) +0.4971*Total Packages – 10.037*Exercises – 54.719*Proper Lifting + 13.729*Standing time – 402.6*RWL + 1.869*Weekly overtine + 0.3731*Age***

The above regression equation for lifter in the hub shows that the coefficients of the number of packages between 10 kg and 50 kg result to a higher CDMQ score. The packages with weight less than 10 kg and those with weight greater than 50 kg but less than 150 kg are not on the list. Although only this weight of the package affect MSDs, the total packages also contribute to increased CMDQ score Other factors such as the standing time, weekly overtime and age cause the CMDQ score to increase. The lifters spend most of their time in standing posture that cause their feet and knees to feel uncomfortable. Similar to the non-lifters and OCSRs, the frequency of exercise of the lifters (stuffing crew and warehouseman) causes their CMDQ score to decrease. Other factors that will decrease the CMDQ score are the recommended weigh limit (RWL) and the proper lifting activities. .

The House of Quality was used to design the workplace and suggests ergonomic intervention for both outlet and hub. The customer's requirements for the outlets comprised of the following: a) Conducive workplace, b) Comfortable while seated, c) Comfortable while standing, d) Easy to handle packages, e) Comfortable in handling packages, f) Easy to weigh, g) Reduce/ prevent discomfort on body parts, h) Convenience for taking the items in and out, and i) Fast service.

Table 9 shows the importance rating of the House of Quality (HOQ) for the outlets.

Table 9. Importance Rating of the House of Quality (HOQ) for OCSRs in Outlets

Functional Requirements	Importance Rating
Elevate the weighing scale where its height is within the counter	210
Provide gravity feeder from the weighing scale to the storage area.	175
Ergonomically designed workplace	167
Redesign of table and chair using Filipino Anthropometric standards	130
Provide a counter where customers directly place the package/s upon entering the outlet	125
Design the table and chair to be suited for both standing and sitting position while working	122
Provide storage area with separate door going out of the outlet	86
Continuously conduct seminar/trainings about proper lifting	81
Implement stretching exercises for sitting posture	50
Shifting schedule prohibiting more than 8 hours of work per day	50
Encourage OCSRs in sport events	50

Based on the above table, the highest importance rating is to elevate the weighing scale where its height is the same with the counter where the customers place their package/s, with the importance rating of 210. With this, weighing will be easier and more comfortable. The next is to provide gravity feeder from the weighing scale to the storage area with a rating of 175. It will provide ease for the OCSRs to transfer the package to the storage area. The next solution with the high importance rating is to design an ergonomic workplace with rating of 167.

Other solutions with high importance rating are the redesign of table and chair using Filipino Anthropometric standards, designing the table and chair to be suited for both standing and sitting position while working and providing of counter where customers directly put the packages upon arrival to the outlet. For other solutions are the considered the least priority in the design decision.

The customer's requirements for the hubs are the following: a) Conducive workplace, b) Comfortable while standing, c) Easy to handle packages, d) Comfortable in handling packages (loading and unloading not included), e) Reduce/prevent discomfort on body parts, f) Easy to find the package, g) Easy and comfortable to load/unload items to/from container van, and h) Easy and comfortable to load/unload items to /from truck.

Table 10 show the importance rating of the House of Quality (HOQ) for the hubs.

Table 10. Importance Rating of the House of Quality (HOQ) for Workers in the Hub

Functional Requirements	Importance Rating
Make use of conveyor when loading / unloading items	190
Ergonomically designed workplace	160
Redesign package (include handle)	79
Setting of standard ways of posting the package label	50
Redesign of package label	50
Engage the workers in sport events	50
Continuously conduct seminars / trainings about proper lifting	50

Based from the results of HOQ for the hub, the most important intervention is to use conveyor when loading/unloading items/packages with a rating of 190. Also, it is also important to have an ergonomically designed workplace with an importance rating of 160. Other functional requirements with the low importance rating are redesign package (include handle), setting of standard ways of posting the package label, redesign of package label, engage the workers in sport events and continuously conduct seminars / trainings about proper lifting

After determining the significant factors for the design improvement of the workplace, contingency plans were made for the design both in outlet and hub using Failure Mode and Effect Analysis (FMEA)

Based on the assessment using FMEA for outlets, the failure mode with the highest risk is the physically unfit OCSR with the risk priority number (RPN) of 100. Those with the moderate risk are frequent lifting of packages (RPN = 64), too much sitting time (RPN = 48), OCSR long daily working time (RPN= 48). The low risks are the OCSRs ignorance of proper lifting practices (RPN =

40), awkward posture (RPN = 20), and awkward sitting posture (RPN = 20).

On the other hand, the FMEA results for the hubs showed that the high risk is the lifting packages with more the recommended weight limit (RPN = 125), followed by lifting of high volume of packages (RPN = 100). The moderate risk is unfit workers (RPN = 60). On the other hand, the low risks are employee's ignorance on the proper lifting procedures (RPN = 32), difficulty in finding packages (RPN = 30), and difficulty in holding the package (RPN = 10).

Based from the results of the HOQ and FMEA, the paper proposed engineering interventions to address the prevalence of MSD among the workers in outlets and hub. These are the administrative and personal interventions for both workers in outlets and warehouses and design of a new workplace using the recommended dimensions for the tables and chairs as shown in Table 11. The perspective view of the outlet's workplace is shown in Figures 1 and 2. Moreover, in order to improve the material handling of packages, the researchers recommended the use of conveyors in their loading/unloading of packages.

Table 11. Recommended Dimensions of the Workplace for Outlet and Hub Workers

Table and Chair Parts	Recommended Dimensions
Table Height	89 cm
Counter Height	89 cm
Keyboard Height	85 cm
Weighing Scale Height	62 cm
Seat Height (max)	74 cm
Seat Height (min)	62 cm
Back Rest Height (from seat)	42 cm
Foot Rest Height (max)	38 cm
Foot Rest Height (min)	15 cm
Arm Rest Height (from seat)	17 cm
Head Rest Height (from seat)	92 cm

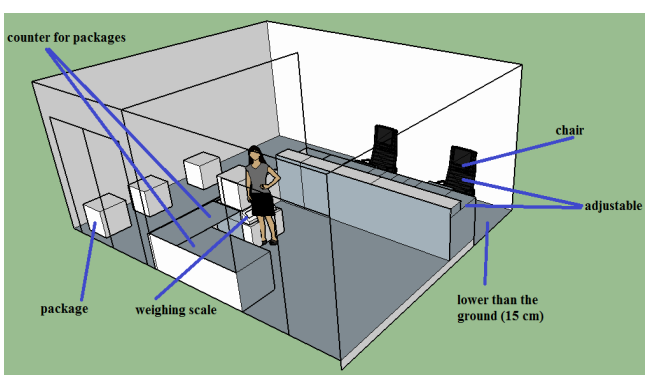

Figure 1. Outlet Workplace Perspective (View 1)

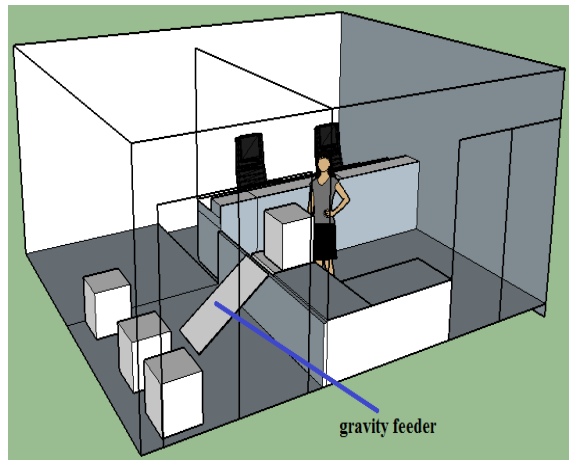

Figure 2. Outlet Workplace Perspective (View 2)

5. CONCLUSION

With this study, the researchers found that there is prevalence of musculoskeletal disorder (MSD) among the workers in outlets and hubs of courier service industry. MSD is more prevalent among the *workers in hubs than workers in outlets. The different setups* considered in the outlets are the stand-alone outlets located in different areas, outlets inside malls and outlets at mall along the driveway. It was found that the workers works inside the outlets are less prone to MSD. In the study, the CMDQ score is the one representing the prevalence of MSD. Different factors were determined to be affecting the CMDQ score of workers in outlets. These are the setup, table height, knowledge about proper lifting, frequency of exercise, sitting hours, standing hours, weekly working days, years working, RULA score for typing, RULA score for measuring and packing, recommended weight limit and the number of transactions per day.

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For the workers in hubs, lifters are the ones that have the higher CMDQ score compared to those non-lifters. The factors that were determined to be affecting CMDQ score among the lifters are the frequency of exercise, knowledge about proper lifting, recommended weight limit, standing time, weekly overtime, age and the number of items lifted per day. On the other hand, the factors affecting CMDQ score among the non-lifters are the frequency of exercise, age and sitting time.

With these factors determined, the researchers was able to use engineering interventions to address the prevalence of MSD among the workers in outlets and hub. This is a design of a new workplace for workers in outlets and hubs. Moreover, the paper recommends

administrative and personal interventions for both the workers in outlets and warehouses.

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Factors Affecting Fine Dexterity: A Structural Equation Modeling Approach

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ABSTRACT
Fine dexterity is one of the most fundamental parts of human factors and ergonomics. The aim of this study was to investigate factors affecting fine dexterity. Gender, age, hand length, grip strength, hand skin temperature, room temperature, and room humidity were analyzed simultaneously to predict fine dexterity by utilizing Structural Equation Modeling (SEM). The results showed that hand skin temperature was the most predicting factor for fine dexterity followed by gender, age, and hand length. Female was found to have better fine dexterity and participants with smaller hand size were also found to have better fine dexterity. In addition, grip strength, room temperature, and room humidity were found not significant predictors for fine dexterity. Interestingly, participants with older age were found had better fine dexterity. The causal relationship derived from SEM could be very significant theoretical foundations which would be beneficial for human factors engineer, hand therapist, and even medical doctors.

CCS Concepts
• **Mathematics of computing→ Equational models**
• **Computing methodologies→ Modeling methodologies**

Keywords
Fine Dexterity; Structural Equation Modeling; Hand Grip Strength; Purdue Pegboard Test.

1. INTRODUCTION
Dexterity is defined as the ability to coordinate arm, hand, and finger movements to manipulate objects in a timely manner [1,2]. It includes neuro-musculoskeletal functions to produce small and precise movements [3]. Based on movement accuracy, dexterity can be classified into gross dexterity and fine dexterity [4].

Fine dexterity is defined as precise motions associated with controlling small objects using thumb and index fingers with eye-hand coordination [4,5]. Based on muscle activation, intrinsic hand muscles have insertions into the proximal phalanx of individual fingers and reported to be fine motor control [6], especially the activation of abductor pollicis brevis (APB) [7]. Finally, pinch grip is widely known as an indication of performing fine dexterity.

There are several factors affecting fine dexterity. Hand skin temperature is one important factor which influences fine dexterity [8]. It is well known that cooling decreases fine dexterity and there is also a significant relationship between the loss of fine dexterity and decrease in finger skin temperature [9]. Decreased skin temperature reduces the oxygen supply to muscle tissue and muscle oxygen saturation may then lead to decreased muscle activity [10].

Movement properties, such as fine dexterity, are influenced by age [11]. Poole et al [12] measured dexterity in children between 4 and 19 years old and mentioned that the speed of fine dexterity improved with age. In contrast, age groups more than 40 years old showed less dexterous comparing to 30 – 39 years old while performing fine dexterity [13]. Movement properties could also be affected by gender and hand dimensions, therefore, it is very valuable to investigate all the affecting factors simultaneously in one model.

Structural Equation Modeling (SEM) is multivariate statistical models that allow complex modeling of relational structures between independent and dependent variables [14]. SEM also allows the researcher to simultaneously estimate all effects in the model whereas regression approaches often require the specification of numerous regression model to estimate different parts of an overall model [15]. Therefore, SEM can be applied to predict fine dexterity by combining all possible influencing factors into one model.

The aim of this study was to investigate factors affecting fine dexterity. Gender, age, hand length, grip strength, hand skin temperature, room temperature, and room humidity were analyzed simultaneously to predict fine dexterity by utilizing SEM. The causal relationship derived from SEM could be very significant theoretical foundations which would be beneficial for human factors engineer, hand therapist, and even medical doctors.

2. METHODOLOGY

2.1 Participants
Ninety males and ninety females aged between 25 to 33 years old were voluntarily recruited in this study. They were not compensated with academic credits or paid. Prior to the study, all participants were asked their dominant hand and only right-handed with no musculoskeletal disorders were recruited.

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Qualified participants were required to fill out a consent form before the data collection.

2.2 Purdue Pegboard Test and Grip Strength

The Purdue pegboard test was utilized to collect the fine dexterity data. In addition, grip strength was also collected by utilizing Camry digital hand dynamometer. Participants were asked to perform fine dexterity test first and followed by grip strength. During the experiment, hand length, hand skin temperature, room temperature, and room humidity were also recorded.

The Purdue Pegboard Test is a rectangular board with 2 sets of 25 holes running vertically and 4 concave cups at the top. Based on Table 1, it is an established test used to measure fine dexterity [17]. The original application for the test was for testing the dexterity of industrial workers. It had since been used for testing of dexterity testing within various populations in the clinical setting, including children and adolescents [17]. Small metal pegs were placed in the cup on the side being tested, with subjects asked to remove the pegs, picked it up with thumb and index finger, and placed them vertically in the holes as rapidly as possible [16]. The number of pegs placed in 30 seconds was scored.

Table 1. Properties of dexterity assessment [17].

Dexterity Assessment	Year Published	Available from	Gross / Fine Dexterity
Box and Block test	1985	Sammons Preston	Gross
Functional Dexterity test	2003	North coast medical	Gross
Bennett Hand Tool Dexterity test	1991	Lafayette Instrument Co.	Gross
Minnesota Rate of Manipulation test	1969	Best priced product, Inc.,	Gross
Nine-Hole Peg test	1971	Sammons Preston	Fine
Purdue Pegboard test	1948	Lafayette Instrument Co.,	Fine

2.3 Structural Equation Modeling (SEM)

Structural equation modeling (SEM) is a method of multivariate statistical analysis capable of measuring the underlying latent constructs identified by factor analysis and assessing the paths of the hypothesized relationships between dependent and independent variables [18]. Overall, SEM has two main advantages: (1) it allows for the estimation of a series, but independent, multiple regression equations simultaneously, and (2) it has the ability to incorporate latent variables into the analysis and accounts for measurement errors in the estimation process [18].

