YANGON TECHNOLOGICAL UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING

IMPROVING THE EFFICIENCY AND PRODUCTIVITY OF GARMENT FACTORY USING INDUSTRIAL ENGINEERING TECHNIQUES

BY

MAUNG AUNG HTET NAING
MECH-19 (FEBRUARY, 2019)

(B.E. THESIS)

SEPTEMBER, 2019
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DEPARTMENT OF MECHANICAL ENGINEERING

We certify that we have examined, and recommend to the University Steering Committee for Undergraduate Studies for acceptance of the thesis entitled **"IMPROVING THE EFFICIENCY AND PRODUCTIVITY OF GARMENT FACTORY USING INDUSTRIAL ENGINEERING TECHNIQUES"** submitted by **Maung Aung Htet Naing, Roll No. Mech-19 (February 2019)** in partial fulfilment of the requirements for the degree of Bachelor of Engineering (Mechanical).

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ABSTRACT

In case of readymade garments (RMG) industries, productivity improvement is vital to decrease the production lead time as well as manufacturing cost. Many garment industries are rapidly evolving in Myanmar due to lesser costs comparing to other countries, economic and political changes. On time delivery with quality and quantity is important for any manufacturing industry. At present, lead time is decreasing day by day and customer requirements are also continuously changing. To fulfill the customer's demand, whole production system should be more capable and efficient. For this reason, productivity is important for manufacturing industries. Reducing costs and increasing profit are must-to-do factors to survive in any competitive market.

This thesis represents the use of some IE tools and techniques for improving the productivity and efficiency throughout the production process. Time study, method study, capacity study alongside with the calculation of SMV, capacity, efficiency are performed on two underwear products. The proper trainings are given to line-leaders and supervisor. Daily efficiency tracker, SMV data bank and non-productive time sheet are installed. Operators are motivated to give their maximum available output. Finding new method improvements to reduce cycle time, using work-sharing method among operators are performed in this study and sewing line efficiency is increased by 5.91 %. The factors that cause low productivity of the line are observed and proper solutions are recommended.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1. The Historical Background of Garment

In earlier days, garment was only a basic necessity used to cover the body and to protect from the weather. Over the time, people became concerned about the comfort of wearing and also the durability of the product. Garment began to be made with different fabrics to suit the climatic conditions and thus the requirement of seasonal wears emerged. When people started having social gatherings, they began to think about having a unique look, which would reflect their lifestyle. Since garment is one of the three basic needs for a human, it has retained an important place in human life starting from the pre-historic era to today's modern world.

1.2. The Myanmar Garment Sector

The garment market is important to the economy in Myanmar. The Asian garment industry is the largest regional garment industry in the world with China alone having 37.8% of global clothing exports by value [1]. Of the leading exporters of clothing in the world by value; 11 of the top 15 exporters are Asian countries. Myanmar does not compete with the low cost, bulk order countries such as Bangladesh, India, Cambodia and Vietnam in terms of product. Although China is a significantly larger player than Myanmar in the global and regional garment industry, the country is rapidly upgrading. This means the importance of the China garment industry is diminishing, as the size of the labor force decreases, and the availability of higher status and higher paid jobs increases.

Myanmar has some advantages over other regional garment producers including low wages (lower than everywhere except Bangladesh) and a ready supply of relatively well educated labor. Wages in other countries such as China are rising, and competition for production capacity is increasing, so buyers are looking for alternative locations for production. Labor shortages and frequent labor strikes in countries such as Cambodia, as well as significant labor standards risks and health and safety concerns in Bangladesh are also driving buyers to diversify their sourcing locations. Constraints to growth still exist in Myanmar especially poor infrastructure, lack of supporting functions, longer lead times and the difficulties of doing business in the country. The WTO estimates that the value of clothing exports from Myanmar in 2012 was US$972 million and the sector accounted for 10.9% of the country's total merchandise exports.

Although Myanmar still can't compete with other regional garment producers, it is in close competition with them. So, in order to keep the market in hand, it is required to adopt the modern management techniques for productivity, efficiency and profit enhancement. Unfortunately, most of the textile industry despite of having a very busy and healthy business activities don't look towards business excellence methods. This causing them extra cost, heavy wastages, price increase and quality issues.

1.3. The Importance of Productivity Improvement and Waste Reduction

Nowadays, it becomes vital to maximize utilization of the resources and increase production capacity of the industries to meet the growing demands. For this reason, garment manufacturers are seeking various effective ways to improve their industrial productivity through minimization of wastes without hampering the product quality. The readymade garment factories are highly labor incentive and working efficiency of the employees has more significant impacts on the productivity of garment industries.

The fast changing economic conditions such as global competition, declining profit margin, customer demand for high quality product, product variety and reduced lead–time etc. have a major impact on any type of manufacturing industries. For any industry, cost and time related to production and quality management or wastages reduction have important impact on overall factory economy. The demand for higher value at lower price is increasing and to survive, garment manufacturers must need to improve their operations through producing more quantity, right first time quality and waste reduction. Henceforth, the manufacturers are looking for some ways to maximize their industrial productivity and minimize product manufacturing cost, so that they can compete with other low cost and higher productive countries of the world. And also, the garment industry is recognized for buyer-driven industry, so the garment production make more extreme force by global competitive market. To remain alive in this competitive world the industry should work more efficient and competent way.

Increasing productivity is one of the major issues for enhancing more profit from same kinds of resources. Productivity improvement helps to satisfy customer and reduce time and cost to develop, produce and deliver products. The use of IE (Industrial Engineering) techniques in garment unit like method engineering, work study, capacity study, line plan and other operations management systems are ultimately leads the industry to timely delivery of goods, high profit and develop the working environment as a happy place. By implementing this technique operation, efficiency is significantly improved. This thesis report provides empirical suggestive remarks to the garment manufacturers about their industrial productivity improvement and cost reduction along with the implemented tools [2].

1.4. Objectives of the Present Work

The objectives of the present work are as follows:

(i) To improve the efficiency and productivity of a sample sewing line by applying industrial engineering techniques.

(ii) To identify the factors that cause low productivity in the sewing line.

(iii) To explore the solutions for the productivity improvement of the garment factory.

1.5. Outlines of the Methodology

The methodologies are as follows:

(i) Hungkiu (Myanmar) garment manufacturing factory located Inntakaw, Bago has been selected for the research purpose. First of all, three topics such as Why Change is Required, SMV and Efficiency, Line Balancing are trained to line-leaders and supervisors.

(ii) Daily efficiency tracker, loss time sheet and SMV Data Bank system are installed for daily information, problems and solutions.

(iii) After choosing one sample sewing line, using time study, SMV is calculated from the cycle time of every process for two products. For the determination of total SMV, basic time and SMV for each operation is calculated. Process wise production capacity for each operator is calculated from cycle time. Hourly target for each operator is set and the operators are started giving hourly targets by motivating them. Method improvements are observed by utilization of method gap analysis, brainstorming and removing operator’s non-value added motions.

(iv) Actual problem areas and causes for less productivity in the industry are identified and represented by Fish bone diagram.

1.6. Scope of the Thesis

The purpose of this work was to improve the productivity and decrease the garment manufacturing cost in the garment industries. In this report, various types of relevant contents such as introduction, literature review, data analysis and results, discussion on results, conclusion and recommendations are arranged chapter wise here.

Chapter 1 includes historical background of garment, the Myanmar garment sector, the importance of productivity improvement and waste reduction, research objectives, outlines of the methodology and scope of the thesis.

Chapter 2 covers literature review of industrial engineering tools, garment factory and its production procedure.

Chapter 3 includes various types of data collection and its analysis with required graphs and tables.

Chapter 4 contains discussions on the results found after time study, method study and capacity study.

Chapter 5 contains conclusion part of the research report which is followed by recommendations for garment industries.

CHAPTER 2
LITERATURE REVIEW

2.1. Efficiency

Efficiency is a term used to describe the state of level at which a business is producing the greatest numbers of units while utilizing the least amount of resources possible. In sewing section of garment manufacturing, efficiency is the ratio of total produced minutes and total available minutes [3].

2.2. Productivity

Productivity is a measure of the efficiency and effectiveness to which organizational resources (inputs) are utilized for the creation of products or services (outputs). In garments industry, “output” can be taken as the number of products manufactured, whilst “input” is the manpower, machinery and factory resources required to create those products within a given time frame. In fact, in an ideal situation, “input” should be controlled and minimized whilst “output” is maximized. Productivity can be expressed in many ways but mostly productivity is measured as labor productivity, machine productivity or value productivity [2]. In simple terms, productivity is the quantitative relationship between what we produce (output) and the resources (inputs) which we used.

2.3. Garment Manufacturing System

Garment industry is divided into number of processes with different operations. An operation is one of the steps in a process sequence which must be completed to convert materials into a finished garment such as cutting, sewing and finishing a garment, component or style. Skilled workers are required for high production rate. Accurate production method and processes, proper training and supervision are essential to achieve the optimum improvements on productivity. There are two types of products made in any garment industry that is constant products and seasonal products. Constant products are those, which are made, are year along and seasonal products are those, which are made for a particular season, that is, summer, winter, for different festival seasons etc. Season products' efficiency of the factory normally is lower than constant products' because of shorter production time and learning time to become habitual for operators. A typical garment manufacturing factory has the following departments.

1. Fabric/Accessories store or Warehouse
2. Sampling Department
3. Cutting Department
4. Stitching /Sewing Department
5. Finishing (Ironing, Washing, Packing) Department
6. Office Area.

Although a garment factory consists of several departments, the sewing department is the most important department in the whole firm. Because it is the most value adding department and there are a number of different operations which are done manually, so it has to be under constant control. Improving the productivity in manufacturing significantly affects the overall efficiency of an organization.

