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A Design Method for Configuration and Setup of a RFID System in a Warehouse

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Abstract--In this paper, a design method is proposed and aided to assist warehouse designers to form a RFID set up and configurations in a cost effective way. The proposed method incorporates the methodology of RFID experiment and mathematical model for the cost and benefit analysis of RFID set up. The proposed model is used to investigate the contribution of the RFID system under different parameters including reliability of the RFID system, tagging strategy, risk of inventory lost and value of tagged objects. With the help of the proposed method, the result can be served as indication for RFID setup in a warehouse.

I. INTRODUCTION

In recent years, the restructure of the customers' supply chain has redefined the way a logistics service is operated. Traditional logistics services have been reformed and integrated with auxiliary function such as light packaging, labelling, knitting, and quality inspection to form an integrated logistics service. Thus, the warehouse operations is no longer for inventory storage and protection of goods only, but includes different operations ranged from receiving, package of goods, after sale services, light assembly, inspection to consolidation. Hence, careful warehouse system design is important to ensure the above operations are executed at the optimum performance level in terms of capacity, throughput and customer service. The design of a warehouse is a complex problem. It includes a large number of interrelated decisions among the warehouse processes, warehouse resources and warehouse organizations [1]. The warehouse system design includes making decisions on the number and location of docks, input/output points and aisles, formation of storage partitions and picking zones, selection of handling equipment and racks and storage arrangements. In addition, designers are also required to consider operational aspect, types of service provided, item flow rate, capacity planning,…, etc. In the literature, number of researchers has proposed different methods and models for the design of warehouse system, nevertheless, the study between the integration of information technology and warehouse system is seldom addressed.

Indeed, various kinds of information system and technology have been well developed and aimed to improve the warehouse operations efficiency and reliability. Warehouse management system (WMS) is one of the information systems that are widely be used to manage and support the inventory and storage operations. In addition, many researchers have now advocated the utilization of an automatic data identification technology, named radio frequency identification (RFID) for the support of warehouse operations. The majority of research reported that the adoption of RFID has greatly improved the inventory accuracy of a warehouse, furthermore, some of the research studies are also be found which demonstrate the RFID adoption for the decision support of resource allocation in warehouse. Unlike the installation of WMS, the set up of RFID is complex and the configuration such as location of reader and tag, selection of RFID technology is highly related to the warehouse system. Hence, after the warehouse location, number and size, forklift selection have been determined, warehouse designer may want to determine what RFID set up are to be included and the type of RFID, so that a full RF coverage can be constructed for a warehouse system. Although the set up of RFID and the specification can be conducted through the experiment, the benefit and cost of analysis of RFID set up are also to be included. Thus, a joint decision regarding RFID set up test and cost and benefit analysis are required to consider sequentially by generating multiple options and then determine which one has the optimum result for the RFID set up at a warehouse.

In this paper, a design method is proposed which will assist warehouse designers to form a RFID set up and configurations in a cost effective way. The proposed method incorporates the methodology of RFID experiment and mathematical model for the cost and benefit analysis of RFID set up. With the help of the proposed method, the result can be served as indication for RFID setup in a warehouse. This paper is divided into four sections. The supportive literature about the warehouse design and RFID technology in warehouse operations is presented in Section 2. Section 3 contains a description of the proposed method. Finally, a conclusion is provided in Section 4.

II. LITERATURE REVIEW

A. Background of Warehouse Design

Warehouses are a key aspect of modern supply chains and play a vital role in the success, or failure, of businesses today [2]. The primary functions of warehouse are providing temporary storage and protection of goods to hold inventory for the customers. In addition to those services, the warehouses have been evolving to act as cross-docking points (where goods are moved directly from inward to outward vehicles without being put away into inventory), value added service centers (e.g. pricing and labeling goods for customers), production postponement points (configuring or assembling goods specifically to customer demand so that a smaller range of generic products can be held in inventory), returned good centers (for reverse logistics of packaging, faulty goods or end-of-life goods) and many other miscellaneous activities, such as service and repair centers [3].

In order to provide higher customer service levels, minimize operations cost and better utilize resources, it is thus imperative that warehouses are designed in a cost efficient way. In spite of the importance of the warehouses design, a number of reviews of literature have been conducted on the above subject [1; 4; 5; 6; 7].