Amos 22 was utilized to derive the SEM with the Maximum Likelihood estimation approach. Following our previous studies [19-23], the goodness of fit was measured by p-value [24-27] for Chi-square, and normed chi-square. In addition, some incremental fit indices such as Normed Fit Index (NFI), Tucker Lewis Index (TLI), and Comparative Fit Index (CFI) were reported. Finally, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), and Root Mean Square Error of Approximation were also reported [19-23].

3. RESULTS

The initial SEM result is presented in Figure 1. Based on this figure, four paths were found not significant. Therefore, a revised model by eliminating several paths: humidity-fine dexterity, room temperature-fine dexterity, age-grip strength, and grip strength-fine dexterity.

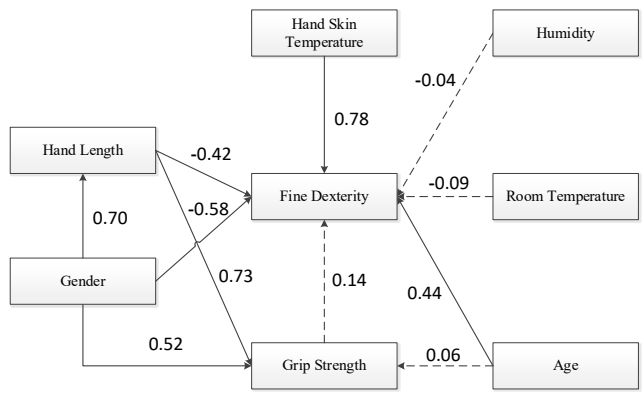

Figure 1. Initial SEM model for predicting fine dexterity.

The Structural Equation Model result of fine dexterity is shown in Figure 2. Based on Table 2, the full model fit test index norm χ^2 was smaller than 2 (norm χ^2 = 0.323, p=0.863) and all goodness of fit indices were greater than 0.99, which indicates that the hypothesized model was a good representation of the observed data. AGFI index of 0.969 was also greater than the recommended value of 0.9. The results of SEM indicate that hand skin temperature was the most important factor affecting fine dexterity (β: 0.73). In addition, age was also found to have a significant effect on fine dexterity (β: 0.42). Finally, female was found faster to perform fine dexterity (β: -0.53) and participants with shorter hand length was also found better for fine dexterity (β: -0.38).

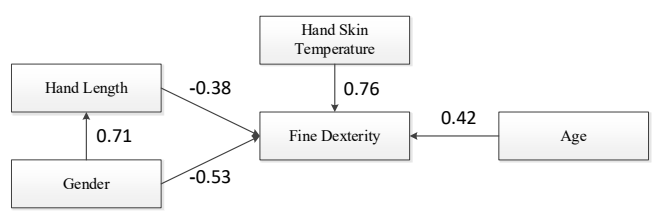

Figure 2. Final SEM model for predicting fine dexterity.

Table 2. Goodness of fit measure of the model.

Goodness of fit measure	Par. estimates	Rec. values	Suggested by
p-value for Chi-square (χ^2)	0.863	>0.05	[19-23]
Chi-square statistic (χ^2)	1.291		
Degree of freedom (df)	4		
Normed chi-square (χ^2/df)	0.323	<2	[19-23]
Incremental Fit Indices			
Normed Fit Index (NFI)	0.996	>0.95	[19-23]
Tucker Lewis Index (TLI)	1.000	>0.95	[19-23]
Comparative Fit Index (CFI)	1.000	>0/95	[19-23]
Goodness-of-fit index			
Goodness of Fit Index (GFI)	0.994	>0.95	[19-23]
Adjusted Goodness of Fit Index (AGFI)	0.969	>0.90	[19-23]
Badness-of-fit index			
Root Mean Square Error of Approximation (RMSEA)	0.001	<0.07	[19-23]

4. DISCUSSION

Fine dexterity is one important research topics in human factors and ergonomics [28-30]. The purpose of this study was to investigate factors affecting fine dexterity by utilizing the structural equation modeling (SEM) approach.

As shown in Figure 1, grip strength did not have a significant effect on fine dexterity. Thus, grip strength and other variables that might have an indirect effect on fine dexterity through grip strength, such as humidity, were removed from the SEM model for fine dexterity. Identical to our finding of an insignificant grip strength effect, Martin et al. [31] also stated that fine dexterity was more dependent on a stable control of the arm, hand, and eye-hand coordination with visual guidance. Several studies mentioned that subjects with higher grip strength scores performed better on gross motor tasks in the larger and medium objects, whereas this was not true for small objects [32]. This may be because fine dexterity involves sensation and coordination to a greater extent, while gross dexterity may be more dependent on strength [32]. SEM indicated that fine dexterity relies on stable control of hand, fingers, and eye-hand coordination with visual guidance [31].

Regarding the environmental factors, the room temperature was insignificant on fine dexterity because fine dexterity was collected under the temperature range between 19.5 and 24.1°C. This is confirmed by Riley et al. [33] who tested fine dexterity under 3 different room temperatures (1.7°C, 12.8°C, 23.9°C) to discover no significant difference in fine dexterity performance between 12.8°C and 23.9°C. A significant reduction was found at 1.7°C. In addition, Muller et al. [34] also discovered no significant difference in fine dexterity performance between 5°C and 25°C conditions.

The SEM result showed that gender effect was significant on fine dexterity. This result is consistent with Desrosiers et al. [35] who collected fine dexterity data from older participants (60 years and older) and reported that females had better fine dexterity than males. However, this finding was contradictory to the studies of Haward and Griffin [36] and Sawyer and Bennett [37]. Haward and Griffin [36] collected fine dexterity data from participants between 18 to 25 years and Sawyer and Bennett [37] collected fine dexterity from participants between 20 to 40 years. Both studies tested on young participants and lead to a contradiction with our finding of insignificant gender effect on fine dexterity.

As for the age effect, our data indicated that age had a direct and positive effect (β: 0.42) on fine dexterity. Older participants aged between 25 to 33 years had better pin insertion performance on the Purdue Pegboard test, same as reported in Wang et al. [13]. Such age-related improvement in manual dexterity through motor learning and job experience was explained by Pennathur et al. [38] and Rueckriegel et al. [11] as the maturation effect on kinematic performance.

As powerful as it seems, there are several limitations when generalizing about the research findings derived from the current SEM model. First of all, the current study chose to measure fine dexterity with the Purdue pegboard test. However, there is more than one method of measuring fine dexterity. The derived SEM models could be different depending on the type of measurement test used for dexterity. Secondly, MacDermid et al. [32] stated that fine dexterity involves a greater extent of sensation and coordination while Dianat et al. [39] confirmed that a higher sensitivity touch threshold (mN) results in a better fine dexterity performance. Further study to incorporate sensation and coordination performance tests can perhaps refine the SEM model for predicting fine dexterity.

5. CONCLUSIONS

Fine dexterity is one of the most fundamental parts of human factors and ergonomics. The aim of this study was to investigate factors affecting fine dexterity. Gender, age, hand length, grip strength, hand skin temperature, room temperature, and room humidity were analyzed simultaneously to predict fine dexterity by utilizing Structural Equation Modeling (SEM). The results showed that hand skin temperature was the most predicting factor for fine dexterity followed by gender, age, and hand length. Female was found to have better fine dexterity and participants with smaller hand size were also found to have better fine dexterity. In addition, grip strength, room temperature, and room humidity were found not significant predictors for fine dexterity. Interestingly, participants with older age were found had better fine dexterity. The causal relationship derived from SEM could be very significant theoretical foundations which would be beneficial for human factors engineer [40], hand therapist [41-43], and even medical doctors [44,45].

6. ACKNOWLEDGMENTS

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Session X

Logistics and Transportation Engineering

Value Stream Mapping-based Logistics 4.0 Readiness for Thailand Automotive-Part Manufacturers

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ABSTRACT
The automotive industry in Thailand have competed fiercely, especially second-tier and third-tier automotive part manufacturers. They are hence impelled to apply technology 4.0 (i.e. robots, automation, and internet of thing). The technology 4.0 application is however achieved when logistics activities are leaned along their value streams. The lean logistics aims to add more values using value stream mapping (VSM). It supports to visualize a current state map of logistics activities along their value stream. The current state map facilitates to analyze the most critical problems having the highest non-value added. They are then overcome with suitable solutions whereas a future state map is drawn. In an industrial case, the most critical activities are case, disc, and cover lathing and washing; and heating respectively. They are replaced by technology 4.0 i.e. robot arms, induction machines, and conveyors in order to shorten cycle time and lead time. They lead to increase value-added ratio.

CCS Concepts
• **General and reference → Cross-computing tools and techniques → Performance**

Keywords
Lean Logistics; Technology 4.0; Value Stream Mapping; Thailand Automotive-Part Manufacturers

1. INTRODUCTION
The automotive industry has play an important role in Thailand to escape from middle income traps [1]. In 2017, it was ranked at 1st and 14th of the motor vehicle exporters in ASEAN and global levels respectively [2]. In addition, motor vehicles are increasingly demanded by emerging markets; i.e., China and India. The demand increasing is predicted as much as three times in 2050 [3]. In 2019, Thailand automotive industry hence targets its production at 2.15 million motor vehicles. 48.84% of the production is domestic sales, whereas the remaining production are exported [4]. 70-75% of the domestic sales are incurred by automotive parts (auto parts) whose 30-40% are supplied for original equipment manufacturers (OEM). Its remaining is required for replacement equipment manufacturers (REM) [2].

Accordingly, Thailand automotive industry has become one of ten s-curve industries remarkably supported by government of Thailand. For example, the governmental support is to apply technology and innovation for manufacturing motor vehicles and adding values to motor vehicles. In addition, the governmental support is to strengthen Thailand automotive industry along its supply chain. There are five main supply chain stages including assemblers, auto-part manufacturers as first-tier, second-tier, and third-tier suppliers, and dealers as shown in Figure 1.

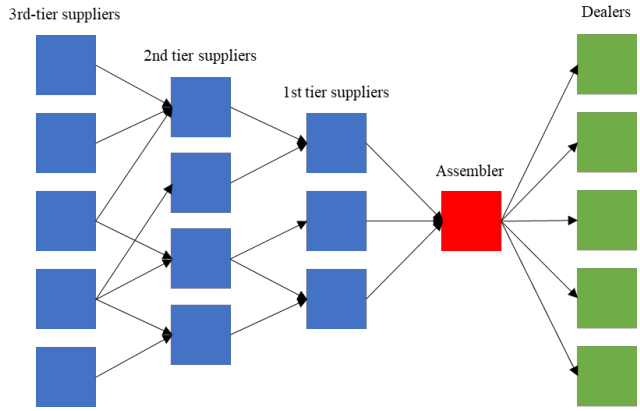

Figure 1. Supply chain of Thailand automotive industry

The majority of assemblers and suppliers at the 1st tier are owned by overseas (e.g. Toyota, Honda, Ford, Nissan, etc.). They are supplied by second-tier and third-tier suppliers whose almost are domestic owners as shown in Figure 2 [5]. Unsurprisingly, the domestic owners are pressured by overseas in the era of fierce competition and technology disruption. Such the pressure is alleviated by incorporating lean management and technology 4.0 into their logistics activities.

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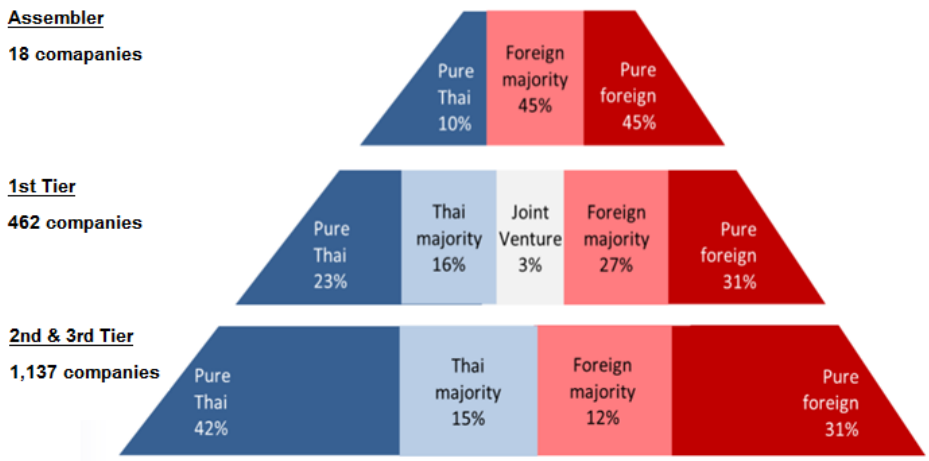

Figure 2. Structure of Thailand automotive industry

The incorporation of lean management into logistics activities fundamentally aims to minimize wastes [6]. They are incurred in overproduction, inventory, extra processing, transportation, waiting or queuing, excess motion, defect or rework, and underutilized people [7]. The fundamental aim of lean management is achieved by five principles including value specification, value stream identification and waste elimination, value flow mapping without interruptions, value pulling by customers, and perfection pursuing. Given that the value is originated by customers. The value of suppliers is hence measured with delivering the right product to the right place at the right time for the right price in the right quantity.

In order to achieve the lean logistics management, value stream mapping (VSM) is required as a potential tool. It supports to visualize current-state and future-state maps of logistics activities along their value streams [8][9]. The logistics activities are classified into three categories, namely value added, non-valued added but necessary, and wastes. The last ones are identified for eliminating, combining, rearranging and simplifying (ECRS) the logistics activities. They aim to offer greater values to customers. As a result, the gap between the current-state and the future-state maps are bridged. One of its breakthrough solutions is technology 4.0.

Technology 4.0 is a combination of cyber-physical system (i.e. machines and robots) and internet of things (IoT). It aims to digitally connect machines and robots for communication with one another. Ultimately, cyber-physical system is capable of making decisions without human involvement [10]. Therefore, technology 4.0 is effectively applied when the logistics activities are leaned. It is the so-called logistics 4.0 readiness.