Breakdown/ Operation bulletin is a listing of the content of a job by elements. A garment consists of some parts and some group of operations. Breakdown means to writing down all parts and all process/operation after one another lying with the complete garment according to process sequence. It is a must to write down the estimated SMV and type of machine beside each and every process in order to allocate workstations and operations before sewing.

The sewing line consists of a set of workstations in which a specific task in a predefined sequence is processed. In general, one to several tasks is grouped into one workstation. Tasks are assigned to operators depending on the constraints of different labor skill levels. Finally, several workstations in sequence are formed as a sewing line. Shop floor managers are concerned with the balance of the lines by assigning the tasks to workstations as equally as possible. Unequal workload among workstations of a sewing line will lead to the increase of both work-in-process (WIP) and waiting time, indicating the increase of both production cycle time and cost. In practice, the sewing line managers or production controllers use their experience to assign tasks to workstations based on the task sequence, labor skill levels and the standard time required to complete each task. As a result, the line balance performance cannot be guaranteed from one manager to another with different assignment preference and/or work experience.

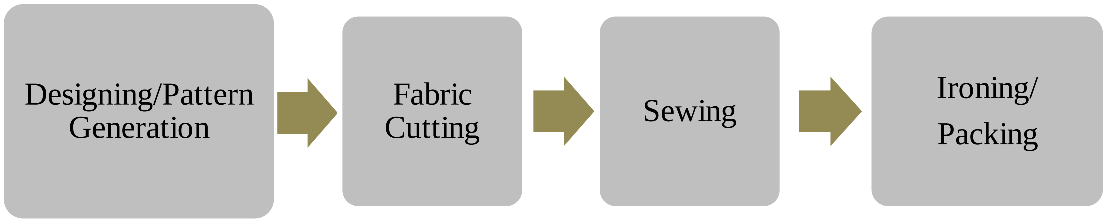


Figure 2.1. General Garment Manufacturing Processes

2.4. Industrial Engineering

Industrial Engineering concerned with the design, improvement and installation of integrated system of man, machine and equipment's drawing upon specialized knowledge and skill in the technical, economics and human science, either with the principles or methods of engineering analysis and design to specify predict and valuate the result be obtained such system [4]. To get an easier understanding, it is a branch of engineering which deals with the optimization of complex processes, systems, or organizations. The basic objectives of industrial engineering are improving operating methods, controlling costs and reducing these costs through cost reduction programs.

2.5. Productivity Improvement Techniques

Higher productivity brings higher profit margin in a business and increment in productivity level reduces garment manufacturing cost. Hence, factory can make more profit through productivity improvement. Machine productivity as well as labor productivity increases when a factory produces more pieces by the existing resources such as manpower, time and machinery. In garment sector, productivity improvement is defined as the improvement of the production time and reduction of the wastage. Sometimes specific problems such as machine breakdown, machine setup time, imbalanced line, continuous feeding to the line, quality problems, performance level and absenteeism of workers may hamper the productivity in garment industries. Productivity of a garment industry can be improved by following principles [5]:

- Conduction of motion study and correction of faulty motions
- Checking hourly worker's capacity and cycle time reduction
- Conduction of research and development for the garment
- Use of best possible line layout

- Use of scientific workstation layout
- Reduction of line setting time
- Improvement of line balancing
- Use of work aids, attachments, guides, correct pressure foots and folders
- Continuous feeding to the sewing line
- Feeding fault free and precise cutting to the line
- Training for line supervisors
- Training to sewing operators
- Setting individual target for workers
- Eliminating loss time and off-standard time of workers
- Using real time shop floor data tracking system
- Using auto-trimmer sewing machine
- Installing better and workable equipment
- Inline quality inspection at regular interval
- Motivation to the workers and ensure other required facilities
- Planning for incentive scheme to the workers
- Using CAD and CAM integrated manufacturing system.

Productivity of the garment industries greatly depends upon its production line efficiency which can be increased by following ways:

- Skill training for low performing workers
- Work utilization or balancing of the lines
- Offering performance incentives to the workers.

In summary, major benefits of controlling line efficiency and productivity improvement are as follows:

- Reduction of manufacturing cost
- More accurate product costing based on order quantity
- Employee motivation is possible through sharing of profits earned for increased efficiency.
- Improved factory capacity that results more option for revenue generation with same capital resources.

In Indian manufacturing industries, assembly line balancing minimized the total equipment cost and number of workstations. Thus, it helped to maximize the production rate in the industry [6].

2.6. Work Study

Work study is the analysis of the operation required to produce a style. Effective work study requires both method analysis and work measurement. Method is studied, analyzed, and the elements of the method measured in terms of time consumed. Data are collected, analyzed and used to support decisions on rates and methods. Work study is also important to ergonomic decisions, job design and workstation development. Decisions must be based on extensive study and documentation that is developed with work measurement procedures. Unsubstantial opinions are not sufficient justification for change. As a definition, it is a generic term for method study and work measurement which are used in the examination of human work in all its contexts and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement. Besides other sectors, work study can also be used in garment sector which includes method study and work measurement [4]. Work study can be best expressed in the following manner:

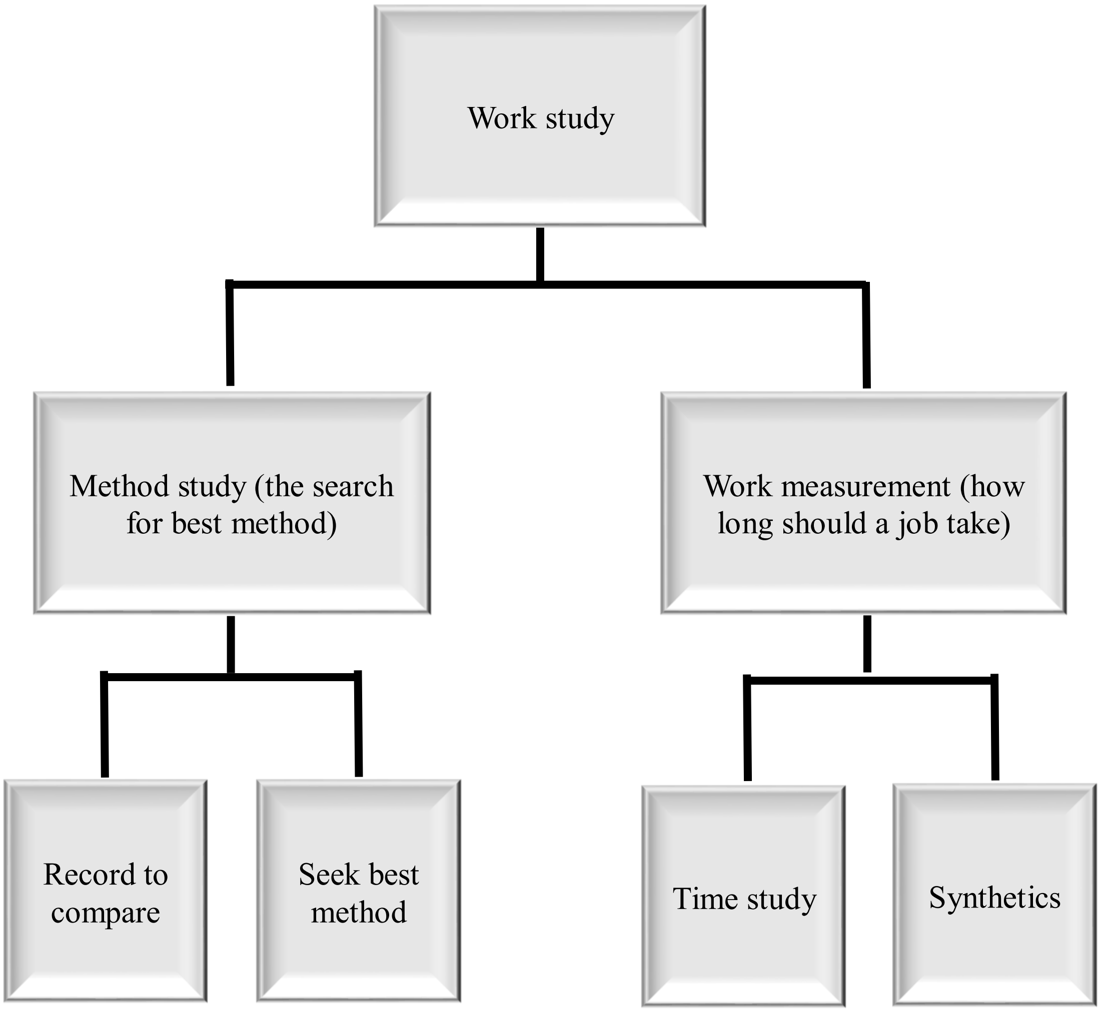


Figure 2.2. Work Study

2.6.1. Method Study

Method study is the systematic recording and critical examination of existing and proposed way of doing work as a means of developing and applying easier and more reducing cost.

1. Select the work to be studied.
2. Record all the relevant facts about the present method by direct observation.
3. Examine those facts criticality and in an ordered sequence, using the techniques best suited to the purpose.
4. Develop the most practical, economic and effective method, having due regard to all contingent circumstance.
5. Define the new method so that it can always be identified.
6. Install the methods as standard practice.
7. Maintain that standard practice by regular routine checks.

These are the seven essential stages in the application of method study; none can be excluded. Strict adherence to their sequence, as well as to their content, is essential for the success of an investigation [4].