At the early of 90's, the emerged of Japan management philosophy-Just-it-time (JIT) production have demanded warehouse to deliver more frequent with short response time from a significantly wider variety of Stock Keeping Units (SKU's). The new interest in quality forced warehouse managers to re-examine their warehouse operation from the viewpoint of minimizing product damage, establishing short and reliable transaction times and improving order-picking accuracy [8]. Hence, there is a great need for the integration of information technology (IT) to support the planning and control of warehouses. The development of IT such as electronic data interchange (EDI), enterprise resources planning (ERP), warehouse management system (WMS) and radio frequency identification (RFID) has widely been adopted to support the operations of warehouse such as improve the cooperation among the companies in the supply chain, provide the immediate feedback of sales data and manage the inventory records. Among these technologies, because RFID system is an automatic data collection tools that is physically located at the warehouses, the effectiveness and set-up of RFID technology should be taken into account during the design of warehouses. However, Rowley [9] comments that there is not a procedure for systematically analyzing the requirement and designing a warehouse to meeting the operational need using the most economy technology. Similarly, Goetschlckx et al. [10] also argue that a comprehensive and science-based methodology for the overall design of warehousing system does not appear to exist. Therefore, it is essential to investigate the contribution of the RFID system for facilitating the formation of a RFID set up and configurations in a cost effective way.

B. RFID adoption in warehouse

The origins of RFID technology can be traced way back to laboratory research in the 1940s that focused on reflected power communication. Its commercial use began in the 1980s, primarily in the railroad and trucking industries [11]. These applications used battery powered active RFID tags and proprietary systems to track and manage capital assets, such as rail cars and cargo containers [12]. In a RFID system, the basic components consist of a tag or transponder, a reader or transceiver that reads, and a computer containing database and information management software [13]. RFID tags can be divided into active, passive, or semi-passive. Passive and semi-passive RFID send the data by reflection or modulation of the electromagnetic field that was emitted by the reader. The typical reading range is between 10cm and 3m. The battery of semi-passive RFID is only used to power the sensor and record the logic. The communication of active RFID is powered by its own battery. This enables higher signal strength and extended communication range of up to 100 m. However, the implementation of active communication requires larger batteries and more electronic components. The typical price of active sensors is between five or ten times the price of semi-passive RFID loggers. The RFID technology has widely adopted in different business operations, including access control to buildings, document tracking, livestock tracking and identification, vehicle security, product authentication, retail, sports timing, supply chain, ticketing, and wireless payment [14]. Partsch [15] illustrates several benefits of adopting RFID technology in warehouse as illustrated below.

- Automated identification of all goods is allowed in the warehouse using RFID label, while the traceability of product or pallet is at a satisfactory level.
- Scanning or inspection is unnecessary so that processing time and costs can be reduced.
- Recycling RFID labels is acceptable so that the material costs are able to be reduced.
- The system can serves as a car-navigation system to support forklift truck (FLT) driver by prohibiting access or transit to incorrect designated area or guiding cargo loading and unloading activities.
- The customer benefits from the implementation of this warehouse positioning systems. Products now can be traced at both inbound and outbound stages in the supply chain.

With such benefits, a number of RFID adoptions have been taken place in warehouse environment. Chow et al. [16] present an RFID-based resource management system using RFID and artificial intelligence technologies to collect dynamic and static logistics data and then formulate a real-time based resource usage package for warehouse operations. Moreover, world-famous companies, such as Wal-Mart, Gillette, and Proctor & Gamble, have implemented RFID technology for handling their warehouse resources [17; 18]. Poon et al. [19] propose a RFID case-based logistics resource management system (R-LRMS) to improve the efficiency and effectiveness of order-picking operations in a warehouse. Lee and Chan [20] demonstrate a RFID-based Reverse Logistics System to present the benefits of using a computational intelligence technique and RFID technology and form an integrated model for optimizing the coverage of product returns.

In summary, RFID system set up in a warehouse system is a complex problem that involves various decisions such as data accuracy and implementation cost issue. Form the reviews of literature, there are many researches on analyzing specific aspects of warehouse design, including system, capacity, sizes and selection of equipment are found. However, a practical guide to the planning, implementation and trade-off analysis of RFID system in a warehouse is seldom addressed. In this paper, a design method is proposed and aided to assist warehouse designers to form a RFID set up and configurations in a cost effective way.

III. METHOD ASSUMPTION FOR THE COST AND BENEFIT ANALYSIS AND RFID SET-UP IN A WAREHOUSE

Since the system of constructing initial information is bi-channel protocol between customer and warehouse database system, the warehouse management system and construction of initial information are independent. The now constructed mathematical model in this paper is directly reflecting the dominant factors from policies of warehouse system, and simply assumed the initial information is under control which is independent to the warehouse management system.