This paper aims to enhance competitiveness in Thailand automotive industry emphasizing on second-tier and third-tier auto-part manufacturers. The aim is measured by values added in logistics activities along their streams. They are visualized and analyzed using a potential lean tool of VSM, whereas overcome applying suitable technology 4 . 0 i.e. robot arms, induction machines, and conveyors.

2. METHODOLOGY

The VSM-based logistics 4.0 readiness is proposed to add more values to all logistics activities along the supply chain. It undergoes four main steps as shown in Figure 3.

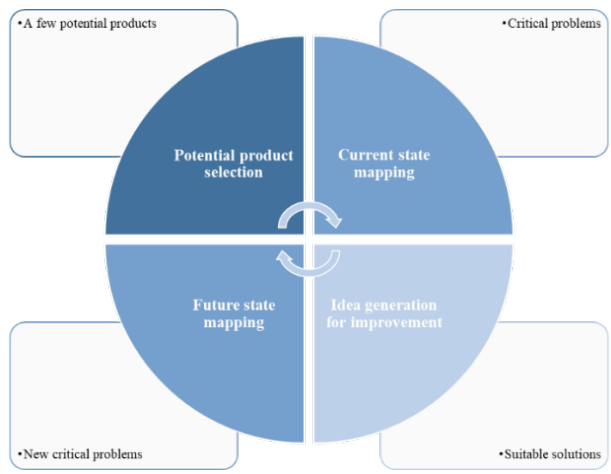

Figure 3. Methodology

Firstly, a few of potential products are selected using product-quantity analysis (P-Q analysis). They are mapped into a current-state value stream as the second step. It supports to visualize all logistics activities along their value chain and explore the most critical problems having the highest non-value added. The current-state exploration aims to add more values (%VA). It is divided by total cycle time (TCT) to production lead time (PLT) (1) [11].

$$VA\% = TCT / PLT \quad (1)$$

The definition of production lead time (PLT) is amount of time spent for delivering a product along its value stream. It is calculated by summation of lead times (LT) for all logistics activities (1, 2, 3, ,…,n) (2) [5].

$$PLT = \sum_{i=1}^{n} LT_i \quad (2)$$

The definition of total cycle time (TCT) is amount of time spent for adding values to one unit of product along its value stream. It is calculated by summation of cycle times (CT) for all logistics activities (1, 2, 3, …,n) (3) [5].

$$TCT = \sum_{i=1}^{n} CT_i \quad (3)$$

The definition of cycle time (CT) is amount of time required to add values to one unit of products for a logistics activity. It is calculated by ratio of processing time (PT) to batch size (B) (4) [5]. Given that

cycle times of individual logistics activities are less than or equal to takt time (TT).

$$CT = PT / B \quad (4)$$

The definition of takt time (TT) is maximum amount of time which customers demand one unit of products. It is calculated by ratio of available time (AT) to customer demand (D) (5) [5].

$$TT = AT / D \quad (5)$$

The definition of available time (AT) is amount of time spent to add values to products within one day. It is incurred by subtraction of working time (WT) from idle time (IT), maintenance time (MT), and others (ETC) (6) [5].

$$AT = WT - IT - MT - ETC \quad (6)$$

Thirdly, the most critical problems are overcome with suitable solutions. They initially apply non-invested techniques i.e. elimination, combination, rearrangement, and/or simplification (ECRS), SMED, standard work, visual control, etc. [12]. After that invested techniques are applied i.e. robots, automation, and internet of things, etc. They are the so-called technology 4.0. As a result, a future state map is drawn in the fourth step. The four-step VSM-based logistics 4.0 readiness is implemented in an automotive part manufacturer in Thailand as a case study.

3. RESULTS AND DISCUSSION

Due to the fierce competition, a large-sized automotive part manufacturer in Thailand is impelled to apply technology 4.0. Its potential product is fan clutch (product group A) demanded by 3,250 units a day – covering 63.71% of sales as shown in Figure 4. The sales orders are forecasted monthly for daily production planning and weekly purchasing orders.

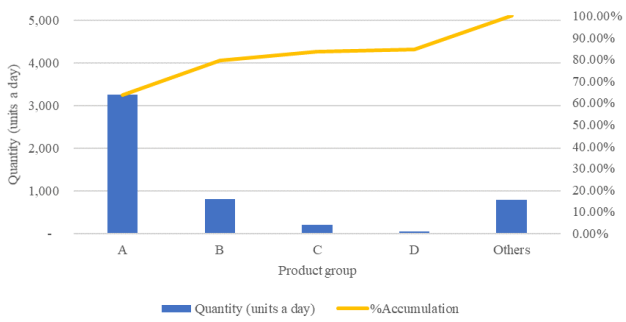

Figure 4. P-Q analysis

Given that a unit of fan clutch is assembled with one unit of cases, one unit of disc, one unit of cover, and one unit of shaft. Their materials are retrieved from warehouse to production. The retrieved materials of the first three assembling parts are lathed and washed. A batch size of 100 cases are heated in an oven before pressed with bearing, seamed, and then assembled with others. After assembled, a fan clutch is tested for water leak and quality, packed, and then stored, before delivered to customers.

These data are mapped as a current-state value stream. Its value-added ratio (%VA) is 0.045 as shown in Figure 5. It is incurred by value added (TCT = 174 seconds) and non-value added (PLT – TCT = 106.15 hours) activities. The non-value-added activities are influenced by stocks of materials (66.50 hours) and followed by finished goods (21 hours) and work in process (18.65 hours).

In addition, the current-state capacity is insufficient for its customer demand. It is caused by the current-state cycle times in four critical activities, namely lathing and washing activities for cases (70 second a unit), discs (66.0 second a unit), and covers (68.33 second a unit); and heating activity (36 second a unit). They are higher than takt time (21 second a unit).

The current-state cycle times in four critical activities are therefore shortened to 21 second a unit as shown in Figure 6. The first three critical activities (i.e. case, disc and cover lathing and washing) are operated by three robot arms instead of six operators. Their machines are also speeded up. The last critical activity (case heating) is operated by an induction machine instead of an oven. Its conveyor is also installed. These actions lead to improve and balance cycle times of the four critical activities requiring lower inventory of work in process (WIP). They support shortening total cycle time (TCT) and production lead time (PLT) by 36.78% and 53.98%. Eventually, the value-added ratio (%VA) is raised by 37.78% at the future-state as shown in Table 3

Table 3. Result comparison

Performance	Current	Future	%Improvement
Cycle time (sec a unit)	70	21	70.00%
TCT (sec)	174	110	36.78%
PCT (hr.)	106.23	48.89	53.98%
%VA	0.045	0.062	37.78%

According to the future-state VSM, robots along with network system could enable to industry 4.0. The network system is capable of collecting data and processing the collected data to monitor and control robots. In addition, a large size of the collected and processed data could be analyzed and synthesized further for production planning and intelligent decisions.

4. CONCLUSION

This paper proposed VSM-based logistics 4.0 readiness. It considered leanness and technology 4.0 of logistics activities along their value streams. Otherwise, attentions to individual logistics activities are paid. The proposed method could be useful for decision makers to enhance competitiveness in Thailand automotive industry emphasizing on second-tier and third-tier auto-part manufacturers. In other words, their values to customers are added. Moreover, the proposed method supports decision makers to generate ideas for bridging the gap between the current-state and the future-state value stream maps. Furthermore, the most suitable ideas along with technology 4.0 are proposed.

Noticeably, logistics activities related to information flows from customers to suppliers are mapped along their value streams but the information flows are not improved. It is because the information-related logistics activities do not have any effect on the value added (VA%). The information flows could be included into the logistics activities using causal linkages [14] [15] and their optimization [16] for further works.

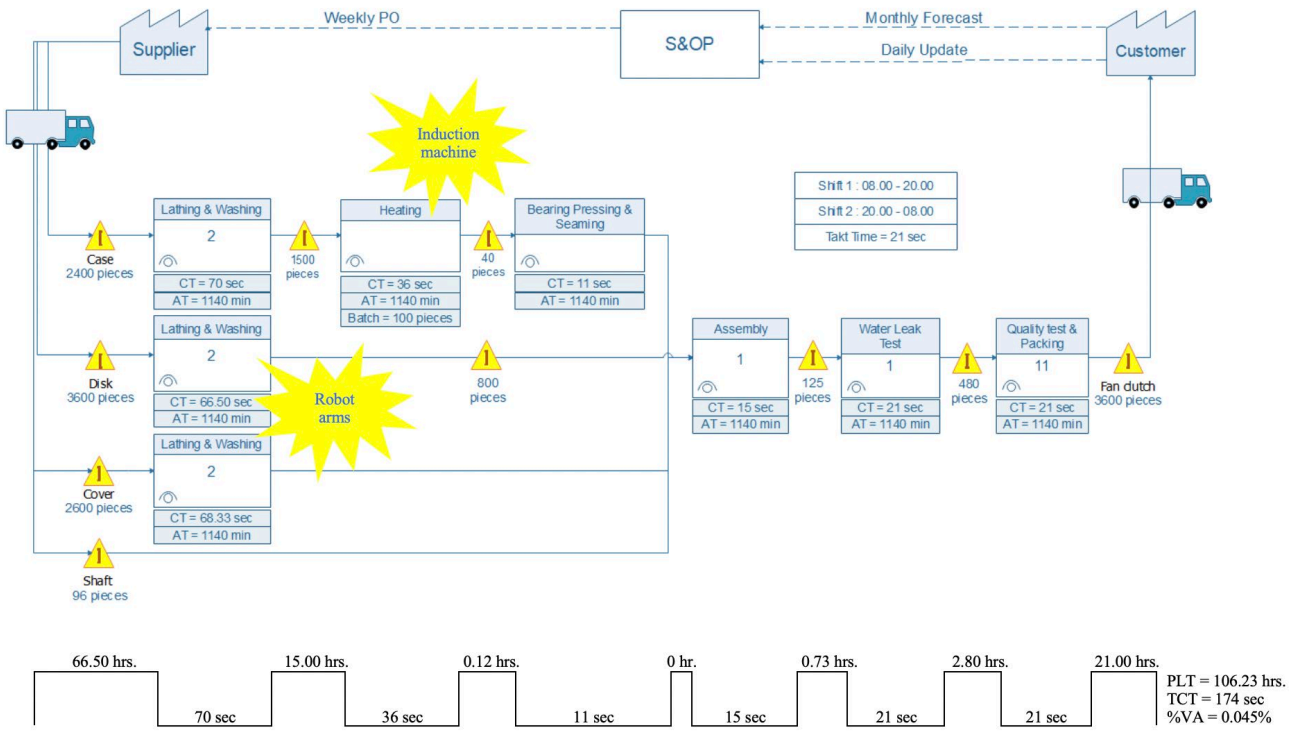

Figure 5. Current-state value stream map

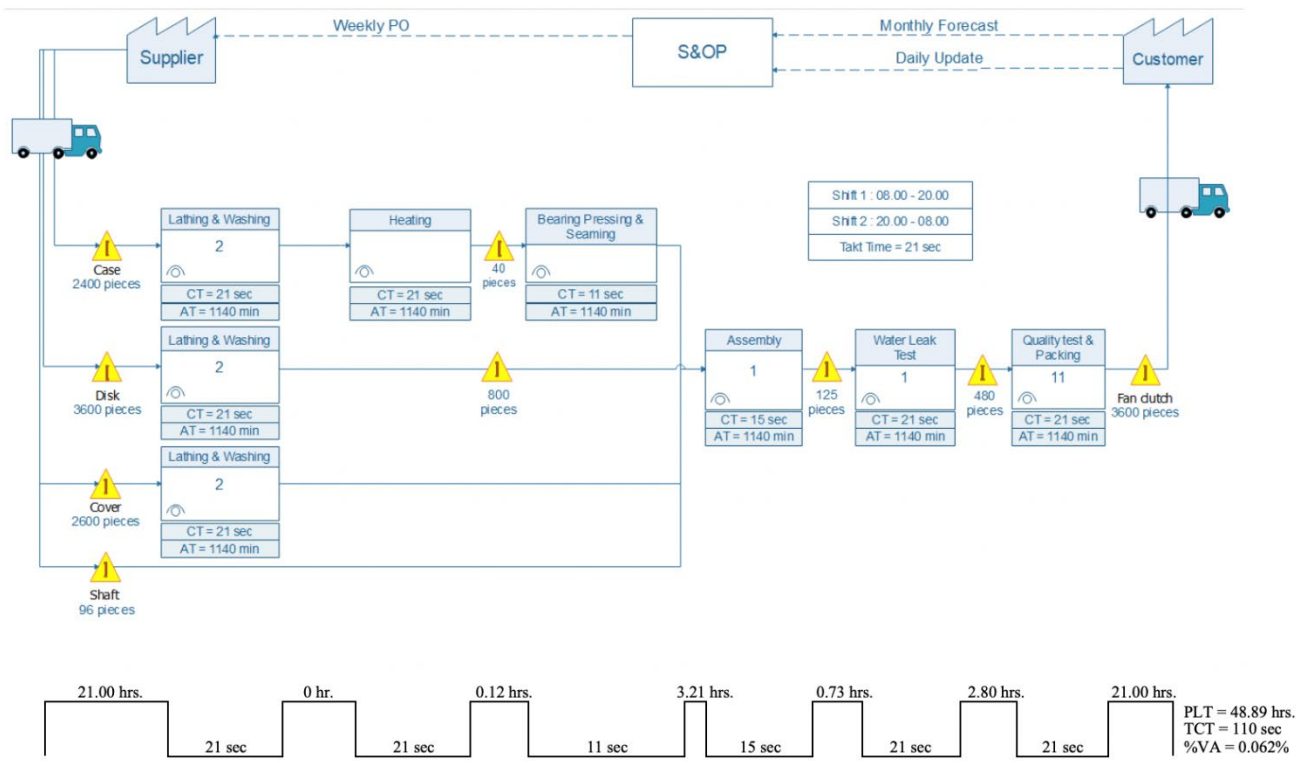

Figure 6. Future-state value stream map

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Container Yard Planning Layout Model Considering Demand and Lost Sale Container

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ABSTRACT
This paper proposed a mathematical model: Mixed Integer Non-Linear Programming to optimize the utilization of space in the container yard. The model developed was considering in two types of different blocks: exclusive block and sharing block. The exclusive block is a space in the container yard uniquely serving to the certain forwarder, otherwise it is classified as sharing block type. Base on this model, the maximum revenue is gained by reducing the loss of sales opportunity and considering fulfilment number of containers demand in each block in the container yard according to the capacity available. The mathematical model was applied to LINGO 11 software to obtain the optimal solution and its results are 14 sharing blocks and 9 exclusive blocks. The Total maximum profit is $ 29,816 per month. The proposed model was flexible enough to respond to changes in parameters related to future demand.