2.6.2. Time and Motion Study

Time study is a work measurement technique for recording the times of performing a certain specific job or its elements carried out under specified conditions, and for analyzing the data to obtain the time necessary for an operator to carry it out at a defined rate of performance. Most common methods of work measurements are stopwatch time study, historical time study, predetermined motion time system (PMTS) and work sampling. Among these, time study by stopwatch is considered to be one of the most widely used means of work measurement. Time study leads to the establishment of work standard. Development of time standard involves calculation of three times such as observed time (OT) or cycle time (CT) and normal time (NT) or basic time (BT) and standard time (ST). The basic steps in a time study are:

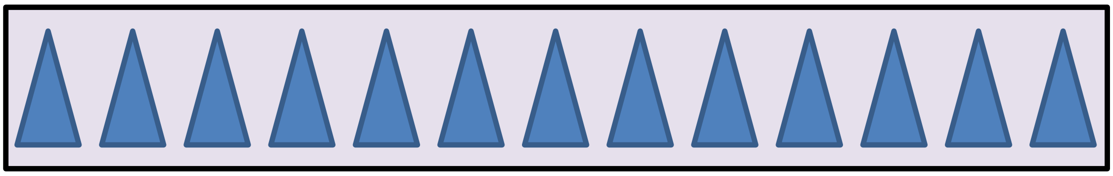
- Defining the task to be studied and informing it to the worker.
- Determination of number of cycles to be observed
- Calculating the cycle time and rating the worker’s performance
- Computing the standard time.

Time study concept was originally proposed by Fredrick Taylor (1880) and was modified to include a performance rating adjustment. Time study helps a manufacturing company to understand its production, investigate the level of individual skill, planning and production control system etc. One problem of time study is the Hawthorne effect where it is found that employees change their behavior when they come to know that they are being measured [7]. Standard allowed time (SAM) or Standard minute value (SMV) is used to measure task or work content of a garment. This term is widely used by industrial engineers and production people in manufacturing engineering. Standard allowed minute of an operation is the sum of three different parameters such as machine time, material handling (with personal allowances) time and bundle time [5]. Material handling and bundle time is calculated by motion analysis. Besides, General sewing data (GSD) is a predetermined time standard (PTS) based time measuring system which has defined a set of codes for motion data for SAM calculation. Time study was done in a Bangladesh furniture industry to measure the standard time for manufacturing of products [7].

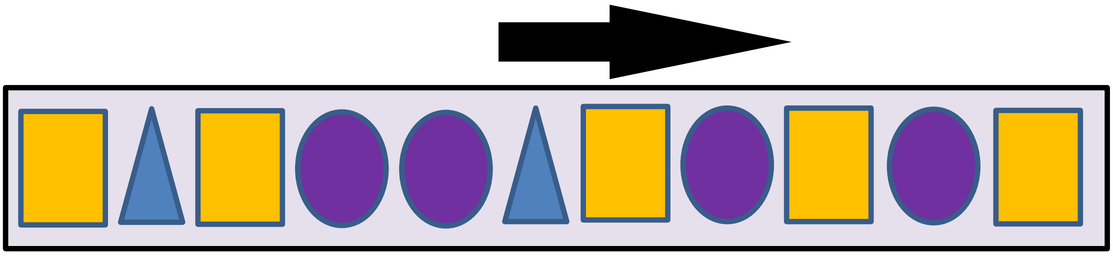
Motion study involves the analysis of the basic hand, arm and body movements of workers as they perform work. The purpose of motion study is to analyze the motions of the operator's hand, leg, shoulder and eyes in a single motion of work or in a single operation cycle, so that unless motions can be eliminated. This is an interpretation of "motion study" in a narrow sense of the meaning. In a broad sense, "motion study" includes the analysis of materials, equipment, attachments and working conditions. Frank Gilbreth (1915) first analyzed and categorized 17 basic motion elements. Basic motions mainly include reach, grasp, move and release. Usually, workers are found to pass their time in the industry through working, waiting and moving here and there. So, it is vital to analyze the movement of workers and eliminate the unwanted motions, which lead increased worker's efficiency and improved productivity in a firm [2].

2.7. Assembly Line Balancing

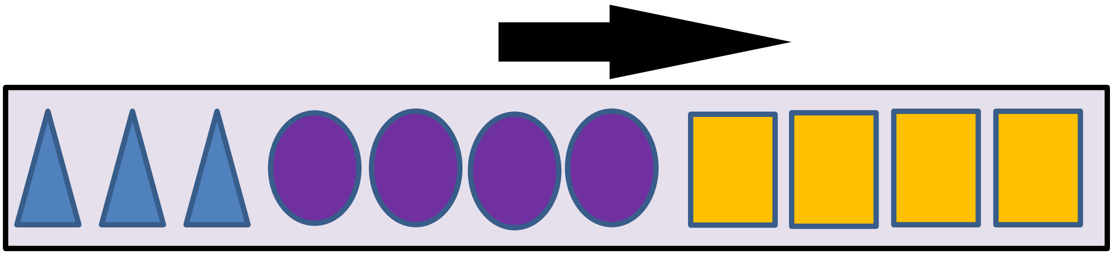
Line Balancing is a very efficient technique which means balancing the production line or any assembly line. The main objective of line balancing is to distribute the task evenly over the workstation so that idle time of man or machine can be minimized. Line Balancing is leveling the workload across all processes in a cell or value stream to remove bottlenecks and excess capacity. Assembly line may be classified as single model assembly line, mixed model assembly line and multi model assembly line as shown in figure 2.3.



(a) Single Model Assembly Line



(b) Mixed Model Assembly Line



(c) Multi Model Assembly Line

Figure 2.3**.** Assembly Lines for Single and Multiple Products [8]

Line balancing is an effective tool to improve the throughput of assembly line while reducing non value-added activities, cycle time. Line balancing is the problem of assigning operation to workstation along an assembly line, in such a way that assignment is optimal in some sense. Assembly line balancing in Indian industries improved the productivity by decreasing the total equipment cost and number of workstations [6].

A sequence of operations is involved in making a garment. In bulk garment production, generally a team works in an assembly line (Progressive Bundle system) and each operator does one operation and passes it to other operator to do the next operation. In this way garment finally reaches to the end of the line as a completed garment. In the assembly line after some time of the line setting, it is found that at some places in the line, work is started to pile up and few operators sit idle due to unavailability of work. When this situation happens in the line it is called an imbalanced line. Normally it happens due to two main reasons which are variation in work content (time needed to do an operation) in different operations and operator's performance level. To meet the production target, maintaining level work flow in the line is very essential. So it is very important to know the basics of quick line balancing. Line balancing can be classified as follows [5]:

2.7.1. Initial Balancing

The sequence of operations of a garment is analyzed and the Standard Minute Values (SMV) is allocated. The SMVs are determined by most manufacturers using standard databases available whereas some companies use their own databases based on past experience and using time studies.

2.7.2. Rebalancing

This is performed after few hours while the whole line is completely laid down and may be performed several times in order to make the material flow with the least bottlenecks in the line. Capacity studies conducted on the line also help the line balancing process.

2.7.3. Reactive Balancing

Despite the production line being balanced, spontaneous variations are inevitable due to problems on the line. Reactive balancing is often done due to machine breakdowns, operator absenteeism, quality defects and shortages. The operators or the machines are moved to the bottleneck until the severity of the problem is concealed. These types of line balancing process are very common in the garment industry.

2.7.4. Late Hour Balancing

In order to fulfill the daily demanded output from a production line the upstream operators are moved to the line end by the supervisors of some garment manufacturing companies. This happens unofficially but not uncommon and makes the line unbalanced in the next day especially in early hours. The downstream operators are waiting to receive garment pieces resulting extremely low output in early hours.

The proposed manufacturing cells for garment manufacturing totally oppose late hour balancing and only initial balancing can give the preeminent result. Line balancing is very effective technique as a well-managed apparel factory could improve its productivity level by 22% thorough line balancing [9].

2.7.5. Progressive Bundle System

The Progressive bundle system gets its name from the bundles of garment parts that are moved sequentially from operation to operation. This system often referred to as the traditional production system, has widely used by garment manufacturers for several decades and still is used today. The use of bundle systems would decrease as firms seeks more flexibility in their production systems. A progressive bundle system may require a high volume of work in process because of the number of units in the bundles and the large buffer of backup work that is needed to ensure a continuous workflow for all operators [10]. The Progressive bundle system is driven by cost efficiency for individual operations. Operators perform the same operation on a continuing basis, which allows them to increase their speed and productivity. Operators who are compensated by piece rates become extremely efficient at one operation and may not be willing to learn a new operation because it reduces their efficiency and earnings. Individual operators that work in a progressive bundle system are independent of other operators and the final product [10].

2.8. Widely Applied Balancing Procedure

This procedure defined in work study is the most popular one in the Sri Lankan apparel sector. Steps of this method can be listed as follows [11];

1. Collect the necessary information required; the list of operations in sequence, the standard time for each operation, the length of the working day and the planned output rate.
2. Compute the capacity per hour for each operation
3. Determine the required output rate
4. Workout the required Theoretical Manning Level for each operation to maintain the required output rate.
5. When you have fraction of operators, combine those operations with similar equipment to get operators with full numbers.
6. Assign operators to perform each operation considering the above calculation and the skill level of operators.

Standard time is the total time in which a job should be completed at the standard performance. The unit that measures the amount of work to be done by an operator in an operation by the number of minutes it should be completed have shown the capability of above mentioned procedure to enhance the productivity significantly.

2.9. Factors Affecting Working Conditions

The following factors do not directly lead to lower productivity of the factory but there is a high risk of having that without these factors. The set of elements constituting the working conditions vector preliminarily consist of the following [4]:

1. Occupational safety and health elements
2. Fire prevention and protection elements
3. Layout and housekeeping elements
4. Lighting 7 ventilation elements
5. Noise and vibration elements
6. Ergonomics elements
7. Arrangement of working time.