In this model, results of Loss, Cost and profit analysis are the most core interesting section for engineers to justify different RFID systems and current warehouse management policies on the same controlled platform. The policy of RFID warehouse management system is divided into three levels of implementation. They are:- pallet-level, case-level and combined mode. The scope of profit, loss and cost investigation of the RFID system is based on an assumption that the initial information is under control with 100% reliability due to the successful implement of SOP for bi-channel protocol between customer and warehouse database system. The constructed mathematical model consists of several policy parameters for analysis of the loss, cost and profit of different warehouse management strategies. Those parameters are statistical estimated values so that those parameters are possibly determined from each individual situation. The flexibility of the mathematical model's parameters provides sufficient informative Loss, Cost and profit analysis to help engineers make decision for their own integrated loss, cost and profit weighting. Hence, the major contribution and scope of this model is addressing the warehouse system's reliability for internal operations due to different RFID implement levels and former comparison system of a warehouse on the same controlled platform and provide sufficient informative Loss, Cost and profit analysis for engineers to justify their own system.

This paper considers RFID set-up configurations and analysis in warehouses that include (a) RFID implementation set-up and (b) Model development for the cost and benefit analysis of RFID set up.

(a) RFID implementation set-up

According to Poon et al. [19], there are four stages, namely, i) Warehouse system study, ii) Evaluation of RFID equipment, iii) Testing of RFID reading performance, and, iv) Results analysis and implementation, for implementing a set of RFID equipment in a warehouse. The detailed descriptions of the steps are shown as below.

Stage 1: Warehouse system study

According to Bhuptani and Moradpour [21], the physical and environmental factors in the warehouse may affect the readability and accuracy of the RFID system. Besides, the systems of warehouse vary among different companies. Thus, it is essential to analysis the layout and specification of warehouse, the specification of material handling equipments and materials to be handled. By studying the actual environment, the specification of the warehouse is determined for RFID equipment selection.

Stage 2: Evaluation of RFID equipment

As mentioned before, there are two common types of RFID equipment available on the existing market, namely active RFID technology and passive RFID technology. The items of equipment of these technologies vary in size, cost, reading performance, and in application domains. The most common RFID equipment used in warehouses is the Active (Alien 2850 MHz Series) and the Passive (Alien 9800 series) RFID apparatus. Experiments have performed for evaluating the reading performance of these types of equipment in order to select the most appropriate one for the actual warehouse environment.

Stage 3: Testing of RFID reading performance

Four tests, namely (i) Orientation Test, (ii) Height Test, (iii) Range Test, and (iv) Material Test, are adopted to evaluate the performance of the RFID equipment.

Stage 4: Result analysis and implementation

After analyzing the result of the tests, the most effective radio frequency (RF) cover range of the reader is determined. Based on the results, the RFID equipment is installed at the appropriate locations in warehouse environment.

(b) Model development for the cost and benefit analysis of RFID set up

There are three tagging strategies for RFID system. They are:- case-level strategy, pallet-level strategy and combined mode strategy, which can be installed in a warehouse system for inventory management and storage purpose. The case-level strategy is tagging the RFID tag on each case of the products, such that neither miss-tagging nor duplicated tagging situations exist under the controlled standard operating procedure. The pallet-level strategy is tagging the RFID tag on the pallet of the products. The tagged information is reliable accordance with controlled standard operating procedure. In addition, combined mode strategy is a tagging procedure which allows ρ_1 portion of product using case-level strategy and ρ_2 portion of product using pallet-level strategy, such that

$$\rho_1 + \rho_2 = 1$$

The RFID system is adopted for the purposes of items monitoring and identification, and the reliability of the warehouse system refers to capability for inventory management and warehouse operations.

(i) Degree of improvement on inventory management under different RFID tagging strategies

In this paper, contribution of RFID system implementation to the warehouse system and inventory management is quantized to be an index value, degree of improvement $\eta_j^r, \forall j \in J$ set of the product types. The degree of improvement is estimating the performance change of the warehouse system after implementation of RFID system (RFIDs) and before implementation of RFID system (nRFIDs). The performance index of the system is denoted as η_j, and

$$\eta_j = \frac{\kappa_j}{c_j + l_j} \tag{1}$$

where κ_j is the profit per unit time of the warehouse system for product *j,* and time-independent estimator

$$\kappa_j = \frac{\chi_j \vartheta_j v_j}{\tau_j^{\vartheta}} - c_j - l_j \tag{2}$$

c_j is the actual operation cost per unit time for product *j;*

l_j is the loss per unit time for product *j*,

χ_j is the scaling factor for determine the proportion the profit margin for product item *j*,

ϑ_j is the ordering quantities, such that the order is periodic $\vartheta_j(t) = \vartheta_j(t + \tau_j^{\vartheta})$,

and v_j is value of one item unit of product *j*.