CCS Concepts
•Mathematics of computing→ Mathematical analysis→ Mathematical optimization→ Mixed discrete-continuous optimization→ Integer programming

Keywords
Container yard layout; exclusive block; sharing block; mathematical model

1. INTRODUCTION
The port as a node of the supply chain has an important role to support a shipment of goods from one point of economic activity to other points. There are several entities involved in the port such: terminal management, shipper, consignee, carrier, and forwarder. These entities are interrelated with each other as a system which affects the port service quality. The most classical problem very often occurs in the port is limited container yard. It causes stagnation of the goods in the port. The limited space in the container yard also raises challenges related to how effective in determining the layout area of the container yard by considering the average ratio of dwelling time. In general, container port operation is divided into three main parts which can be seen in Figure 1, namely: (1) stevedoring, it is the work of unloading goods from the ship to the dock/truck, or loading goods from the dock/truck into the ship until neatly arranged in the hatch by using container crane, stevedoring activity is the core of container terminal services. (2) Cargodoring, it is the work of releasing slings of goods from the cargo hook of the ship at the dock and moving the goods from the dock to the storage yard, then arranging it at the storage yard or vice versa. (3) receiving/delivery, it is the work of receiving goods in a warehouse or stacking field and handing over the goods recipient truck for unloaded containers, otherwise for containers to be loaded onto ships delivered to ships.

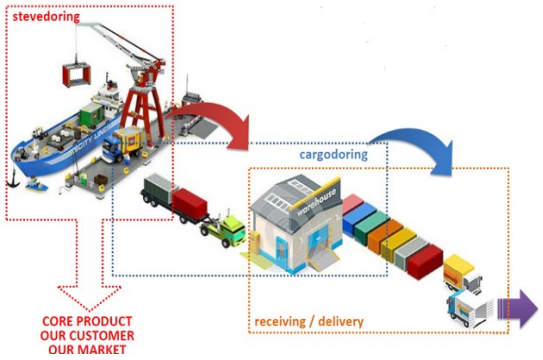

Figure 1. Three mains activity on container port

As a part of the container port, the layout on container yard divided into two types: (1) Sharing block (Figure 2) is a block type that is used dynamically by all ships arriving. Some vessels use an extra storage yard that holds containers. (2) Exclusive blocks (Figure 3) are special type blocks (exclusive) provided for each ship. This block arrangement is usually used for containers that have a relatively long storage duration.

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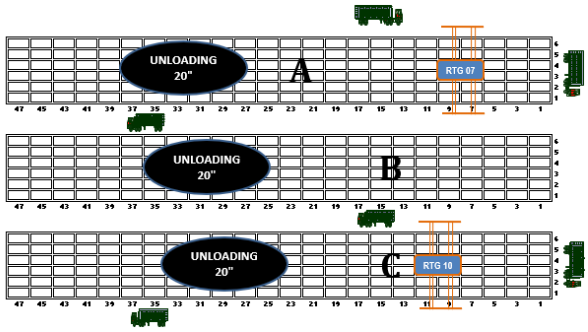

Figure 2. Sharing container yard layout

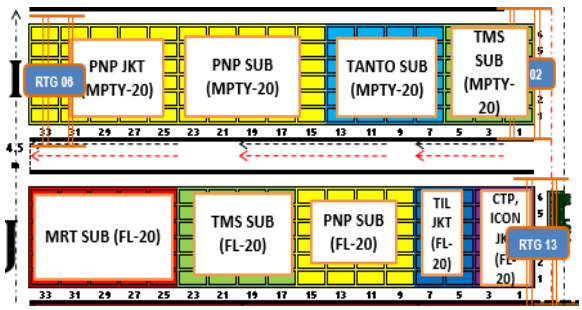

Figure 3. Exclusive container yard layout

Container yard planning is very rare to modify. But, sometimes there is updating the available template of container yard due to operational reason on certain days such as the number of ship visits and the number of containers entering and leaving the port.

The aims of this paper would present how to determine the optimal area of the container yard and the number of blocks between exclusive and sharing blocks according to the container traffic in a container port. The optimal solution obtained can be delivered to the decision-maker as a reference to maximize the container port revenues.

2. LITERATURE STUDY

2.1 Previous Study about Container Yard Design

Many studies related to container port have been conducted. Some of these are exciting topics that were carried out by Carlo. He had done its works for the complexity of the specific part of the storage yard operation in container terminal [1]. Self-container yard can be divided into different sections of yard [2]: yard blocks [3], yard sub-blocks [4] [5], yard bays and individual slots [6] [7]. In this paper, which is the main topic of discussion is to determine the optimal block on container yard using a mathematical model.

Afterward, Wiese et al. [8] used a mathematical model to determine the storage area of a page. He used Linear Programming for solving the small-scale problem, for example, the problem in the form of rectangular. If the storage yard form is non-rectangular, so need the heuristic approach, the Variable Neighborhood Descent (VND) algorithm, to complete its problem. Next, Zhen et al. [9] determined storage space in the yard for incoming ships depends on the number of ship visits at a terminal. Hence, he recommended the proposed model is based on the number of containers in and out of the container terminal.

2.2 Material Handling Equipment (MHE)

The Container yard layout consists of rectangular blocks. Material handling equipment is used to load one block in the container yard, as illustrated in Figure 4. Types of blocks consist of several rows of containers. The height of the container blocks contains only a maximum of 4 stacks according to safety and work regulations in Indonesia.

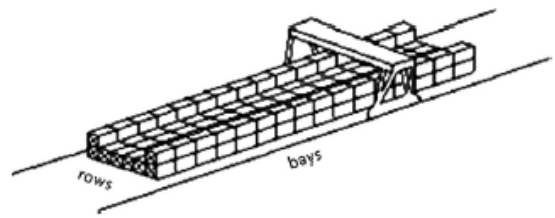

Figure 4. Layout on one block and RTG

Wiese et al. [8] stated on 114 container terminals data around the world showed that RTG (Rubber Tyre Gantry) is the most common type of equipment used to stack containers. Most of the terminal port, about 63.2% of them use RTG for stacking operations, while 20.2% others use SC (Straddle Carrier). RTG is familiar with container port equipment in Asia, at least 75.5% of terminals use RTG as equipment for stacking. Galle [10] stated that straddle carriers provide better flexibility but lower storage capacity than yard crane. However, layout and equipment are chosen, as well as the container traffic and the overall container capacity of the terminal ultimately affects to the overall productivity of the container terminal.

3. PROBLEM DESCRIPTION

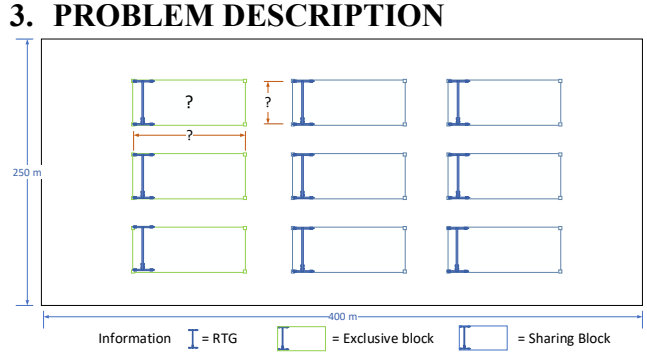

Figure 5. Problem description

The problem discussed in this paper can be illustrated as shown in Figure 5. There are the number of blocks in the 400 x 250 m area with two types of exclusive and sharing blocks. The container traffic in the container port is estimated to refer to the number of the container coming in and coming out of the container terminal. All of the handling equipment is used, namely RTG, the number of RTG, is calculated based on the number of blocks to be determined in the container yard. Suppose, the width of the container RTG width a maximum of six containers and the height of the container follows a maximum of four containers (work safety as reference). This paper present how to determine the number of container blocks and the length of the block. Mathematical modelling: Mixed Integer Non-Linear Programming (MINLP) will be used to approach the problems.

4. CONTAINER YARD MODEL FORMULATION

4.1 Model Assumptions

A mathematical model certainly has limitations in the range of variables considered. Therefore, the model assumptions make limitations of the range of variables that exist in the mathematical model acceptable and reasonable. The model assumptions used as follows:

1) The type of container size considered in this model is TEUs (Twenty Equivalent Units) / 20 ft. Whereas the size of FEUs (Forty Equivalent Units) / 40 ft. is not considered. But this model can certainly be modified if the FEUs size is considered.
2) One block uses only one MHE namely RTG. RTG is used as the most common equipment used in container yard to stack container from or to trailer trucks.
3) The basic configuration parameters of the container yard layout model are given, such as available space, the maximum height of the stack of containers, and the demand for container for each block type.
4) Only exclusive block types can be changed to be a sharing block. This is based on temporary storage demand on a sharing type block greater than the exclusive block type.

4.2 Notations Definition

Notations:

Z Total revenue from storage yard design ($)

P_j Tariff for type block j ($/TEUs)

FD_j Demand of block type j that can fulfilled (TEUs)

LC Lost sale penalty ($/TEUs)

LD_j Lost demand of block type j (TEUs)

FC_j Fixed cost of block type j ($)

w Yard depth (TEUs)

H Container height (m)

VC_j Variable cost of block type j ($)

S Space available (m^2)

B Container length (m)

R Container width (m)

S^L The length of storage yard layout

S^W The width of storage yard layout

Indexes:

i The number of block (i = 1, 2, . . ., m)

j The type of block (j= 1, 2, . . ., n)

k The initial number of exclusive block (k= 1, 2, . . ., m)

Sets:

A sets number 1, 2, . . ., m

B sets number 1, 2

C sets number 1+k, 2+k, . . ., m+k

Decision Variables

x_{ij} set to 1 if block i for type j is needed and 0 otherwise

y_{ij} set to 1 if block i for type j is needed to swap to another type j

and 0 otherwise

L_{ij} The length of container block i for type j in TEUS

4.3 Mathematical Model

Based on the problems have been defined in the previous sub-chapters, these problems can be modelled into a mixed integer non-linear programming as follows:

Objective function:

$$\text{Max Z} = \sum_{j=1}^{n} P_j\, FD_j - LC\ LD_j - \quad (1)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}\, FC_j - \quad (2)$$

$$\sum_{i=1+k}^{m}\sum_{j=1} y_{ij}\, FC_j - \quad (3)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} w\, H\, VC_j - \quad (4)$$

$$\sum_{i=1+k}^{m}\sum_{j=1} y_{ij}\, L_{ij}\, w\ H\, VC_j \quad (5)$$

s.t

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}L_{ij}\, w\, B\, R + \sum_{i=1+k}^{m}\sum_{j=1} y_{ij}L_{ij}\, w\, B\, R \le S \quad (6)$$

$$\sum_{i=1}^{m-k}\sum_{j=1} x_{ij} \le 1 \quad (7)$$

$$\sum_{i=1}^{m} x_{ij}L_{ij} w\, H \ \ge\ FD_j \ \ \forall\, j \in 1 \quad (8)$$

$$\sum_{i=1+k}^{m} y_{ij}L_{ij}\, w\, H + \sum_{i=1}^{m} x_{ij\,+1}L_{ij}\, w\, H \ \ge\ FC_j \quad (9)$$

$$x_{ij} + y_{ij} = 1 \quad \forall\, i \in A, \forall\, j \in B \quad (10)$$

$$FC_j + LD_j = AD_j \quad \forall\, j \in B \quad (11)$$

$$L_{ij} \le 30 \quad \forall\, i \in A, \forall\, j \in B \quad (12)$$

$$L_{ij} = L_{i+1\,j} \quad \forall\, i \in C \quad (13)$$

$$S = S^L S^W 0.3 \quad (14)$$

$$x_{ij} \in \{0,1\} \quad (15)$$

$$y_{ij} \in \{0,1\} \quad (16)$$

$$L_{ij}, integer \quad (17)$$

Objective function is to maximize the storage yard revenue that contains several costs, equation (1) is income from demand that can fulfilled. Equation (2) is the total cost to make all blocks consider fixed costs. Equation (3) is the total cost of converting an exclusive block to be a sharing block. Equation (4) is the total cost to make all block consider variable costs. Equation (5) is the total variable cost based on the number of blocks created and converted to be sharing block.

Constraint (6) is to limit area of the total blocks made do not exceed available space. Constraint (7) for exclusive types are provided at least according to the block type demand. Constraint (8) is the number of exclusive type blocks must meet exclusive type demand. Constraint (9) is the number of exclusive type blocks that do not actively fulfil the demand will change to be a sharing type block. Constraint (10) is block number that are larger

than m-k block number of exclusive block type can change to be a sharing type blocks. Constraint (11) states that the demand for block type j cannot be fulfilled. Constraint (12) is the limit of the length of the container block. Constraint (13) is the length of block i is the same as other blocks. Constraint (14) for the total area of storage yard layout is not fully used, minimum 30% of total space for roads. Constraint (15) and (16) are binary. Constraint (17) is integer.

5. NUMERICAL EXPERIMENT AND ANALYSIS

5.1 Parameters Setting

The numerical experimentation was conducted to validate the effectiveness of the proposed model. The parameters used in this numerical experimentation as seen in Table 1.