2.10. Fishbone Analysis

The fishbone analysis is a tool to evaluate the business process and its effectiveness. It is defined as a fishbone because of its structural outlook and appearance [12]. Because of the function of the Fishbone diagram, it may be referred to as a cause-and-effect diagram. Fishbone diagram mainly represents a diagrammatic model of suggestive presentation for the correlations between an event (effect) and its multiple happening causes. A cause-and-effect diagram can help to identify the reasons why a process goes out of control. It helps to identify root causes and ensures a common understanding of the causes.

Root-cause identification for quality and productivity related problems are key issues for manufacturing processes. Tools that assist groups or individuals in identifying the root causes of problems are known as root-cause analysis tools. Every equipment failure happens for a number of reasons and root-cause Analysis is a systematic method that leads to the discovery of faults or root cause. A root-cause analysis (RCA) investigation traces the cause and effect trail from the end failure back to the root cause [6]. In short, the user asks “why” to a problem and its answer five successive times. There are normally a series of root causes stemming from one problem, and they can be visualized using fishbone diagrams or tables [13].

Fishbone analysis was practiced to evaluate the supply chain and business process of a Hospital. The analysis reveals that the problem areas are lack of proper equipment, faulty process, misdirected people, poor materials management, improper environment, and inefficient overall management [12].

Fishbone analysis was also practiced for the analysis of the probabilities and the impact which allow determining the risk score for each category of causes as well as the global risk [14]. Root-cause analysis was done to identify the defects and eliminates those defects in cutting operation in CNC oxy flame cutting machine [6].

Application of fishbone analysis in garment industries is essential to identify various problem areas for productivity improvement.

CHAPTER 3
METHODOLOGY

3.1. Training

First of all, three kinds of training are instructed to the line-leaders and supervisors before installing IE tools. First topic is “Why Change Required” and the main reason of this training is to give the audience awareness and reminding how people of old days change and become to current civilization, how their family is dependent to their earning, the history of garment producing to garment factory and the importance of garment factory to develop continuously.

After first training, the audience is motivated to change and upgrade. Second training is “SMV and Efficiency”. The basic knowledge of standard minute value and efficiency are taught to line-leaders and supervisors. The equations and usage of SMV and efficiency are taught to them in order to be familiar with IE concept and to have an eagerness to achieve much efficiency.

Last topic of the training is “Line Balancing”. Since they are the closet ones dealing with production lines, they need to know what is bottleneck, how to solve bottleneck, benefit of solving it, how to balance the line to get more output. After giving training, most of the audience are motivated and willing to co-operate with industrial engineers to achieve more output.

After giving these trainings, the audience get the give the motivation to change and the basic knowledge of SMV, efficiency and line balancing. Moreover, these trainings help to create a better relationship and co-operation between the line-leaders and industrial engineers when using industrial engineering techniques in sewing lines. (Training photos are shown in Appendix A.)

3.2. Installing IE Tools

Daily efficiency tracker, loss time sheet and SMV data bank are installed for better information, to know non-productive time in the sewing lines and to have a better system of calculating SMV of the products.

3.2.1. Daily Efficiency Tracker

The tracking system based on excel software is constructed and required data such as number of present working operators, style numbers, output amounts with respect to each number of sewing line are recorded daily. Each and every data is put in excel tracker system to calculate efficiency of each line. (The tracker system with the data of sample line during the work is shown in Appendix B.)

3.2.2. Loss Time (Non-productive Time)

Time that is spent by an operator without producing any garment is called non-productive time. In garment production, lost time is recorded to show the management the problems for low production or lower line efficiency in sewing lines and to have a willingness to solve these problems. Loss time sheets are spread to every each line and ask the line-leaders to fill according to given factors in sheet. This takes a proper time to become habitual and to fill correct data for them. The sheets are recollected after each working day and the data are put in excel system. (The loss time data during the work is shown in Appendix B.)

3.2.3. SMV Data Bank

It is a data collection of process name, part of garment, stitch per inch (SPI), stitch length, type of used machine, fabric type, etc. with respect to their standard times. Whenever a new style is produced into line, time study is done and required data are filled in excel software. To get a perfect SMV data bank, it needs to be updated whenever a new style is produced. The main reason of installing SMV data bank is not to do time study if a similar style is produced and to do pre-line balancing before changing the style of the line. (The example SMV data bank is shown in Appendix B.)

3.3. Time Studies

Time study is very much essential tool for work measurement and it can be done by the calculation of standard minute value (SMV). In this work, SMV was calculated based on individual task by time studies. For the calculation of SMV, allowance (for machine and personal) factor was added with the basic time whereas basic time was determined by multiplying worker’s performance rating with the cycle time. Cycle time means total time taken to do all tasks to complete one operation, i.e. time from pick up part of first piece to next pick up of the next piece. Average cycle time was counted after measuring time for five repetitive operations with a stopwatch by standing side of every operator during different periods of a day. The measurement was avoided if found any abnormal time in the process. The procedure was repeated for all operations in a production line and cycle time was measured accordingly. In work measurement, it is very important to measure the performance rating of the worker, whose job is measured. According to International labor organization (ILO), rating is the measurement of the worker's rate of working relative to the observer's concept of the rate corresponding to the standard pace. The performance rating scale of the worker ranges from 0-150 (whereas 0 for no activity and 100 for standard performance) based on British Standard Institute (BSI) and ILO (Appendix C). Besides, allowance factor was considered to be 15% based on machine and personal allowance according to paper presented [**9**]. Equations [3.1], [3.2] and [3.3] are used to collect cycle time, and to calculate basic time and SMV.

The following equations are used to calculate the required data and analysis of the work.

$$\text{Observed Average Time} = \text{Average of Cycle Times} \qquad [3.1]$$

$$\text{BT} = \frac{\text{Observed Average Time x Operator Rating}}{100} \qquad [3.2]$$

$$\text{SMV} = \text{BT x (1+Allowance)} \qquad [3.3]$$

$$\text{Hourly Capacity} = \frac{\text{Working Time}}{\text{Observed Average Time x (1+Allowance)}} \qquad [3.4]$$

$$\text{Line Efficiency} = \frac{\text{Total Output per Day x SMV x 100 \%}}{\text{Working Time x Total Manpower Used}} \qquad [3.5]$$

Production Target =

$$\frac{\text{Target Efficiency x Working Time x Total Manpower Used}}{\text{SMV}} \qquad [3.6]$$

$$\text{BPT or Average Capacity} = \frac{\text{Total Capacity}}{\text{Total Number of Processes}} \qquad [3.7]$$

$$\text{UCL} = \frac{\text{Average Capacity}}{\text{Target Balancing Efficiency}} \qquad [3.8]$$

$$\text{LCL} = (2 \text{ x BPT}) - \text{UCL} \qquad [3.9]$$

$$\text{Labor Productivity} = \frac{\text{Total Output per Day}}{\text{Total Manpower Used}} \qquad [3.10]$$

Minute Lost per Hour=(Hourly Capacity - Bottleneck Capacity) x SMV [3.11]

In this work, SMV of these products are calculated by making time studies on the most output producing lines and using equations [3.1], [3.2] and [3.3] (product photos are shown in Appendix C). The bottleneck of the line is also analyzed which is a constraint for smooth flow of operation, limits the flow of production rate. The least output producing line is chosen as a sample line (Photos are shown in Appendix F) and time study is done for three times, two times for product 1 and one time for product 2. The collected time studies data are calculated (as shown in Appendix D). Table 3.1 shows the types of garments studied during the work.

Table 3.1. Type of Garments Studied

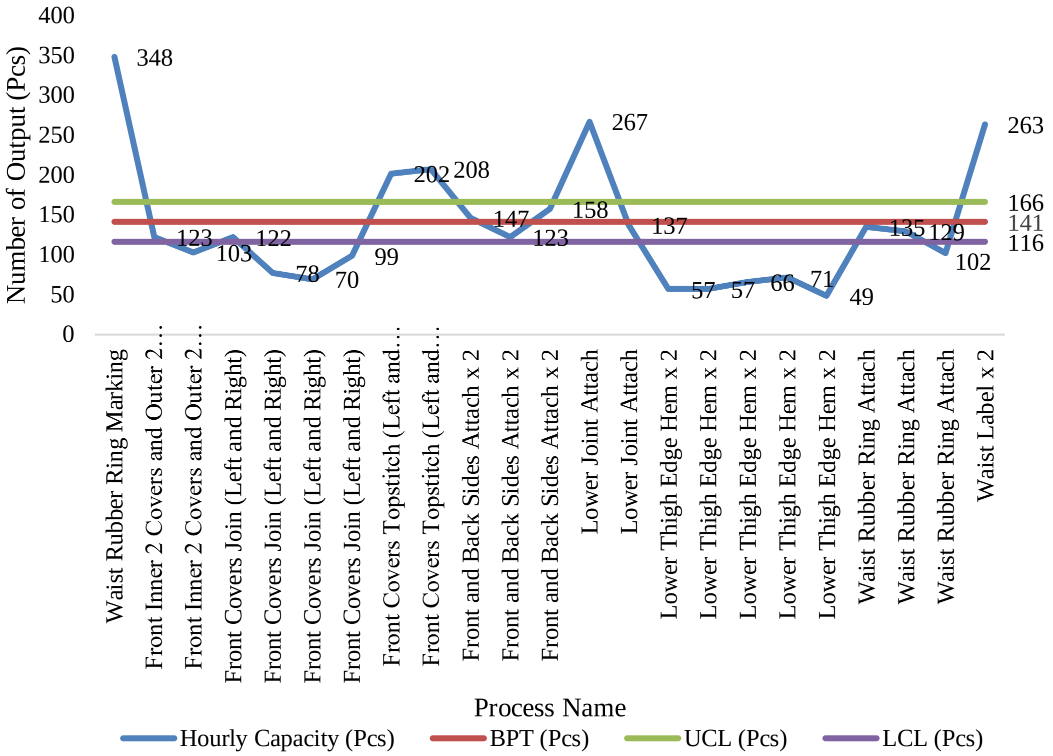
Number of Product	Type of Garment	SMV
Product 1	Short Boxer	2.9 min
Product 2	Long Boxer	3.5 min

Time study is done on product 1 and figure 3.1 shows the variation of hourly capacity of each operator with relevant process name. Hourly capacity for each operator is calculated using equation [3.4]. Basic pitch time, upper control limit and lower control limit are calculated using equations [3.7], [3.8] and [3.9] and data are drawn together with the production curve.