Furthermore, the degree of improvement η_j^r is defined as follows

$$\eta_j^r = (-1)^k \left[\frac{\eta_j(RFIDs)}{\eta_j(nRFIDs)} - 1\right], \quad k = \begin{cases} 0 & if \quad \eta_j(nRFIDs) \geq 0 \\ 1 & elsewhere \end{cases} \tag{3}$$

A mathematical model is developed to investigate phenomena of limited reliability of the warehouse system, such that existence of transaction error, in probability, due to the limited reliability of the system is affecting the performance of the warehouse system, actual operation cost and risk loss. The mathematical model of transaction error is described as below.

(ii) Transaction error of a warehouse system before and after implementation of RFID system

Transaction error of a warehouse system due to reliability of the constructed RFID system for product *j* is denoted as e_{1j} for reading process, $\forall j \in J$. The characteristics of reliability of the constructed RFID system, before implementation of RFID system (nRFIDs) and after implementation of RFID system (RFIDs) are shown in **Table 1.**

TABLE 1 - THE CHARACTERISTICS OF RELIABILITY OF THE RFIDS AND NRFIDS

	Probability of miss counting	probability of exact counting	probability of repeated counting
(RFIDs)/ for 1 tagged item unit	p_0	p_1	p_2
(nRFIDs)/ for 1 item unit	φ_0	φ_1	φ_2

$$p_0 + p_1 + \sum_{n=1}^{\infty} p_2^n = 1, \quad p_2 = \frac{1 - p_0 - p_1}{2 - p_0 - p_1};$$
$$\varphi_0 + \varphi_1 + \sum_{n=1}^{\infty} \varphi_2^n = 1, \varphi_2 = \frac{1 - \varphi_0 - \varphi_1}{2 - \varphi_0 - \varphi_1} \tag{4}$$

The probability of repeated counting follows geometric distribution and time-independent, so that the mathematical expressions of equation 4 are constructed.

The expectation of counting result for 1 item unit is denoted as $\hat{n}$,

$$\hat{n} = \begin{cases} \hat{n}_1 = p_0(0) + p_1(1) + \sum_{n=1}^{\infty} p_2^n(n+1) = p_1 + (3 - p_0 - p_1)(1 - p_0 - p_1) & for \quad RFIDs \\ \hat{n}_2 = \varphi_1 + (3 - \varphi_0 - \varphi_1)(1 - \varphi_0 - \varphi_1) & for \quad nRFIDs \end{cases} \tag{5}$$

and time-independent transaction error for product size M_j is e_{1j} which is different between the actual amount and expectation of the counting result.

$$e_{1j} = M_j - \hat{n} M_j = (1 - \hat{n}) M_j$$

In this paper, it is assumed that the transaction error of a RFID system only happened when the product has more than one tag, such as case-level tagged product. The one-to-one product assessment, pallet-level tagged product, is assumed to be zero transaction error for the RFID system. After the introduction of the statistical model of transaction errors, the "loss and risk" due to transaction errors and actual operating cost models for *RFIDs* and *nRFIDs* are illustrated at section (iii) and (iv) respectively.

(iii) "Loss and risk" models due to transaction errors of RFID system l_j

The loss and risk for the warehouse system is related to inaccurate delivered quantities to the customers, shrinkage or over-transferring of the order execution and value of unit product *j* is v_j. In this paper, the ordering quantity is a periodic function as stated in section 4.1, $\vartheta_j(t) = \vartheta_j(t + \tau_j^{\vartheta})$, where τ_j^{ϑ} is ordering period for product *j*. Loss of item due to the transaction errors of RFID system such as mis-read of RFID tag, malfunction of RFID reader and tag under different tagging RFID strategy are defined as below.