Table 1. Parameters used in this model

Parameters	Value
m	[10 ,15 ,20]
n	2
k	7
AD_j	[4974 9949]
LC	1
FC_j	[4 2]
P_j	[6 4]
VC_j	[4 2]
w	6
H	4
B	6.1
R	2.44
S^L	400
S^W	250

5.2 Numerical Experiments

Data sets used in the numerical experiments was obtained from the data of a container terminal in Borneo, Indonesia. The average container demand entering to the container terminal is 4947 TEUs/month for exclusive blocks and 9949 TEUs/month for sharing blocks. Considering to Indonesian port safety regulation, the maximum container stack is 4 container stacks. The rate of temporary container block in Indonesia, it is vary around IDR 20.000-28.000 or equal to $2,0 for sharing blocks, and exclusive block are usually charged higher than $2,0. Assumed it is $4,0 as exclusive blocks rates.

There are 3 data sets for numerical experiments, i.e.

1) The maximum number of each block type is 10, but the number of each type block that can swap is not limited. initial number of k used in this data is 7.
2) The maximum number of each block type is 15, but the number of each type block that can swap is not limited. initial number of k used in this data is 7.
3) The maximum number of each block type is 20, but the number of each type block that can swap is not limited. initial number of k used in this data is 7.

To verify the effectiveness of the proposed model, a trial experiment with various situations are conducted.

The result of numerical experiments can be seen in Table 2 and Figure 6 as follows:

Table 2. Result of numerical experiment

Result	m		
	10	15	20
Obj. Function	$23.435	$29.784	$29.816
Lost sale	[0 589]	[0 0]	[0 0]
Total Iterations	863	1.334.274	690.740
Total block type	7 exclusive blocks 13 sharing blocks	9 exclusive blocks 14 sharing blocks	9 exclusive blocks 14 sharing blocks
Converted block	3 exclusive blocks to be sharing block	None	None

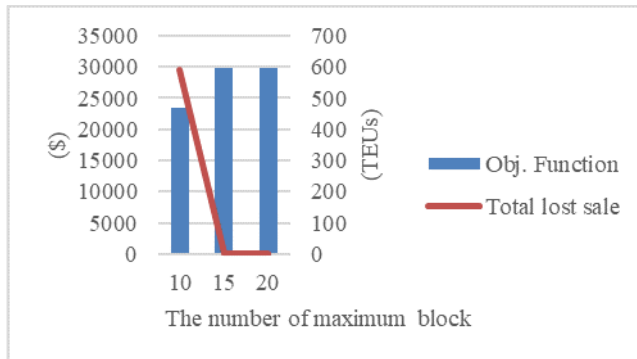

Figure 6. The result of numerical experiment comparison

Refer to the numerical experimental, the optimal results are obtained 9 exclusive blocks and 14 sharing blocks in the container yard to fulfil the container demand with a total maximum profit of $29.816 per month. Whereas if layout m=10 chosen, the result obtained 7 exclusive blocks and 13 sharing blocks in the container yard. It will not be optimal and lost the sale containers for the sharing block of 589 TEUs and just getting the profit $23.435 per month.

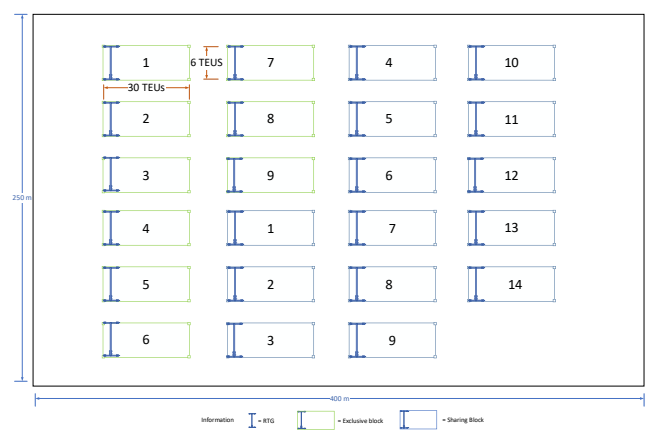

Figure 7 The optimal container block layout

The optimal container block layout can be seen in Figure 7. The length of the container block layout is 30 TEUs and the width is 6 TEUs. Material handling equipment used is one block for one

RTG. The container block layout flexible enough and easily adjust facing the number of container traffic increases. To anticipate the demand change, parameter of the model proposed can be adjusted.

6. CONCLUSIONS

The limitation of Mixed Integer Non-Linear Programming (MINLP), occurred when the problem encountered has many binary decision variables. However, LINGO 11 still able to solve the problem with variables decision is not more than 20 (20 exclusive blocks and 20 sharing block). Metaheuristic approach is proposed when the decision variables are more than 20 and the problem is more complex.

In the numerical experimentation which is conducted, the number of block types was adapted to the traffic of the container block type itself. While the tariff charged also affects to the priority of container blocks.

In this case the sharing block type container has more demanded than the exclusive block type, but the tariff charged on the exclusive block type is more expensive than the sharing block type.

The layout design m = 10 there were 589 TEUs of idle containers yard in the sharing block type, while for m = 15 and m = 20 there are no idle container yard.

The optimal container yard layout is determined by the maximum profit. It consists of 9 types of exclusive containers yard and 14 types of sharing container blocks and reached a maximum profit of $ 29,816 per month.

The length of container block of each type is 30 TEUs and the width is 6 TEUs. All of those blocks using RTG as MHE. Those lay-out can be adapted to the number of container traffic trend. The proposed model is able to adjust to the future demand of container, by changing the parameter setting.

7. FUTURE WORK

In this paper, average actual demand is used based on historical data. However, demand for each type of container block is stochastic probabilistic event. Hence for the future research, it is recommended the actual demand variable as stochastic probabilistic function.

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Operational Efficiency Model for a Railway Transit in the Philippines

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ABSTRACT
This paper presents a model for a railway transit in the Philippines focusing on the operations of the whole line in order to reduce the queuing time spent by every passenger in the system. Based on the assessment of the current operations, this railway transit was unable to provide efficiency and satisfaction to the passengers due to the long queuing time experienced by them especially during peak hours. This paper assessed the factors that affect the waiting time and determine significant factors that contribute to the issue using analysis of variance (ANOVA) and Tukey's Post Hoc Test and using various industrial engineering tools such as motion and time study, forecasting, queuing analysis, and simulation to develop the model. This paper presents different simulated scenarios such as controlled volume of passengers in the platform, additional trains and cars, number of servers, schedule for skipping trains, maximizing the speed of trains, and fixed dwell time to reduce the waiting time of passengers, and to improve efficiency of the operations of the railway transit.

CCS Concepts
•General and reference→ Document types→ General conference proceedings

Keywords
Operations efficiency; model; railway transit; queuing analysis; simulation.

1. INTRODUCTION
Rail transits are one of the most in demand mode of transportations in our society nowadays. Its volume of passengers is extremely growing for the past few years. Due to increasing number of commuters, transportation becomes a major problem to them since it causes road traffic congestions, pollution, and stress to all the commuters. According to the study of [8], there were several reasons why passengers prefer to use light rail rather than bus transit and other means of transportation which are it has higher capacity, lower operating cost, lower noise, and higher speed, reliability and efficiency. On the other hand, while light rail is having higher carrying capacity than most buses, it also requires higher investment like the powers systems with overhead wires that will give power to the trains, signal systems, guide way-rail, track ballast, etc. Reference [9] stated that use of rail transits grows in the face of rising in demands resulting to unsustainability. Reference [6)] also stated that volume of passengers in rail transits also increases that result to different problems like overflowing passenger volume, long service in buying tickets, and long waiting time on trains that causes delay to the passengers. These problems result to stress and productivity loss of the passengers based on the study of [12]. Reference [9] said that when this type of problems occurs, its only solution is to improve train's management system such as pre-programming schedules based on historical information and incorporate strategies for keeping trains in the right schedule in the right stations. According to [11], due to the increasing demand for public transportation, trains have become one of the most viable alternatives by the commuters especially for daily commuting to avoid congested highways. Furthermore, reference [11] stated that while transit agencies are excited with the increasing ridership, they are challenge also with a higher volume of passenger flow and longer queuing lines at the existing stations. Simulation [1] used in order to improve the current situation and evaluate station design, queue management, fare equipment design and fare policy impacts since simulation is a powerful tool for train station passenger flow improvement, planning and design analysis. The rail transit system relieves the congestion of road traffic by improving the traffic supply [5]. It also gives the city to improve its comprehensive value with large investment to the rail transits. As mentioned by [2], the train scheduling is one of the most challenging problems in railway planning, and many researchers studied this for decades via different techniques

As the demand of the railway transits grow rapidly, the management of the Light Railway Transit Authority (LRTA) Line 1 (LRT Line 1) in Metro Manila is currently encountering difficulty in providing accommodations and good services for the passengers. Passengers are experiencing long waiting time before they can board the train. The design of the station depends on its location. The central station of LRT Line 1 experiences long queuing time in the checkpoint, ticketing, entrance, and in the platform during peak hours. The reasons of having long queuing time are first, the trains arrived in the station are already full of passengers, resulting to inability of passengers in the next station to board the train.

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Secondly, the inter-arrival rate or headway of trains increases its standard time that is 4 to 5 minutes. Lastly, current number of trains cannot accommodate all the railway transit users even its load increases its capacity.

Metro Manila has four railway transits used as public transport to people that provide faster, cheaper and more eco-friendly mode of transportation system for sustainable community living. The LRT Line 1 in Metro Manila consists of 20 stations that has an 18 kilometers elevated railway system servicing routes from Baclaran in Pasay City to Roosevelt in Quezon City and vice versa. The LRT Line 1 was considered as the first light railway transit system in Southeast Asia.

However, most of the commuters are dissatisfied with the performance service given by the management of LRT Line 1. Thus to provide better service, the management must serve all demand with a least time available according to passenger's standards. Currently, its train headway is 2 to 4 minutes during peak hours and 5 to 8 minutes during non-peak hours.

This paper focused on the operational system of the LRT Line 1 in Metro Manila starting from the checkpoint up to the boarding of the passengers. Furthermore, the paper aims to improve the operational efficiency of LRT Line 1 by providing cost-effective and best service to their passengers that includes scheduling, maintenance, operations from ticketing up to the platform, and its facilities.

2. METHODS

2.1 Data Collection

The researchers conducted an assessment on the existing operations of LRT Line1 and data on daily ridership on different stations for the past five years, scheduling procedures, dimensions and number of trains, distances between stations, and current operating strategies implemented by the LRT1 management. Moreover, the researchers conducted interviews not only to passengers but also to operations director and personnel.

Moreover, the researchers undertook motion and time studies to gather data on the passengers' queue time spent in the system, from checkpoint, ticketing and beep loading machines, before entering the station, and at the platform. The researchers observed these activities during peak hours of weekdays in order to determine the maximum total waiting time of passengers in all stations for both the north and south bounds. The morning peak hours in all stations are from 7:00 am to 9:00 am while 5:00 pm to 7:00 pm in the afternoon. The other data gathered comprised of the arrival rate per minute of passengers during peak hours in every side of each station and the headways, dwell and travel times of trains, capacity of trains, number of passengers in the train, time of operations, and others to mention.

2.2 Statistical Analyses

After the data were gathered, the researchers performed statistical tests using Analysis of Variance (ANOVA) to determine significant difference on a) the number of daily ridership on a given day, b) different level of stations on the dwell time [13], c) type of train based on dwell time, and d) different headways based on total waiting time. These significant factors were determined using the Tukey's pairwise test.

2.3 Conversion of Raw Data to Probability Distribution

In order to come up with the probability distribution of the arrival rates in each station during peak hours of morning and afternoon trips in both directions (north and south bounds), Stat Fit in ProModel software was used.

2.4 Queuing Analysis

The researchers were able to determine the current and future expected service time given the current number of servers and the alternative number of servers. The queuing analysis [3] were applied to determine the possible number of checkpoints, ticketing servers, beep-loading machines and tap entrance based on the data gathered to lessen the current total waiting time of the passengers.

2.5 Simulation of the Current and Proposed Operations of LRTA Line 1

This paper used the ProModel simulation software [3], [4] to run the simulated actual data in order to show the difference between the current system and proposed system using different alternative scenarios.

3. RESULTS

The LRT Line 1 railway system has 40 trains of which 28 trains are operational. The trains comprised of three generations. There are 21 trains in the first generation, 12 trains in the second generation, and 7 trains in the third generation. The train cars very from 2 to 4 cars and also vary in size depending on the generations. The capacity of the trains also depends on the generations. Table 1 presents these details.

Table 1. Existing and Current Operating Train Specifications

	1st Generation Trains		2nd Generation Trains	Third Generation Trains
Total Number of Trains	21		12	7
Number of Trains in Running Condition	6	9	6	7
Number of Cars	2	3	4	4
Car size	2.5 m (8 ft 2 in) wide; 29.28 m (96.1 ft) long	2.5 m (8 ft 2 in) wide; 29.28 m (96.1 ft) long	2.59 m (8 ft 6 in) wide; 26-26.5 m (85-87 ft) long	2.59 m (8 ft 6 in) wide; 26-26.5 m (85-87 ft) long
Capacity per Train (Passengers)	748	1,122	1,358	1,384

Table 2 shows the distances (in meters) between stations, standard and actual travel times (in seconds), and dwell time (in seconds).

Table 2. Distance, Travel Time (Standard and Actual) and Dwell Time Between Stations

Line System				
Stations	**Distance (in meters)**	**Travel Time (in seconds)**		**Dwell Time (in seconds)**
		Expected	**Actual**	
Baclaran – EDSA*	588	52.92	69	33
EDSA – Libertad	1,010	90.9	113	31
Libertad – Gil Puyat	730	65.7	86	38
Gil Puyat – Vito Cruz	1,061	95.49	116	33
Vito Cruz – Quirino	827	74.43	96	33
Quirino – Pedro Gil	794	71.46	90	34
Pedro Gil – United Nations Avenue	754	67.86	86	35
United Nations Avenue – Central Terminal	1,214	109.26	133	33
Central Terminal – Carriedo	725	65.25	94	38
Carriedo – Doroteo Jose	685	61.65	82	25
Doroteo Jose – Bambang	648	58.32	76	17
Bambang – Tayuman	618	55.62	75	27
Tayuman – Blumentritt	671	60.39	83	28
Blumentritt – Abad Santos	927	83.43	120	17
Abad Santos – R. Papa	660	59.4	85	16
R. Papa – 5th Avenue	954	85.86	104	22
5th Avenue – Monumento	1,087	97.83	117	29
Monumento – Balintawak	2,250	202.5	253	23
Balintawak – Roosevelt**	1,870	168.3	221	52
Total (Distance and Travel Time)	**18,073**	**1626.57**	**2098**	**564**
*up to the south end of the platform				
**up to the north end of the platform				

Table 3 shows the morning average daily ridership per station for both north and south bounds.