Minute lost per hour for each operator is calculated using equation [3.11] through three times of time studies. These minutes lost can be reduced by line balancing, bottleneck solving and reducing work-in-process (WIP). Total lost minutes are shown in table 3.2 (Minute lost per hour for each operator is shown in table D.2, D.3 and D.4).

Table 3.2. Calculated Minute Lost per Hour of Sample Line during Time Studies

Sample Line	1st Time Study	2nd Time Study	3rd Time Study
Minute Lost per Hour	538.98	534.5	553.73



Name (1^{st} Time)

Figure 3.2 shows the production curve of product 1 with BPT, UCL and LCL. It is a process-wise curve and the bottleneck of the line is 226.

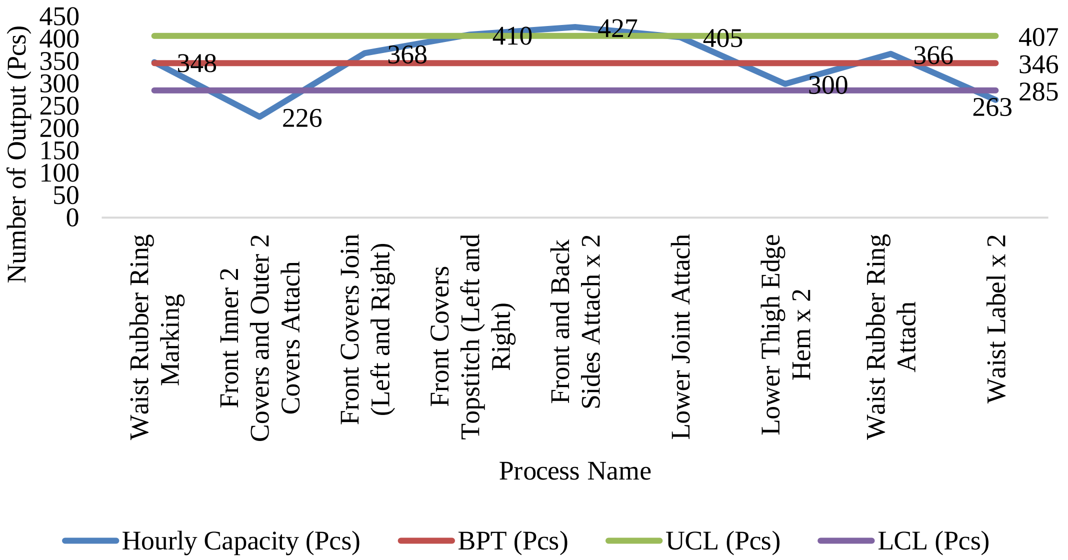


Figure 3.2. Process-Wise Production Curve of Product 1 Showing the Bottleneck (1^{st} Time)

After calculating production target for each operator based on 60 %, the calculated hourly capacities are set as their targets and push them to hit their target by motivating them. Following two figures show the resulting day of product 1 after making time study for second time.

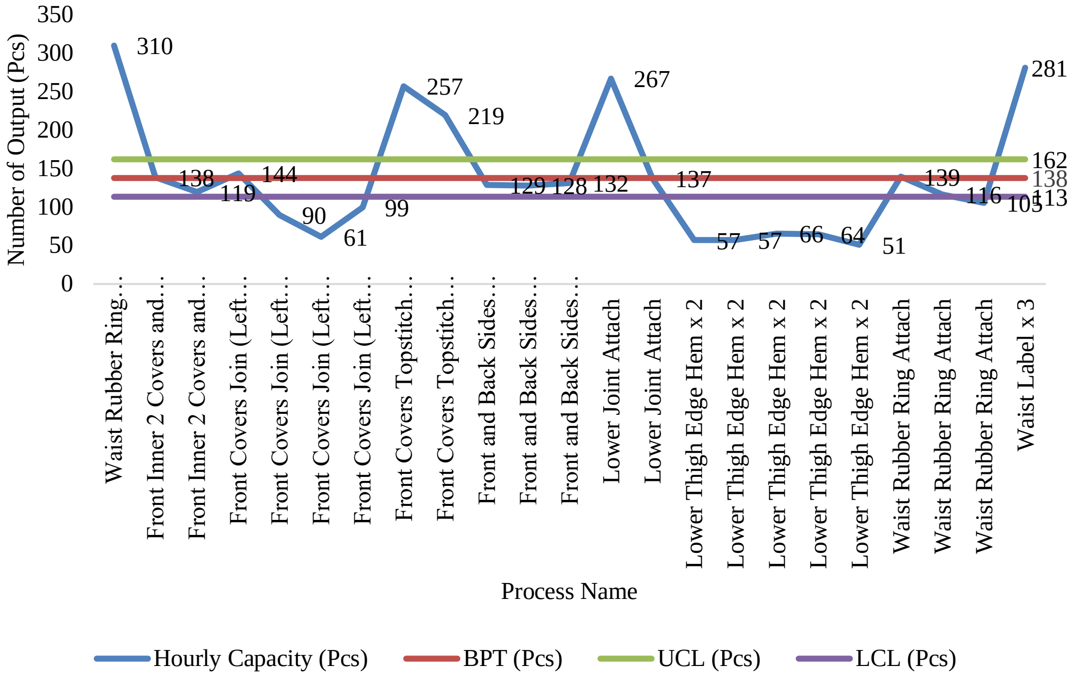


Figure 3.3. Operator-Wise Production Curve of Product 1 with Relevant Process Name (2nd Time)

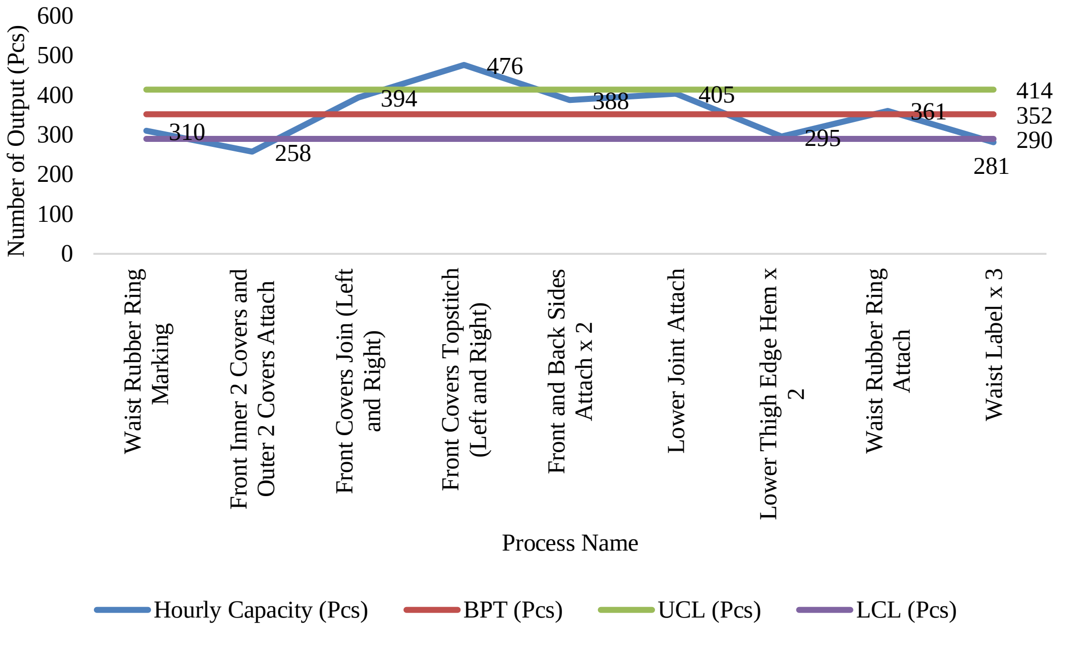


Figure 3.4. Process-Wise Production Curve of Product 1 Showing the Bottleneck (2nd Time)

After the style is changed to product 2, time study is done on the sample line again. Following two figures show the results of product 2 after time study.