The values difference of requested quantity ϑ_j and actual pickup quantity $\hat{\vartheta}_j$ is defined as $\varepsilon_j = \vartheta_j - \hat{\vartheta}_j$. The time-independent loss per unit time is denoted as l_j . The total loss for product j is defined as $L_j = |\varepsilon_j| v_j$ and v_j is product's value. If $\varepsilon_j < 0$, this is a situation that the actually delivered quantity is more than requested quantity due to the ordering from customer and the loss is undertaken by the warehouse system. Else if $\varepsilon_j > 0$, this is a situation that the actually delivered quantity is less than the requested quantity ordering from customer, and there is penalty on the warehouse system. So that risk loss due to compensation or shrinkage per unit time l_j is defined as total loss for product j over the ordering period.

$$l_j = \frac{v_j|\varepsilon_j|}{\tau_j^{\vartheta}}, \varepsilon_j \approx \begin{cases} \left(1-\frac{1}{\hat{n}_1}\right)\vartheta_j & for\ \ case-level\ \ strategy\ \ of\ \ RFIDs \\ \left(1-\frac{1}{\hat{n}_2}\right)\vartheta_j & for\ \ pallet-level\ \ strategy\ \ of\ \ RFIDs\ \ or\ \ nRFIDs \\ \left(1-\frac{\rho_1}{\hat{n}_1}-\frac{\rho_2}{\hat{n}_2}\right)\vartheta_j & for\ \ combined\,\mathrm{mod}\,e\ \ strategy\ \ of\ \ RFIDs \end{cases} \tag{6}$$

(iv)Actual operating cost model analysis for inventory management before and after RFID system implementation

The actual cost is conceptual related to the accurate inventory level of the warehouse. In this model, the receiving quantities of product j is periodic function, similar to ordering function, $R_j(t) = R_j(t + \tau_j^R)$ and the measured receiving quantity is denoted as $\hat{R}_j = R_j$ and the transaction error is eliminated at the tagging stage under controlled standard operating procedure. Hence, the inventory level $I_j(t)$ at time t and its time derivative $I_j'(t)$ are defined as follows.

$$I_j(t) = R_j(t) - \hat{\vartheta}_j(t),$$

$$I_j'(t) = \frac{\partial}{\partial t} I_j(t) = \frac{\partial}{\partial t}\left(R_j(t) - \hat{\vartheta}_j(t)\right) \approx \frac{R_j}{\tau_j^R} - \frac{\hat{\vartheta}_j}{\tau_j^{\vartheta}} \approx \frac{\hat{R}_j}{\tau_j^R} - \frac{\vartheta_j - \varepsilon_j}{\tau_j^{\vartheta}} \tag{7}$$

The time derivative $I_j'(t)$ are approximated by first order derivative, and hence the actual time-independent operating cost of handling product j per unit time due to storage are respectively defined as c_j

$$c_j \approx c_j^0 + \bar{c}_j \left|\frac{\partial}{\partial t} I_j(t)\right| = c_j^0 + \bar{c}_j \left|\frac{\hat{R}_j}{\tau_j^R} - \frac{\vartheta_j - \varepsilon_j}{\tau_j^{\vartheta}}\right| \tag{8}$$

The constant c_j^0 is minimum facilitate cost per unit time and $\bar{c}_j$ is average cost per unit product for handling product j. That implies even the receiving rate and the delivering rate are synchronized, such that the cost for physical storage is zero, there is fundamental cost, permanent facilitated, due to the equipment setup for that product j. The parameters of the actual operating cost per unit time model are illustrated in **Table 2**.

TABLE 2 - PARAMETERS OF THE ACTUAL OPERATING COST PER UNIT TIME MODEL

	RFIDs (case-level strategy)	RFIDs (pallet-level strategy)	RFIDs (combined mode strategy)	nRFIDs
c_j^0	α_0	β_0	$\rho_1\alpha_0 + \rho_2\beta_0$	γ_0
$\bar{c}_j$	$\bar{\alpha}_0$	$\bar{\beta}_0$	$\rho_1\bar{\alpha}_0 + \rho_2\bar{\beta}_0$	$\bar{\gamma}_0$

Verification of the mathematical models

In this section, an illustrative example for verification of the models is used for study the improvement of the systems RFIDs (case-level strategy, pallet-level strategy and combined mode strategy) to nRFID system. The combined mode of the RFID system is proposed to be $\rho_1 = \rho_2 = 0.5$. For investigation of RFID system, there are 5 parameter sets $\{p_0, p_1\}$ to control the reliability of the RFID systems; for the nRFID system, one control set of reliability parameters is given as $\langle\varphi_0, \varphi_1\rangle = \langle 0.20, 0.60\rangle$. Now, the warehouse system consists of 10 products, $J = 10$ and the testing parameters are initiated as follows.