Table 3. Morning Average Daily Ridership (North and South Bounds)

Station Level	Ridership Range	North Bound		South Bound	
		Station	**Ridership**	**Station**	**Ridership**
1	0 – 1999	Libertad	1405	R. Papa	1395
		Vito Cruz	1217	Abad Santos	1336
		Quirino	1128	Gil Puyat	1182
		Pedro Gil	1063	UN Avenue	958
		Carriedo	895	Carriedo	926
		D. Jose	872	Pedro Gil	897
		UN Avenue	610	Bambang	897
		Abad Santos	348	Libertad	646
		Tayuman	302	Central	539
		R. Papa	249	Quirino	471
		Central	239	Edsa	229
		Bambang	187	Vito Cruz	208
		5th Avenue	132		
		Balintawak	141		
		Blumentritt	82		
2	2000 – 5999	Baclaran	5668	5th Avenue	4973
		Monumento	3156	Balin-tawak	4931
		Gil Puyat	3083	D. Jose	2893
				Blumen-tritt	2496
				Tayuman	2492
3	6000 and above	Edsa	9605	Roosevelt	7868
				Monu-mento	7456

On the other hand, Table 4 presents the afternoon average ridership for both north and south bounds.

Table 4. Afternoon Average Daily Ridership (North and South Bounds)

Station Level	Ridership Range	North Bound		South Bound	
		Station	**Ridership**	**Station**	**Ridership**
1	0 - 1999	Central	1776	Baclaran	1988
		Libertad	1519	Pedro Gil	1793
		Quirino	1373	Tayuman	1524
		Monumento	1236	Quirino	1369
		Tayuman	1006	Balint-awak	1143
		Bambang	727	Vito Cruz	1113
		Blumentritt	663	5th Avenue	1053
		5th Avenue	594	Libertad	912
		R. Papa	308	Blumen-tritt	832

		Abad Santos	195	Abad Santos	441
		Balintawak	33	Bambang	377
				R. Papa	249
				EDSA	132
2	2000 – 3999	UN Avenue	3924	UN Avenue	3847
		Pedro Gil	3421	Roosevelt	2982
		Carriedo	3362	Carriedo	2974
		Vito Cruz	2552	Central	2940
		D. Jose	2515	Gil Puyat	2356
				D. Jose	2056
3	4000 and above	EDSA	6853	Monu-mento	7456
		Gil Puyat	5454		
		Baclaran	4844		

The queuing problems of LRT 1 starts from the checkpoint, then ticketing, and tapping of tickets and lastly, in the platform area where passengers wait for the train. Table 5 shows the waiting time of each components of the process in percentage during morning for both the north and south bounds.

Table 5. Waiting Time of Passengers By Components (in Percentage) During Morning

Station	North Bound				South Bound			
	Checkpoint	Ticketing	Tap	Platform	Checkpoint	Ticketing	Tap	Platform
Baclaran	12	36	0	52				
Edsa	21	15	10	54	0	0	5	95
Libertad	0	0	0	100	0	0	0	100
Gil Puyat	31	10	0	59	0	1	0	99
Vito Cruz	0	0	0	100	0	0	0	100
Quirino	0	6	0	94	4	13	0	83
Pedro Gil	4	4	5	87	22	17	0	61
UN Avenue	0	0	0	100	1	14	21	64
Central	0	0	0	100	0	0	0	100
Carriedo	0	4	0	96	0	8	0	92
D. Jose	7	9	8	76	5	6	0	89
Bambang	1	1	0	98	1	7	0	92
Tayuman	1	4	0	95	14	4	20	62
Blumen-tritt	0	3	0	97	25	2	31	42
Abad Santos	0	1	0	99	33	20	8	39
R.Papa	1	6	0	93	45	5	16	34
5th Avenue	0	1	0	99	23	3	23	51
Monu-mento	4	6	0	90	30	23	26	21
Balin-tawak	9	14	0	77	1	2	52	45
Roosevelt					19	15	29	37

Table 6 also presents the waiting time of passengers in riding the train by percentage during the afternoon for both the north and south bounds.

Table 6. Waiting Time of Passengers By Components (in Percentage) During Afternoon

Station	North Bound				South Bound			
	Checkpoint	Ticketing	Tap	Platform	Checkpoint	Ticketing	Tap	Platform
Baclaran	5	21	24	50				
Edsa	28	17	7	48	0	0	1	99
Libertad	11	3	5	81	0	0	0	100
Gil Puyat	54	8	13	25	35	9	23	33
Vito Cruz	24	7	0	69	3	1	0	96
Quirino	32	16	0	52	3	16	4	77
Pedro Gil	31	8	20	41	18	22	0	60
UN Avenue	30	3	31	36	24	22	0	54
Central	26	7	17	50	27	19	0	54
Carriedo	7	12	17	64	0	14	21	65
D. Jose	3	8	9	80	1	7	0	92
Bambang	1	2	0	97	2	2	0	96
Tayuman	3	18	0	79	7	8	0	85
Blumen-tritt	8	18	0	74	2	9	0	89
Abad Santos	1	2	0	97	1	4	0	95
R.Papa	0	2	0	98	1	3	0	96
5th Avenue	0	8	0	92	1	11	0	88
Monu-mento	0	34	0	66	5	4	0	91
Balin-tawak	1	7	2	90	3	2	0	95
Roosevelt					0	12	0	88

The factors that affect waiting were determined using statistical test. Table 7 presents the summary of the statistical analyses for this paper.

Table 7. Summary of Statistical Test Performed Using ANOVA and Tukey's Test

Description	p-value	Remarks
Variation between Time of Day and Ridership	0.973	Not Significant
Different Levels of Station based on Dwell time	0.000	Significant (Level 2 station's dwell time is longer than Level 1 and Level 3.)
Types of Trains based on Dwell time		
Morning Peak Hours (North Bound)		
Level 1 (Blumentritt)	0.888	Not Significant
Level 2 (Monumento)	0.667	Not Significant
Level 3 (EDSA)	0.061	Not Significant
Morning Peak Hours (South Bound)		

Level 1 (Central Station)	0.823	Not Significant
Level 2 (UN avenue)	0.170	Not Significant
Level 3 (EDSA)	0.002	Significant (3rd generation trains have shorter dwell time than the 1st and 2nd generation trains
Afternoon Peak Hours (North Bound)		
Level 1 (Central Station)	0.616	Not Significant
Level 2 (UN Avenue)	0.247	Not Significant
Level 3 (EDSA)	0.299	Not Significant
Afternoon Peak Hours (South Bound)		
Level 1 (Monumento)	0.254	Not Significant
Level 2 (UN Avenue)	0.631	Not Significant
Different Headway based on Total Waiting Time		
Morning Peak Hours (North Bound)		
Level 1 (Blumentritt)	0.000	Significant (different Level stations have different headways)
Level 2 (Monumento)	0.000	-do-
Level 3 (EDSA)	0.00	-do-
Morning Peak Hours (South Bound)		
Level 1 (Vito Cruz)	0.000	Significant (different Level Stations have different headways)
Level 2 (Tayuman)	0.000	-do-
Level 3 (Monumento)	0.000	-do-
Afternoon Peak Hours (North Bound)		
Level 1 (Central Station)	0.000	Significant (different Level stations have different headways)
Level 2 (UN Avenue)	0.000	-do-
Level 3 (EDSA)	0.000	-do-
Afternoon Peak Hours (South Bound)`		
Level 1 (Monumento)	0.00	Significant (different Level stations have different headways)
Level 2 (UN Avenue)	0.00	-do-

4. DISCUSSION

A total of 40 trains or 140 cars comprised the LRT line 1. Out of these 40 trains, only 28 trains were functioning. Due to insufficient cars, the capacity of the train exceeded by 10-20%. When it comes to the arrival of trains, it arrives randomly. Table 1 presents the specifications of trains that were operating.

The LRT 1 system has 20 stations spanning a total .distance of approximately 18 kilometers as shown in Table 2. The train system starts in Baclaran station (North bound) and ends in Roosevelt station (South bound). During weekdays (Mondays to Fridays), the train starts its commercial operation in Baclaran station at 5:00 in the morning bound for Roosevelt station, The last north bound commercial train leaves Baclaran terminal bound for Roosevelt station at 9:30 in the evening. On the other hand, the last south bound commercial train leaves Roosevelt station bound for Baclaran station at 10 pm. Furthermore, during weeken (Saturdays and Sundays) and holidays, the same time schedule as in weekdays except for the closing time of the railways system which is 9:00 pm (from Baclaran station to Roosevelt station) and 9:30 pm (from Roosevelt station to Baclaran station). Moreover, the average speed of train management of LRT 1 wants to achieve is 40 kilometers per hour, however, as shown in Table 2, the actual travel time is much longer than the target travel time. This means that the actual travel time of trains did not meet the expected speed of 40 kilometers per hour. Furthermore, the train's dwell time during the duration of the trip was 564 seconds or approximately 28.2 seconds per station.

The 20 stations are categorized into three station levels based on the number of daily ridership during the morning, for both the north bound and south bound directions. The station level 1 has a ridership of 0 – 1999, station level 2 has a ridership of 2000 – 5999, and station level 3 has a ridership of 6000 and above as shown in Table 3. EDSA station which is he second station from the sout bound has the highest daily ridership of 9605 passengers while Baclaran, being the first station from the south bound, ranks second with a 5668 daily ridership. These are the first two stations that passengers take their ride going to the north bound where schools and business are located, The third is Monumento station which the second station before reaching the Roosevelt station (last station of the north bound). Usually, passengers take this station in going to the next railway transit system going to Makati (a business area). In going to the south bound route, Roosevelt station has the highest daily ridership, being the first station going to south bound and Monumento ranks second with a daily ridership of 7456. This is the station where people comes from the different areas in the north of Manila.

Furthermore, during the afternoon, these 20 stations were also categorized into three station levels based on the number of daily ridership for both the north bound and south bound directions. The station level 1 has a ridership of 0 – 1999, station level 2 has a ridership of 2000 – 3999, and station level 3 has a ridership of 4000 and above as presented in Table 4. For north bound, EDSA station has the highest daily ridership being the second station from the south bound, This was followed by Gil Puyat station with a daily ridership of 5454 passengers. This station is usually the starting point of people from the Makati area in going to their respective homes. The third highest daily ridership is Baclaran, being the first station from the south bound with a daily ridership of 4844 passengers. On the other hand, Monumento station has the highest daily ridership of 7456 passengers going to south band followed by UN Avenue station with 3847 ridership. The third is Roosevelt station, being the first station, with a 2982 ridership,

Passengers encountered queuing issues as they enter the train station. Before passengers can ride the train they have to pass through the checkpoints, buy tickets, tap tickets then go to the platform to wait for the train. In these activities, passengers encounter longer waiting time. As shown in Table 5, bulk of the percentage of waiting time was encountered in the platform during the peak hours in the morning for both north bound and south bound. Even during the afternoon peak hours, the platform showed the highest waiting time in terms of percentage as presented in Table 6. This is due to insufficient number of trains plying the LRT Line 1. As such, to minimize overcrowding in the platform during peak hours, management implemented the crowd control and skipping train. Once the platform areas in stations have reached 80% of the passenger volume, crowd controls on the checkpoints, tap areas, and before the platform areas were implemented. Crowd controls were implemented to minimize passengers that will board the train in order to allot space for the passengers in the next stations. But currently, there were no specific percentage of passengers that will occupy the train allotted in every station. Skipping trains are trains that load passengers in a certain station. The head guard or supervisor in the control room dispatched the

skip train gin the most congested stations. Those 2-car trains were usually used as skip trains. There was no current schedule of skipping trains. Mostly, the long queue time at the checkpoint and tap entrance machines was due to the crowd control implementation. Queue time spent at the ticketing servers was due to the limited number of servers and overflowing passengers from the crowd control. The waiting time at the platform area was due to the headway of trains and skipping trains that makes the waiting time longer.

Furthermore, statistical test showed that variation between time of day and ridership is not significant ($p = 0.973$). However, different levels of stations and dwell time showed significant difference ($p = 0.000$). This indicates that the level 2 stations have a longer dwell time compared to levels 1 and 3 stations. With regard to type of trains and dwell time, statistical test showed no significant difference in both north bound and south bound during morning and afternoon except for Level 3 in the morning going south bound which showed significant differences ($p = 0.002$). This indicates that the third generation trains have a shorter dwell time compared to the first generation and second generation trains. However, the statistical test between different headway and total waiting time showed significant difference ($p = 0.000$). This means that different level stations have different headways. The summary of statistical tests is shown in Table 7.

Simulation software was used in order to show the difference between the current system and proposed system by testing the different alternatives below:

Alternative 1: Control the number of passengers at the platform depending on the volume of passengers at the station. There will be a certain percentage allotted for each station on the capacity of the train in order to accommodate all the stations. In the platform, there will be a line marking on how many passengers to be accommodated per batch assuming that the line marking will depend on the number of passenger. This will allow the equality of ridership in every station depending on their arrival rate.

Alternative 2: Additional trains and cars. Since there are several cars that were not in use, the researchers planned to recommend for repair and maintenance for the unused cars to transform every train to a 4-car train that will surely accommodate and serve more passengers that may result to lesser waiting time. The total number of additional trains is based on the result of the simulation together with the other alternatives.

Alternative 3: Another alternative is additional number of servers at the checkpoint and ticketing. Number of servers that were tested are based on the Queuing Analysis made above.

Alternative 4: The trains will be divided into three groups. There will be trains that will pick up passengers on the first group stations 1 to 11 only, and then other trains will pick up passengers on the stations on the second group stations 11 to 20 and third group the trains that will pass all the stations.

Alternative 5: Schedule for skipping train. Selected stations will be assigned with skipping trains not being requested. For example, every 8 trains that will pass there will be 1 skipping train assigned for the selected station.