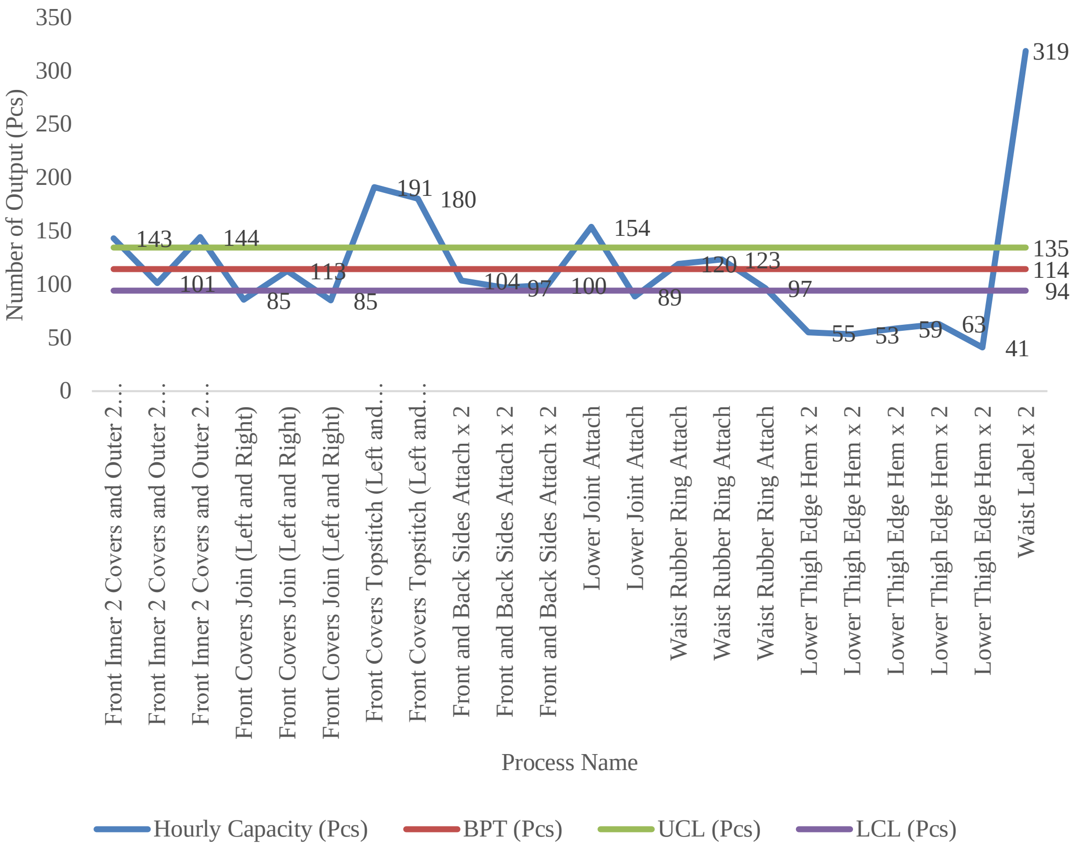


Figure 3.5. Operator-Wise Production Curve of Product 2 with Relevant Process Name (3rd Time)

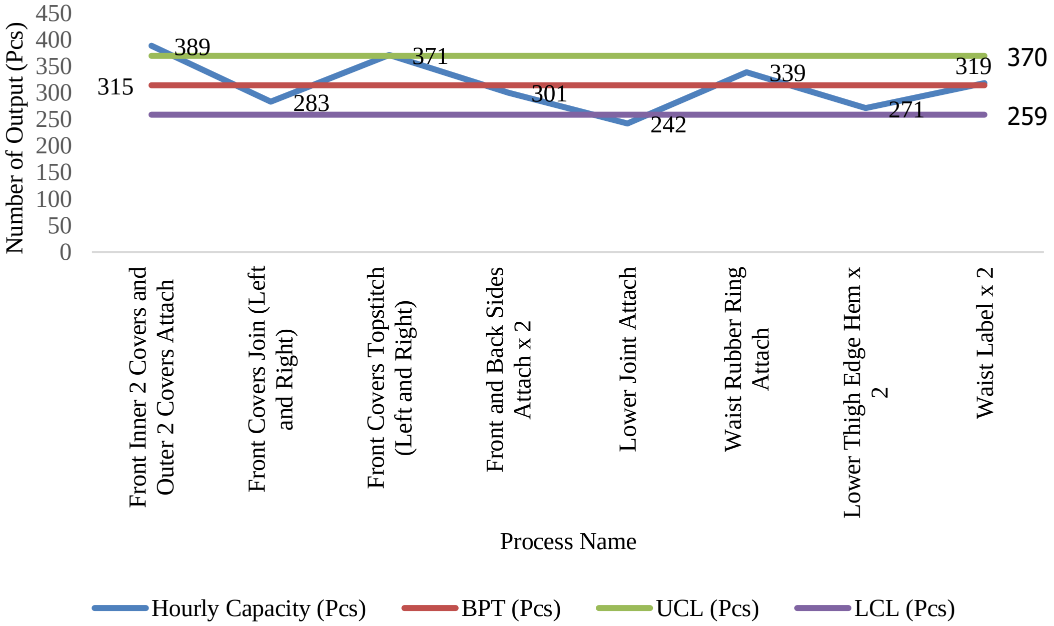


Figure 3.6. Process-Wise Production Curve of Product 1 Showing the Bottleneck (3rd Time)

3.4. Method Studies

During the work of time studies, method studies are also analyzed and various types of method improvements are installed into the sample line.

3.4.1. Workstation Arrangement

The workstations of the process "Waist Rubber Ring Attach" are moved to the right side of the sewing line. Normally, the workstations have the pulley near the right shoulder of the operators and so the operators can't easily take the pieces located on the flowing table at their right side. After arrangement (as shown in Appendix E), they can take the pieces easily with their left hand and it reduces the handling time.

3.4.2. Method Improvements

During this work, following method studies are analyzed and done. Method study can be done by recording the video, analyzing, researching and brainstorming to find the solution. After achieving the results, they can be shown by recording and comparing videos of old and new methods.

3.4.2.1. Using a vertical support

For the waist rubber ring attaching process, the operators pull out the rubber ring out of the messy rubber ring bundle. A vertical rode is supported at the workstation and the rings are hung at the rode (Appendix E). So, the operators can take easily from the support and reduce the handling time.

3.4.2.2. Waist label attach

Sewing method is changed from picking a single piece, stitching and disposing to picking the pieces, folding all pieces, unfold the last piece, stitch, fold again in reverse way and repeat for remaining pieces. After stitching all pieces, the operator disposes them (Appendix E). It reduces the material handling time (picking and disposing).

3.4.2.3. Removing marking process

Rubber rings are normally marked at the sides of the ring. At waist rubber ring attaching process, the operators attach the lower body of the garment with the rubber ring. The marking helps the sides of the ring match with the side of the boxer. The marking process is removed by adjusting the pulley of the workstation of the rubber ring attaching process. The pulley is adjust according to the width of rubber ring. The operator put the rubber ring bartack point on the pulley and attach the garment (Appendix E).

3.4.2.4. Combining process

Side seam process and joint attach process are combined into one process (Appendix E). Normally, these two processes are operated separately. The workstations of the processes are the same machines and so the processes are able to combine. The benefits are that bottleneck between these two processes are removed, no need to worry about the effect of the absenteeism among two processes and trimming and handling time are reduced.

3.4.2.5. Pocket card and board

Pocket card showing the equations of efficiency and production target is given to the line-leader of the sample line to be able to calculate the efficiency of her line daily and to be familiar with efficiency and target concept (Appendix E).

The detail calculation of efficiency and production target are shown in the board (as shown in Appendix E) and the board is hung at the middle of floor to be able to be seen clearly. Everyone in the floor can see the calculation step by step and will know how to calculate. Moreover, the incentive bonus award is declared that they can get if they hit the production target to become motivated to produce more.

3.5. Fishbone Diagram Analysis

Fish bone diagram is also known as cause-effect diagram which identifies actual causes for any result. The problem areas in garment industries were closely noticed and identified during working time in the production floors and after discussion with the managers and supervisors in the industries. In this work, different problem areas for less productivity, more wastage and more production time are found in garment industries as shown in Fig.3.7.

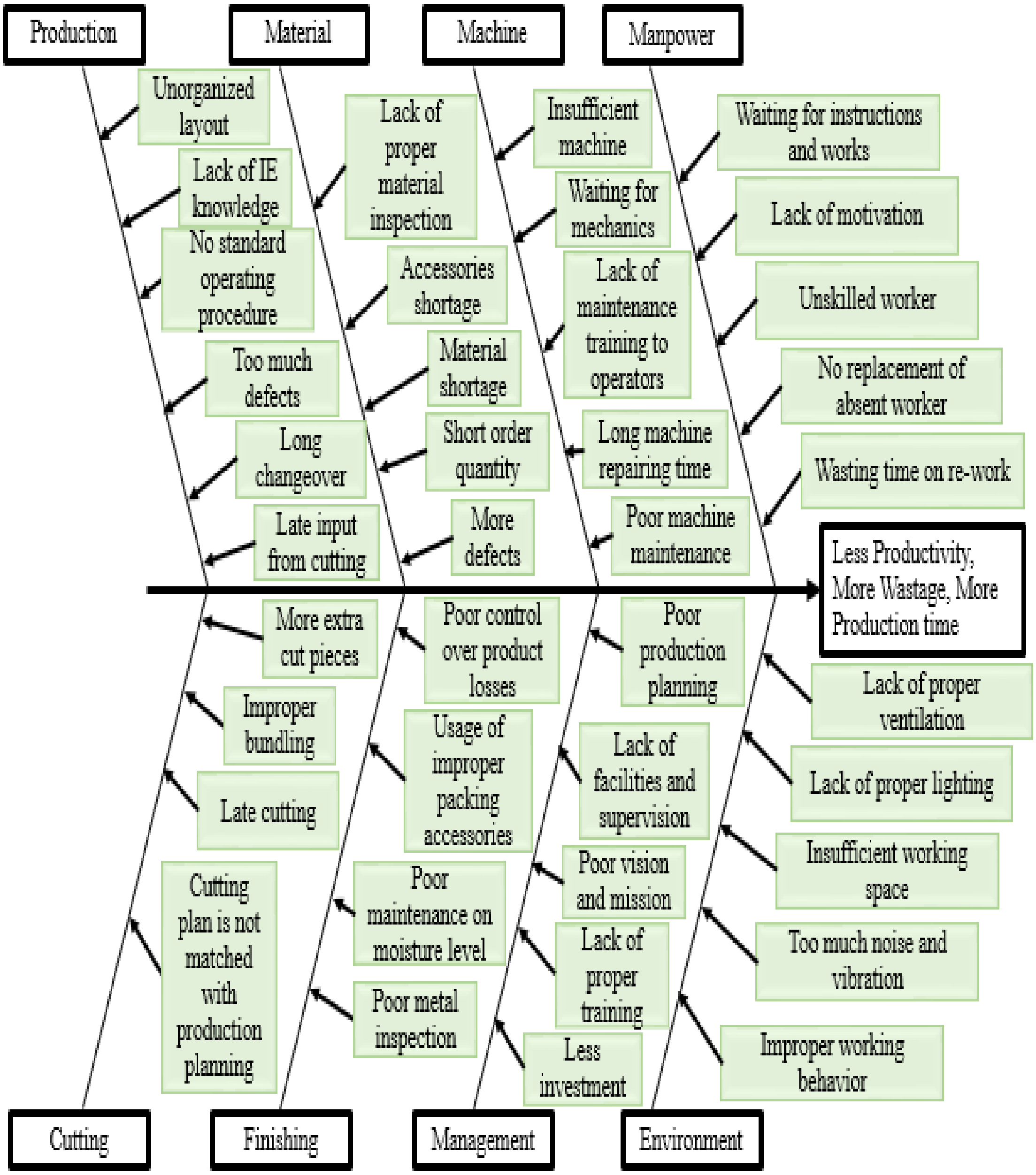


Figure 3.7. Fishbone diagram for less productivity, more wastage and more production time in RMG industries