$$\alpha_0 = 20, \beta_0 = 20, \gamma_0 = 10; \bar{\alpha}_0 = 1.5, \bar{\beta}_0 = 1.0, \bar{\gamma}_0 = 3.0$$

$$\tau_j^R = \tau_j^{\vartheta} = 1,$$

$$\vartheta_j(t) = \vartheta_j\left(t + \tau_j^{\vartheta}\right), \underset{\sim}{\vartheta} = \langle 30\ 30\ 40\ 60\ 70\ 30\ 29\ 49\ 65\ 100\rangle^T$$

$$R_j = 1.2\vartheta_j, \quad \chi_j = 1.2$$

Suppose the profit margin ration is a constant for all product j and the ordering-receiving period are identical, the results of the systems performance for each product are shown in **Table 3**.

TABLE 3 - VERIFICATION OF THE PERFORMANCE MODEL OF RFIDS AND NRFIDS

nRFID													
	psi0	psi1	eta1	eta2	eta3	eta4	eta5	eta6	eta7	eta8	eta9	eta10	
	0.20	0.60	12.20	12.20	12.84	13.53	13.75	12.20	12.12	13.21	13.65	14.15	
Case-level RFID													
	p0	p1	eta1	eta2	eta3	eta4	eta5	eta6	eta7	eta8	eta9	eta10	Degree of Improvement
	0.05	0.90	22.52	22.52	27.12	33.94	36.54	22.52	22.00	30.51	35.29	42.35	1.25
	0.10	0.80	19.35	19.35	22.70	27.36	29.05	19.35	18.96	25.06	28.25	32.67	0.85
	0.20	0.70	7.58	7.58	8.13	8.74	8.94	7.58	7.51	8.46	8.85	9.30	-0.36
	0.30	0.60	3.44	3.44	3.58	3.73	3.77	3.44	3.42	3.66	3.75	3.86	-0.72
	0.40	0.50	1.62	1.62	1.67	1.72	1.74	1.62	1.62	1.70	1.73	1.76	-0.87
Pallet-level RFID													
	p0	p1	eta1	eta2	eta3	eta4	eta5	eta6	eta7	eta8	eta9	eta10	Degree of Improvement
	0.05	0.90	13.33	13.33	14.92	16.90	17.56	13.33	13.14	15.95	17.25	18.87	0.19
	0.10	0.80	13.33	13.33	14.92	16.90	17.56	13.33	13.14	15.95	17.25	18.87	0.19
	0.20	0.70	13.33	13.33	14.92	16.90	17.56	13.33	13.14	15.95	17.25	18.87	0.19
	0.30	0.60	13.33	13.33	14.92	16.90	17.56	13.33	13.14	15.95	17.25	18.87	0.19
	0.40	0.50	13.33	13.33	14.92	16.90	17.56	13.33	13.14	15.95	17.25	18.87	0.19
Combined mode RFID													
	p0	p1	eta1	eta2	eta3	eta4	eta5	eta6	eta7	eta8	eta9	eta10	Degree of Improvement
	0.05	0.90	16.75	16.75	19.25	22.56	23.72	16.75	16.46	20.95	23.17	26.11	0.55
	0.10	0.80	15.78	15.78	17.99	20.87	21.87	15.78	15.51	19.48	21.40	23.90	0.44
	0.20	0.70	15.18	15.18	17.23	19.87	20.77	15.18	14.93	18.60	20.35	22.61	0.38
	0.30	0.60	7.71	7.71	8.27	8.91	9.11	7.71	7.64	8.61	9.02	9.49	-0.35
	0.40	0.50	4.47	4.47	4.69	4.92	4.99	4.47	4.44	4.82	4.96	5.12	-0.64

IV. CONCLUSIONS

This paper has proposed a design method for configuration and setup of a RFID system in a warehouse. The paper described the experiments of physical RFID tagging and reader read range study and mathematical model for the analysis of RFID trade-off analysis. The results of this paper not only provide a practical guidance for warehouse designers in RFID set-up, but also enable warehouse designers to define the benefits obtained after the adoption of the RFID system. Therefore, the contribution of this paper would be of great assistance on the current techniques used by practitioners for the RFID set up in a warehouse. In future, the scope of the proposed method will be enriched by adopting the simulation analysis thereby providing qualifying data and information for warehouse designers.

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