Alternative 6: Maximize speed of trains. For the headway of trains, currently the trains have a maximum speed of 40 kilometers per hour and it can be maximized up to 55 kilometers per hour if trains will be repaired and maintained.

Alternative 7: There will be a fixed dwell time. Proposed dwell time will be ranging from 20 seconds to 40 seconds dwell time for every station.

Aside from these alternatives, the researchers determined the additional number of servers in every station, number of checkpoints, ticketing servers, beep-loading machines, and tap entrance using queuing analysis.

This paper presented two different combinations of alternatives by analyzing the relationship with each other. Testing of one alternative alone will not affect much and results will not vary on the actual data gathered. The different combinations were tested on the simulation software to determine the most effective alternatives that will reduce the total waiting time of the passengers.

The first combination used comprised of alternatives 1 – 3 – 5 – 6 – 7, as shown below:

Alternative 1: Platform percentage

Alternative 3: Additional number of servers

Alternative 5: Schedule for skip trains

Alternative 6: Increase in speed

Alternative 7: Fixed dwell time

Percentage improvements were computed by using the actual average waiting time from the actual data gathered and the simulated values of the combination 1. In overall percentage improvement of the first combination, the improvement ranges only from 8 to 13% or an average percentage improvement of 10.22%.

The second combination comprised of alternatives 2 – 3 – 6 – 7, as shown below:

Alternative 2: Additional cars

Alternative 3: Additional number of servers

Alternative 6: Increase in speed

Alternative 7: Fixed dwell time

For the combination 2, additional number of cars, additional number of servers of every step in selected stations, increase in speed of 55 KPH in order to further decrease the waiting time spent in every process and all trains are complete with a 4-car train were combined and tested. As a result of the second combination composed of alternatives 2-3-6-7 tested in the simulation software, the improvement percentage ranges from 20% to 35% or an average percentage improvement of 30.32%

Combination of alternatives 1-3-5-6-7 has a lesser percentage improvement but cost was determined to be less than the cost of the other combination.

The only alternatives that will contribute cost are the additional number of servers and increase in speed. Additional number of servers will require an additional number of employees and/or tap machines and beep loading machines while increase in speed of trains will require repair and maintenance on the railways. Repair and maintenance of railways will demand 2-5 days. For that length of repair and maintenance, the whole line will not operate.

The second combination comprised of alternatives 2-3-6-7 has a higher percentage improvement compared to the first combination. Additional cars, number of servers, and increase in speed will

definitely result to a higher cost than the first one. For the additional cars, with the current number of unused train, the company can repair them of purchase new trains. Adding number of servers will increase manpower cost because of manpower hiring and additional machines will result to increase in repair and maintenance.

Considering the results of the simulation tests and computation of improvements, Combination 2-3-6-7 will provide better efficiency and satisfaction to the passengers than Combination 1-3-5-6-7. Second combination may require higher cost than the first combination, but it will give a higher improvement to the system of LRT Line 1.

The best alternative and combination to be selected is the combination 2-3-6-7 that comprised of converting every train to 4-car trains, additional servers in different stations, increase in speed from 40 kph to 55 kph and propose a fixed dwell time in every station. These alternatives will be able to reduce the total waiting time of passengers and provide satisfaction to the passengers.

5. CONCLUSION

In determining the factors affecting the long waiting time of passengers, this paper assessed and examined the current operations of LRT Line 1. Factors affecting the long queuing time are the availability of number of servers in every station, dwell times, no schedule for skip trains, speed were not maximized due to poor maintenance on railways, and most importantly is the long headway.

Different alternatives were tested using the simulation software based on the combinations provided by the researchers. Two combinations were tested, combination 1 – 3 – 5 – 6 – 7 resulted to a lesser percentage improvement of 10.22% but required lesser cost while combination 2 – 3 – 6 – 7 may require higher cost but will improve the efficiency to 30.32%.

The main goal of this study is to reduce the total waiting time of passengers and to improve the efficiency of LRT Line 1 operations. Based from the simulation that results, the most effective combination of alternatives that will improve the current system are by converting every train to a 4-car train, additional number of servers, increases the speed of trains and by proposing a fixed dwell time that is the combination 2 – 3 – 6 – 7.

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Supply Chain Coordination Optimization Under the Influence of Customer Strategic Behavior and Retailer Risk Preference

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ABSTRACT
When wholesale price contracts encounter customers' strategic behaviors, they cannot coordinate the supply chain, so they introduce buyback contracts. However, in real life, people usually estimate the risks before making decisions, and so do supply chain members. Literature study has shown that retailers' risk preference will have a significant impact on their purchasing decisions, which in turn will affect retailers' inventory. Therefore, this paper mainly studies whether the use of buyback contracts can coordinate the supply chain under the influence of customer strategic behavior and retailers' risk preference. The research method is the Mean-CVaR, and this risk measurement tool can be used to describe the risk preference of retailers.

CCS Concepts
• **Applied computing → Enterprise computing → Enterprise modeling**

Keywords
Customer Strategic Behavior; Risk Preference; Mean-CvaR

1. EXPLANATION and HYPOTHESIS
This paper mainly refers to the analysis ideas of Huo shasha (2013) and Qiu ruozhen (2011). Both of them introduce risk factor $\alpha(0 < \alpha < 1)$ and pessimistic coefficient $\lambda(0 \le \lambda \le 1)$ on the basis of CVaR. This paper mainly determines the risk preference type of retailers through the size between them, so as to further study and analyze supply chain coordination. Here is the meaning of the letters used below:

c: marginal cost per unit product

w :the order price of the retailer's unit product;

j：: retail price of the retailer's unit products;

s：residual value of unsold products;

Q：retailer's orders;

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L(u)：distribution function of random demand u;

l(u)：density function of random demand u, and assume its continuity;

$\prod^{r}$： profit function of the retailer;

$\prod^{s}$：profit function of suppliers;

$\prod^{sc}$：profit function of the whole supply chain

Assumptions :(1) suppliers have no risk preference, while retailers have risk preference; (2) following Yang's definition of supply chain coordination, this paper defines supply chain coordination as follows: ①the profit of both suppliers and retailers is greater than zero; ② the retailer's Mean-CVaR value is the largest; ③maximize the overall profit of the supply chain.

2. MODEL ESTABLISHMENT
In sales at the beginning retailers and wholesalers to negotiate first set a wholesale price of w, the supplier's decision variables for the repurchase price b, there must be at this time b,p,s disappear, the processing of the end of the season market strategy customers don't buy or can only be purchased at full price, so the retailers in pursuit of profit maximization, the retail price policy of j must be set to customers for products of psychological value v . The profit function of the retailer is:

$$\prod(Q,U) = (v-w)Q - (v-b)\int_0^Q (Q-U)du \qquad 1\text{-}(1)$$

The profit function distribution of retailers can be expressed as:

$$L_T(t) = \begin{cases} L(Q + \dfrac{t-(v-w)Q}{v-b}), & t < (v-w)Q \\ 1, & t \ge (v-w)Q \end{cases}$$

So the target is:

$$\frac{1-\lambda}{1-\alpha}\left[(v-w)Q - (v-b)\int_0^Q (Q-U)dL(U)\right] +$$

$$\begin{cases} \dfrac{\lambda-\alpha}{1-\alpha}[(b-w)Q + \dfrac{v-b}{\alpha}\displaystyle\int_0^{L^{-1}(\alpha)} UdL(U)], & Q > L^{-1}(\alpha) \\ \dfrac{\lambda-\alpha}{1-\alpha}[(v-w)Q + \dfrac{v-b}{\alpha}(\displaystyle\int_0^{Q} UdL(U) - QL(Q))], & Q \le L^{-1}(\alpha) \end{cases}$$

The retailer's optimal order quantity is:

$$Q_r^* = \begin{cases} L^{-1}(\frac{v-w}{v-b} + \frac{\alpha-\lambda}{1-\lambda}\frac{w-b}{v-b}), & \lambda < \frac{v-w}{v-b} \\ L^{-1}\left(\frac{\alpha}{\lambda}\frac{v-w}{v-b}\right), & \lambda \ge \frac{v-w}{v-b} \end{cases} \qquad 1\text{-}(2)$$

2.1 Ordering Strategy

Risk-averse retailers choose ordering strategies with higher conditional value-at-risk, while risk-averse retailers do the opposite.

Corollary :

$\alpha = \lambda$ means the retailer's appetite for risk is neutral

$\alpha < \lambda$ means the retailer's appetite for risk is risk aversion

$\alpha > \lambda$ means the retailer's appetite for risk is risk preferences

Prove:

When $\alpha = \lambda$

$$\frac{\lambda-\alpha}{1-\alpha}CVaR_{\alpha}[\prod(Q,U)] + \frac{1-\lambda}{1-\alpha}E[\prod(Q,U)] = E[\prod(Q,U)]$$

This is the profit expectation function when the retailer is risk-neutral.

When $\alpha < \lambda$

$$CVaR_{\alpha}[\prod(Q,U)] \le \prod(Q,U)$$

$$\frac{\lambda-\alpha}{1-\alpha}CVaR_{\alpha}[\prod(Q,U)] + \frac{1-\lambda}{1-\alpha}E[\prod(Q,U)] \le E[\prod(Q,U)]$$

Therefore, the risk preference at this time is risk aversion.

When $\alpha > \lambda$

$$\frac{\lambda-\alpha}{1-\alpha} < 0 \ ; \ \frac{1-\lambda}{1-\alpha} > 0$$

$$\frac{\lambda-\alpha}{1-\alpha}CVaR_{\alpha}[\prod(Q,U)] + \frac{1-\lambda}{1-\alpha}E[\prod(Q,U)] \ge E[\prod(Q,U)]$$

So the risk preference is the risk preference.

2.2 Supply Chain Coordination

When the repurchase contract is faced with the strategic behavior of customers and the risk preference of retailers, what relationship should be satisfied between the repurchase price and the wholesale price to ensure the coordination of the supply chain?

Corollary :

The retailer's buyback price has the following relationship with the wholesale price when the retailer has a risk preference and the supply chain using the buyback contract achieves coordination.

$$b = \begin{cases} m_1 w + n_1, & \alpha < \dfrac{v-c}{v-s}, 0 \le \lambda \le 1 \\ m_2 w + n_2, & \alpha \ge \dfrac{v-c}{v-s}, 0 \le \lambda \le 1 \end{cases}$$

$$\begin{cases} m_1 = \dfrac{(1-\alpha)(v-s)}{(1-\lambda)(v-c)+(\lambda-\alpha)(v-s)} \\ n_1 = \dfrac{v(1-\lambda)(s-c)}{(1-\lambda)(v-c)+(\lambda-\alpha)(v-s)} \end{cases}$$

$$\begin{cases} m_2 = \dfrac{\alpha(v-s)}{\lambda(v-c)} \\ n_2 = \dfrac{v[\lambda(v-c)-\alpha(v-s)]}{\lambda(v-c)} \end{cases}$$

$$w_{min} < w < w_{max}$$

1-(3)

Prove:

According to the definition of supply chain coordination, the optimal order quantity of the retailer with risk preference is equal to the optimal order quantity of the whole supply chain with risk neutrality.

$$Q_r^* = Q_C^* = \frac{v-c}{v-s}$$

$$\begin{cases} \dfrac{v-w}{v-b} + \dfrac{\alpha-\lambda}{1-\lambda}\dfrac{w-b}{v-b} = \dfrac{v-c}{v-s} \\ \dfrac{\alpha}{\lambda}\dfrac{v-w}{v-b} = \dfrac{v-c}{v-s} \end{cases}$$

1-(4)

$$\left[1 - \frac{m}{Q}\frac{(v-c)Q-\prod_b^{sc}}{v-s}\right] \ge \frac{n-s}{Q}\frac{(v-c)Q-\prod_b^{sc}}{v-s} + c$$

$$w\left[1 - \frac{m}{Q}\frac{(v-c)Q-\prod_b^{sc}}{v-s}\right] \le v - \frac{v-n}{Q}\frac{(v-c)Q-\prod_b^{sc}}{v-s}$$

1-(5)

The positive or negative of the equation in brackets depends on the α、λ. To sum up, when the parameters (w,b) of the buyback contract satisfy equations 1-(3) and 1-(5), the supply chain reaches the coordination state.

2.3 Relationships

The repurchase price in the repurchase contract directly affects the validity of the repurchase contract. In other words, it is necessary to explore the relationship between the repurchase price and risk factors and pessimistic coefficient, so as to develop a more effective repurchase contract.

Corollary :

Repurchase price b in piecewise interval （0，$\frac{v-c}{v-s}$）and [$\frac{v-c}{v-s}$, 1) are respectively about risk factors α reduction function and decreases with the increase of α; the repurchase price is about the negative factor λ on [0, 1] increasing function, increases with the increase of λ..

Prove:

According to 1-(3) ,

When $\alpha < \frac{v-c}{v-s}$, $\frac{\partial b}{\partial \alpha} = \frac{(1-\lambda)(c-s)(w-v)}{[(1-\lambda)(v-c)+(\lambda-\alpha)(v-s)]^2}$, $w < v$, so $\frac{\partial b}{\partial \alpha} < 0$,

The repurchase price is about the risk factors of **α** reduction function and decreases with the increase of **α**.

When $\alpha \ge \frac{v-c}{v-s}$, $\frac{\partial b}{\partial \alpha} = \frac{(v-s)(w-v)}{\lambda(v-c)} < 0$

The repurchase price b is about the risk factors of **α** b and decreases with the increase of **α** reduction function.

When $\alpha < \frac{v-c}{v-s}$, $\frac{\partial b}{\partial \lambda} = \frac{(c-s)(v-s)(1-\alpha)(v-w)}{[\lambda(c-s)-\alpha(v-s)+(v-c)]^2} > 0$

The repurchase price b is about the risk factors of **α** b and decreases with the increase of **α** reduction function.

Since the buyback price b is a piecewise function about a, it can only be verified that the buyback price b is a subtraction function about a risk factor in the piecewise interval, but it cannot be determined that the buyback price b is a subtraction function about a risk factor in the whole domain. But the repurchase price

is about the negative factor b **λ** increasing function, has nothing to do with piecewise interval.