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1. The Analysis of Productivity and Efficiency Based on Daily Efficiency Tracker

After recording the sample line data daily through the work, the data are analyzed and calculated in daily tracker system. Following table shows the average data for each month through the work. Average labor productivity and average line efficiency are calculated using equations [3.10] and [3.5]. Average Output and efficiency become decreased after July because of short order style and size problem due to wrong cutting starting from 6th July to 13th July as shown in table 3.6 (Appendix B).

Table 4.1. Analyzed Data of Sample Line for Five Months

Sample Line	March	April	May	June	July
Average SMV	3.08	3.22	2.98	3.09	3.16
Average Output per Day	1678	1435	1910	2059	1784
Average Manpower per Day	26	23	23	23	22
Average Working Hours per Day per Worker	7.766	7.3411	8.568	8.8476	8.79
Average Labor Productivity	64.54	62.39	83.04	89.52	81.09
Average Line Efficiency	43%	46%	48%	52%	49%

4.2. Non-Productive Time Analysis

Non-productive time sheet is given to line-leader of the sample line and ask her to fill if there is any problem of wasting time. The following factors are highlighted and allowed blanks to fill.

- Absenteeism
- Migration
- Input Delay
- Electricity
- Quality

- Other Problems such as meeting, salary day, earthquake, fire, etc.

Although tracking the non-productive times in the line and solving these data are very good, tracking the data needs better method. Since the data are filled by the line-leader, these data are not accurate and trustful. Following figures show the month-wise data of the major loss time for the sample line.

Table 4.2. Major Loss Times of April

Major Problem	Loss Minutes Due to Major Problem
Absenteeism	3625
Machine Breakdown	566
Re-Work Due to Poor Quality	285
Electricity Cut Off	834

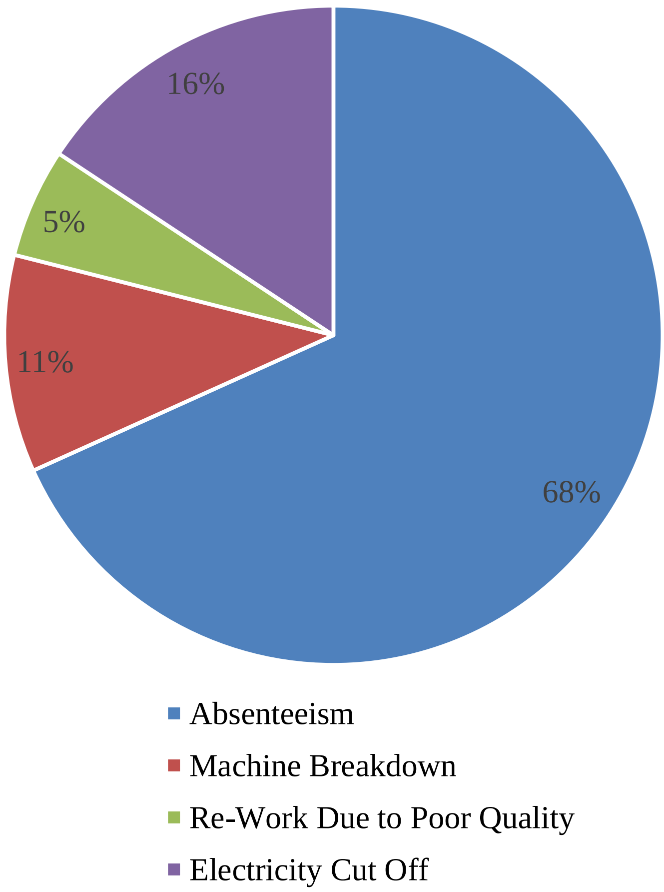


Figure 4.1. Loss Minutes Due to Major Problem of April

Table 4.3. Major Loss Times of May

Major Problem	Loss Minutes Due to Major Problem
Absenteeism	2880
Re-Work Due to Poor Quality	238
Electricity Cut Off	1363
Input Delay	600

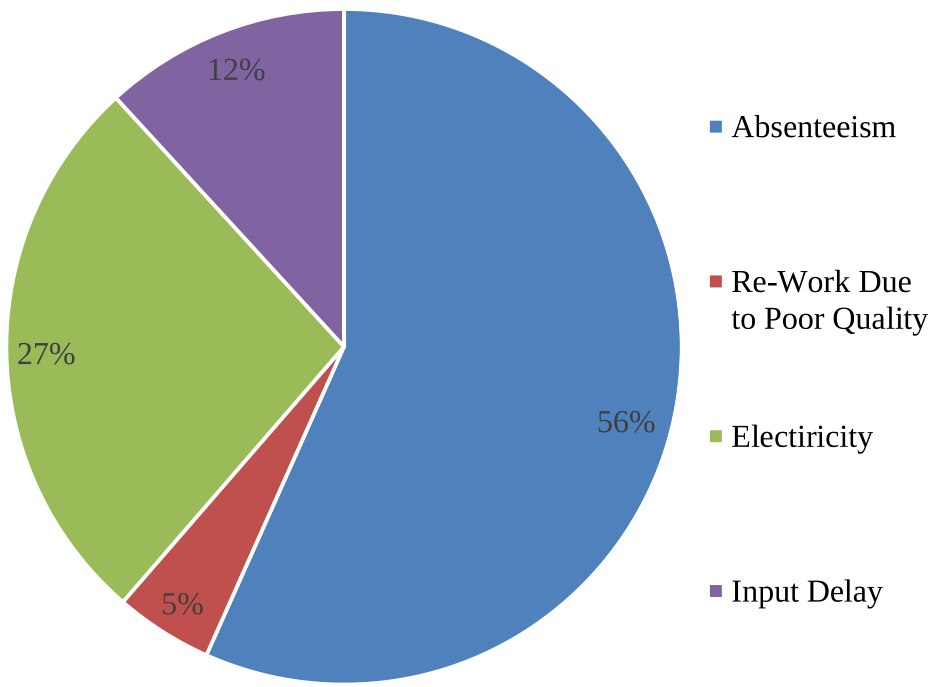


Figure 4.2. Loss Minutes Due to Major Problem of May

Table 4.4. Major Loss Times of June

Major Problem	Loss Minutes Due to Major Problem
Absenteeism	13200
Electricity Cut Off	1306
Re-Work Due to Poor Quality	1265

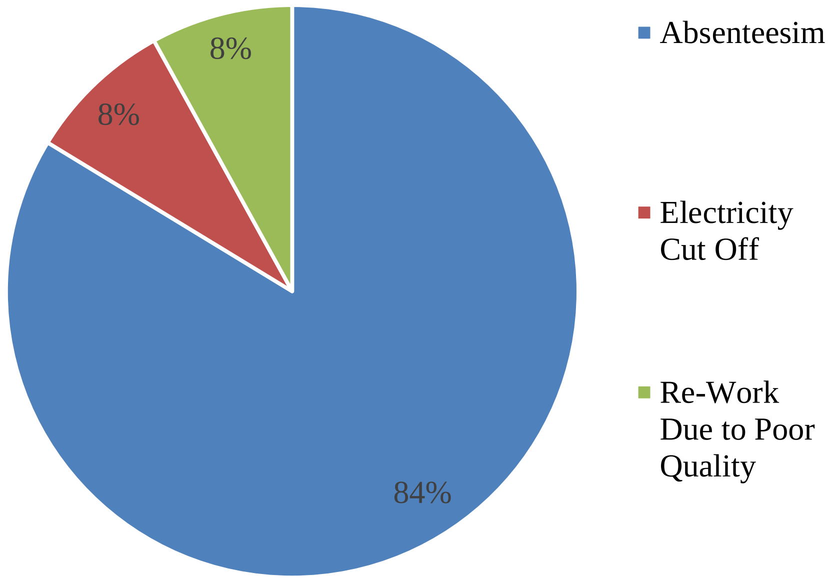


Figure 4.3. Loss Minutes Due to Major Problem of June

Table 4.5. Major Loss Times of July

Major Problem	Loss Minutes Due to Major Problem
Absenteeism	18240
Electricity Cut Off	1858

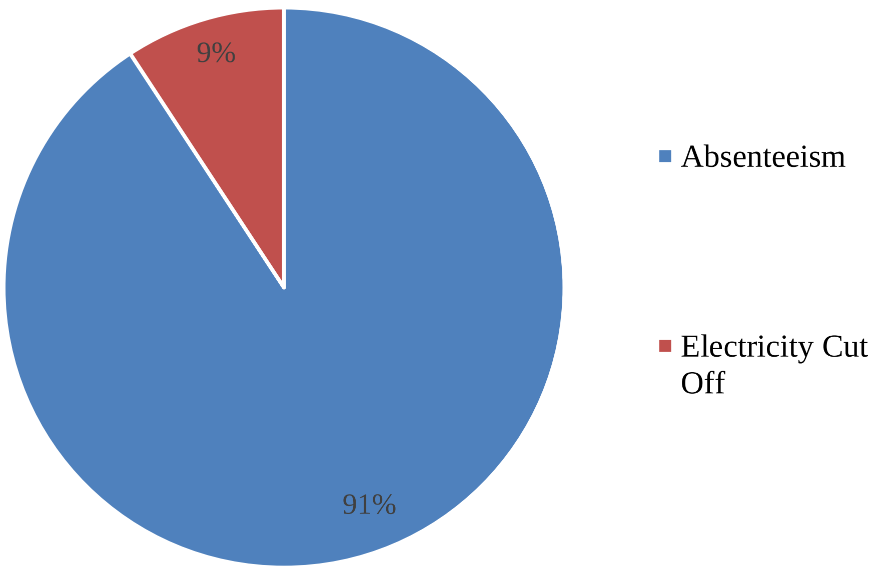


Figure 4.4. Loss Minutes Due to Major Problem of July

Table 4.2 to 4.5 show the various major factors of loss time that is going through the line. Figures 4.1 to 4.4 show the clear visibility to major problem of loss time. The management authorities need to solve these factors by applying special method to each factor or solving the root cause for each factor.