2.4 Wholesale Price

The setting of the repurchase price in the repurchase contract directly affects the validity of the contract. It is still worth exploring to what extent the contract is effective, which is not only helpful to the policy formulation of suppliers, but also to protect the interests of suppliers and retailers, so as to ensure win-win cooperation between both parties.

Corollary :

There is a wholesale price w_0 that makes the buyback price b under the buyback contract equal to the residual value s. When the wholesale price is less than w_0, the buyback price b starts to be less than s, and the retailer will not participate in the buyback contract.

Prove:

$$b = \begin{cases} m_1 w + n_1, & \alpha < \dfrac{v-c}{v-s}, 0 \le \lambda \le 1 \\ m_2 w + n_2, & \alpha \ge \dfrac{v-c}{v-s}, 0 \le \lambda \le 1 \end{cases}$$

when $b = s$;

$$w_0 = \begin{cases} \dfrac{s-n_1}{m_1}, & \alpha < \dfrac{v-c}{v-s}, 0 \le \lambda \le 1 \\ \dfrac{s-n_2}{m_2}, & \alpha \ge \dfrac{v-c}{v-s}, 0 \le \lambda \le 1 \end{cases}$$

$$\begin{cases} m_1 = \dfrac{(1-\alpha)(v-s)}{(1-\lambda)(v-c)+(\lambda-\alpha)(v-s)} \\ n_1 = \dfrac{v(1-\lambda)(s-c)}{(1-\lambda)(v-c)+(\lambda-\alpha)(v-s)} \end{cases}; \quad \begin{cases} m_2 = \dfrac{\alpha(v-s)}{\lambda(v-c)} \\ n_2 = \dfrac{v[\lambda(v-c)-\alpha(v-s)]}{\lambda(v-c)} \end{cases}$$

According to the corollary 2, the repurchase price on the wholesale price of w b first derivative is greater than zero, namely the repurchase price decreases with the decrease of the wholesale price, while wholesale prices $w < w_0$, repurchase price b will begin to less than the salvage value s, appear this kind of circumstance, is mainly due to the supplier set the wholesale price in a lower wholesale price level, the purpose is to stimulate the retailer to order products, but the risk preferences, the retailers intends to increase the quantity of product unsalable.

With sale in the final, according to the regulations of the buy-back contract supplier failed to sell products to repurchase, so don't consider the inventory risk under the buyback contracts of retailers, suppliers and the retailers' inventory risk, but this is held on the basis of sacrificing their profits, but the supplier is bound to be on this order too much, so when the supplier set wholesale price under w_0, repurchase price b will begin to less than the salvage value s, unsalable caused by excessive order to prevent retailers, in particular, when the wholesale price $w = w_0$ buy-back contract degradation for the wholesale price contract at this time.

3. VALIDATIONG

According to the actual investigation, the orders of a Marketing Department in henan in recent 16 years are summarized, and the data are summarized as shown in table 1. According to the actual data in the table, the conclusion of the above theoretical exploration is verified in practice.

Table 1. Order summary for retailer W

YEAR	FREQUENCY	QUANTITY	SUM	CATEGORIES
2000	1	579	579	3
2001	1	554	554	4
2002	1	538	538	3
2003	1	548	548	5
2004	2	521,210	731	8
2005	2	498,255	753	7
2006	2	493,495	988	9
2007	2	441,430,	871	7
2008	2	439,428	867	10
2009	2	527,469	996	10
2010	3	351,327,360	1038	12
2011	3	360,359,343	1062	11
2012	3	420,380,406	1206	12
2013	5	290,326,321,314,302	1553	17
2014	5	299,290,505,272,263	1629	14
2015	5	326,529,211,234,259	1559	17

According to the data in table 1, the random demand of retailer W is assumed to be uniformly distributed, and the confidence level is taken as 95%. The average value and standard deviation of the order quantity in the above table are calculated as 386.8 and 106.9 respectively, and the confidence interval is calculated as (177,597) according to the confidence level.

In the sales cycle, the wholesale price of the retailer is w=1500 yuan, the cost of the supplier is c=1000 yuan, the selling price of the product is j=2000 yuan, and the residual value of the product is s=800 yuan. In order to simplify the calculation, the unit of the price is changed to 100 yuan.Therefore, the wholesale price of the retailer w=15, the cost of the supplier c=10, the customer's valuation of the product v=20, and the residual value of the product s=8.

Assume that pessimistic factors λ=0.2,λ=0.5,λ=0.8, the rest of the values are the same, discusses value as the change of risk factors, draw the image as shown below:

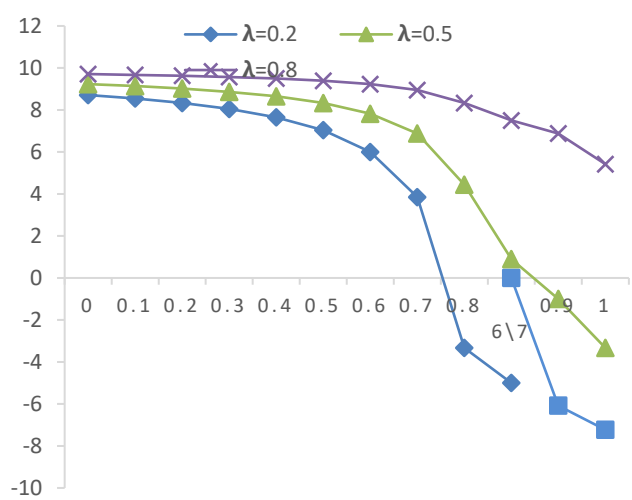

Figure 1. Influence of risk preference parameter λ.

As shown in figure 1, when pessimistic factors $\boldsymbol{\lambda}$ to a certain value, the repurchase price in range interval decreases gradually decreases as the risk factors, such as $\boldsymbol{\lambda}$= 0.2, the repurchase price b in (0, 6/7) and (6/7, 1) is about the risk factor reduction function respectively, in range $\frac{\partial b}{\partial \alpha} < 0$ interval has permanently tablished at this time. This situation shows that the greater the risk factors of retailers, the lower the degree of risk aversion at that time, the retailers will increase quantity of order to prevent the retailer's excessive lead to serious is greater than the market demand, product quantity appeared serious extrusion products, lead to products unsalable, in turn, damage the interests of the suppliers, so suppliers set lower the repurchase price to inhibit excessive order of retailers.

When the risk factors α is a certain value, the repurchase price b as pessimistic factor $\boldsymbol{\lambda}$ gets bigger and bigger, at this time $\frac{\partial b}{\partial \lambda} > 0$, the repurchase price b is increasing function of factor $\boldsymbol{\lambda}$ pessimistic. This indicates that the increasing pessimistic factor represents the retailers' strategy of reducing orders due to their preference for low profits. Therefore, in order to stimulate retailers to increase orders, suppliers will gradually increase the repurchase price to offset the pessimistic sentiment of retailers. When negative b has no actual meaning, can only explain the repurchase price b is about negative factor $\boldsymbol{\lambda}$, because once the repurchase price is less than the salvage value goods, retailers will have no incentive to participate in the repurchase contract.

On the basis of figure 1, when the risk factor $\boldsymbol{\alpha}$ or pessimistic factor $\boldsymbol{\lambda}$ as a fixed value, the retailer, the repurchase price, and the optimal quantity of the supply chain members of their respective profits as the change of another variable can present a what kind of change trend. Assume that pessimistic factors $\boldsymbol{\lambda}$ = 0.55, the rest of the variable values are the same, the present model in chapter, using the Matlab simulation when the risk factors $\boldsymbol{\alpha}$ from 0 to 1.0, the retailer's optimal order, the repurchase price changes and their profit of supply chain members, as shown in table 2.

Table 2 Supply chain performance under risk factor values

Unit: yuan

$\boldsymbol{\alpha}$	b	RERALIER PROFIT	SUPPLIER PROFIT
0	9.3	1700.16	-62.31
0.1	9.2	1672.70	-34.85
0.2	9.1	1638.37	-0.52
0.3	9.0	1590.00	47.54
0.4	8.8	1525.08	112.77
0.5	8.5	1428.96	208.89
0.6	8.1	1267.61	370.24
0.7	7.3	999.84	638.01
0.8	5.3	309.81	1328.00
0.9	4.2	-1183.53	2821.39
1.0	0.9	-1911.32	3549.17

Using Matlab to draw these groups of data, more intuitive to show the results of the study.

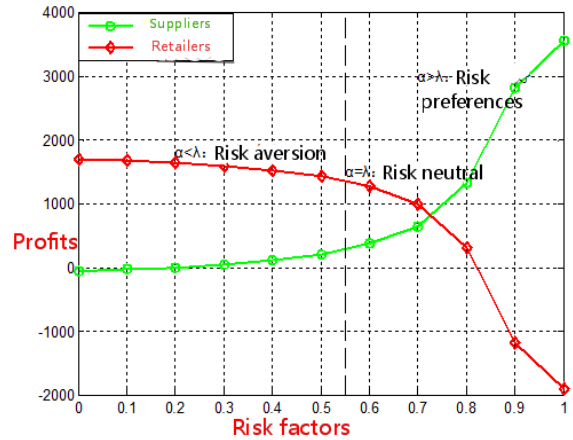

Figure 2. Supply chain performance under risk factor values

According to table 1 and figure 2 , when pessimistic factor $\boldsymbol{\lambda}$ = 0.55, under the condition of the supplier's expected profit as risk factor $\boldsymbol{\alpha}$ increases. When the risk factors in the interval (0,0.3), the supplier's expected profit is negative, this is mainly due to the wholesale price remains the same, on the basis of suppliers in order to stimulate the risk aversion and the retailers to increase quantity of set higher as a result of the repurchase price, because the repurchase price is too high the supplier's profits would suffer, so that there will be negative, but this situation will only appear in the special period, such as new product launch period. Whe retailers risk neutral gradually, the repurchase price is gradually back the supplier's profit is begins to increase gradually, but tend to risk appetite gradually as the risk preference of retailers, retailers excess order began to appear, suppliers in order to prevent the retailer's order to reduce excessive repurchase price until it is equal to the residual value s, therefore, the supplier's expected profit as risk factor $\boldsymbol{\alpha}$ and continue to increase.

Retailer's expected profit is decreased with the increase of risk factors, in contrast to the analysis of the supplier, when retailers are risk averse, suppliers will higher the repurchase price to stimulate the retailers ordering more, even at the expense of their own profits to stimulate retailers to increase your order, so the retailer's profit is the largest. When retailers' own risk appetite gradually tends to be neutral, the buyback price starts to fall at the same time the retailers' expected profit also starts to fall. As retailers to risk preferences when retailers tend to be high risk value ordering strategy which began to increase your order, but suppliers in order to prevent product unsalable began to use low repurchase price to suppress the retailer's order too much, as the bottom line is the salvage value s of the repurchase price is lower than retailers, at this time of the repurchase contract has no binding, retailers expect profits also fell to the lowest at this time.

In the same way, we can also assume that pessimistic factors $\boldsymbol{\alpha}$ = 0.55, the rest of the variable values are the same, when risk factors $\boldsymbol{\lambda}$ from 0 to 1.0, using Matlab to observe the retailer's optimal order, the repurchase price and value their profits of supply chain members, as shown in table 3.

Table 3 Supply chain performance under Pessimistic factor values

Unit: 100 yuan

λ	b	RERALIER PROFIT	SUPPLIER PROFIT
0	5.3	340.71	1297.14
0.1	6.0	563.85	1074
0.2	6.6	769.83	888.02
0.3	7.1	955.21	682.64
0.4	7.7	1130.29	507.56
0.5	8.1	1288.21	349.64
0.6	8.5	1439.62	198.59
0.7	8.9	1576.57	61.28
0.8	9.3	1703.59	-65.74
0.9	9.6	1823.74	-185.9
1.0	12	1937.04	-299.19

Using Matlab to draw these groups of data, more intuitive to show the results of the study.

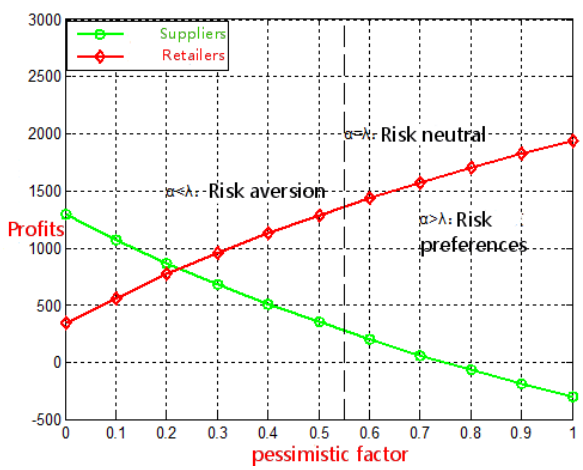

Figure 3. Supply chain performance under pessimistic factors values

When risk factors **α** fixed, the repurchase price b as retailers is gradually increasing with the increase of **λ** pessimistic factors. The retailer's optimal order decreases gradually with the increase of negative factors **λ**.The negative factor **λ** gradually increase represents the retailers are more likely to get low profit and began to reduce the quantity, the supplier in order to stimulate the retailers started to use gradually increased the repurchase price increase your order b stimulate retailers to increase your order, now the whole supply chain inventory risk to start a transfer this to suppliers, so the supplier's expected profit has declined, and the corresponding is the retailer's expected profit growth.

4. CONCLUSION

This paper comprehensively considers the two variables that can affect the retailer's decision, customer strategic behavior and retailer's risk preference. The main purpose is to hope that the optimized repurchase contract can better adapt to the real environment, so that the supplier can make a more reasonable repurchase price to guide the retailer to place a reasonable order. The study found that when retailers have unilateral risk preference, repurchase contracts that meet certain conditions still have a coordinating effect on the supply chain, in which the first partial derivative of the repurchase price with respect to the wholesale price is always greater than zero, indicating that regardless of retailers' risk preference, the repurchase price still increases with the increase of the wholesale price. In addition if supplier hope by setting the lower wholesale prices to stimulate retailers to increase your order, so in order to buy back price will appear smaller than the salvage value of the situation, the main reason is to stop the retailer's order caused by excessive product unsalable, less than the salvage value of the repurchase price main purpose is to make compensation to the supplier's loss of profit.

5. ACKNOWLEDGMENTS

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