4.3. Analysis of Time Studies

Time study is an effective tool in analyzing the sewing line. But, it can have some errors in matching with the actual data. In time study, the operators are assumed to be operating the recorded process for the whole day. So, if they do extra process or change the current process, there will be an error. Time study must be done where the operators cannot notice that he or she is recording. If they notice, they might change their operating rate and they only do so during time study. The operators must be carefully checked if there is any missing work that is not recorded in time study. Each and every work must be recorded to have a correct data.

The person who do the time study must have a correct sense of giving operator rating to each operator. In some cases, the operators have reduced their working rate normally that is they do not work continuously, no focus and very talkative while working. So, time study can be done and the calculated hourly capacity for each operator is the maximum available target for the operator. Setting the target for each operator will lead them to focus on their work.

4.4. Analysis of Method Studies

Method study used in sewing lines is actually finding a better way of stitching the garment. That is finding a way that can reduce operation time, handling time, bundling (un-bundling) time and trimming time. Moreover, it is finding the way that the operator can work with less body movements because it can also lead to more relaxing time after working for long time. The industrial engineers have to think the better methods by watching the operators how they work, by video recording and by brainstorming while watching the video.

Installing a new method in sewing line is difficult to do. The operators don’t want to accept a new method because they are using an old method for a long time, they don’t think that a new method is better than the old one. One more thing is they are afraid that they will have a low output for a certain period of time after using a new one. Once they become habitual, they will get more output than that of using old one. They don’t want to get learning curve for a new one. So, the operators must be explained a detailed comparison of new and old methods, and motivating them to accept the learning curve. After they have accepted that the new one is better, they will never change back to old one. Using a psychology trickily helps to change their mindset.

If it is hard to find a new method, industrial engineers should watch all the similar processes operating in the floor. Sometimes, an operator may be operating his or her own way that can save time and reduce personal fatigue. So, that method should be analyzed and if it has no problem in using, that must be installed in all the lines. The best sewing methods must be founded out, installed and standard operating procedure (SOP) must be used in the floor to maintain the best methods.

4.5. Fishbone Diagram Analysis

Different problem areas in garment industries coupled with eight variables such as manpower, machine, material, method, production, cutting, finishing, management and environment are identified and accounted for more wastage, more production time, less productivity and higher production cost. Very common problems highlighted in the garment industries for less productivity are:

- Production time is enlarged due to lack of pre-line balancing, no layout plan and no preparation of machine and method in line changing. Besides, input delay and unequal fabric from cutting and poor production planning were also responsible for higher production time and lower productivity in the industries.
- Productivity is decreased due to absence of skilled supervisor, operator, helper and quality controller in the production lines.
- Lack of industrial engineering impeded well distribution of work load among the workers. As a result, more work-in-process and bottlenecks were resulted in the production lines, which is a waste of manpower and minimized the productivity.
- Workers’ concentration towards the work is reduced due to poor ventilation and lighting facilities, etc. which were also accountable for less productivity.
- Lack of motivation, supervision, overall co-ordination and poor management in the garment industries were some obstacles for productivity improvement.

CHAPTER 5
CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

5.1. Conclusion

This work is started by giving the trainings and these help the industrial engineers to become familiar with line-leaders and supervisors. Installing daily efficiency tracker help the sewing floor of the industry for better information of line efficiencies. Actually, giving trainings and tracking system lead to a minute and efficiency based working culture in the industry. Tracking the non-productive time of the floor is required to know what are the wastes and losses in the sewing lines. After tracking these losses, industrial engineers and the management authorities need to find the solutions and do immediate solving actions. Installing SMV data bank is necessary for better system of pre-line balancing and SMV calculation. Having SMV data bank helps calculate the required amount of manpower, machine, work allocation, work flow which lead to having a high efficiency at the start of the learning curve.

By the time study, hourly capacities for operators in the sample line are calculated. In this work, setting the hourly target for each operator is required since the floor has poor supervision, i.e., the operators do not focus on their work and are talkative. After setting the hourly target, time study is done again after some time to renew their targets. The cut pieces are put in front of their workstations so that the operators can see them and have an eagerness or willingness to work.

Through time study, method study is also done by analyzing and brainstorming each process of the sample line. A new method is installed with the help of production manager after it has found out. Non-value added or low-skill activities of the sample line is analyzed and removed or reduced. The motivation to operators to overcome the learning curve is given and after that curve, they accept the new method and work better. Time study is done on new method, taken the record to compare the new one and the old, and explain to production manager and the changed operator. From the data shown in table 4.1, the labor productivity is increased from 64.54 to 81.09, and the line efficiency is increased from 43 % to 49 %. The analysis of low productivity, long production time, much wastage is analyzed by fishbone diagram based on the experiences throughput the work.

5.2. Limitations

In this work, there are some challenges and limitations. The departments have poor co-operations and transparencies between each other. Production plan is not visible to production department and cutting plan of cutting department is not matched with production plan. Input shortage is happened often due to poor working merchandiser. Delay of fabric input lead to step by step delay among departments and finishing department is normally have overtime due to close shipment date. Or sometimes it leads to having overtime at production department to catch up with the shipment date. Poor production planning and input shortage leads to changing the line for again and again. After the line is changed, input for the changed style is shorted and the line is changed again to available input style. Industrial engineers are not given authorities to do line balancing, and only post-line balancing and finding better methods are available to do. The acceptance of industrial engineering among the departments is low which lead to poor co-operations and to have a block in improvements.

5.3. Recommendations

The sewing departments of the garment industries are the most value adding department to the garments. After installing industrial engineering tools, the sewing section needs to deal with IE techniques for better productivity and efficiency. After installing the IE system among each step of production, these techniques should be applied in the cutting and finishing sections for further increase in more productivity and wastage reduction. This is a long mission to upgrade all parts of the garment industry. After that, lean manufacturing culture is the another step for further improvements. By achieving these improvements, the garment industries can survive among the market and can establish the sustainable working environment.

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APPENDICES

APPENDIX A

TRAINING PHOTOS

Figure A.1. Training Section Photo 1

Figure A.2. Training Section Photo 2

Figure A.3. Training Section Photo 3

APPENDIX B

DATA OF IE TOOLS

Table B.1. Daily Tracker Data for March of Sample Line

Item	1	4	5	6	7	8	9	11	12	13	14	15	16	18	19	21	22	23	25	26	28	29	30	Average
	Fri	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Thu	Fri	Sat	Mon	Tue	Thu	Fri	Sat	
SMV	2.90	2.90	2.90	2.90	3.45	3.45	2.90	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	2.90	2.90	2.90	2.90	2.90	2.90	2.90	
Target Output	2681	2681	2681	2410	2170	2170	2334	2311	2222	2123	2222	2400	2356	2400	2311	2311	2532	2582	2396	2607	2607	2607	1291	
Output	1800	1950	1600	1900	1725	1400	1800	800	1700	1690	1690	1990	1990	1990	1990	1990	983	1800	1800	1800	1800	1800	600	
Attendance	27	27	27	25	26	26	25	26	25	24	25	27	27	27	26	26	26	26	24	26	26	26	26	
Working Hours	216	216	216	194.17	208	208	188	208	200	191.07	200	216	212	216	208	208	204	208	193	210	210	210	104	4644.24
Total SMV	5220	5655	4640	5510	5951.25	4830	5220	2592	5508	5476	5476	6448	6448	6448	6448	6448	2851	5220	5220	5220	5220	5220	1740	119006.15
EFF	40%	44%	36%	47%	48%	39%	46%	21%	46%	48%	46%	50%	51%	50%	52%	52%	23%	42%	45%	41%	41%	41%	28%	43%

Table B.2. Daily Tracker Data for April of Sample Line

Item	1	2	3	4	5	6	8	9	10	11	12	18	19	20	22	23	24	25	26	27	29	30	Average
	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	
SMV	2.90	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.20	3.20	
Target Output	2284	2133	2311	2311	2222	1156	2311	1778	2311	2311	1111	1067	1067	533	2311	2311	2311	2222	2222	1111	2160	2340	
Output	1012	1990	2140	2140	2590	600	1990	0	1990	2140	200	0	0	0	1690	1990	2140	2290	2440	700	1690	1840	
Attendance	23	24	26	26	25	24	26	20	26	26	25	12	12	12	26	26	26	25	25	25	24	26	
Working Hours	184	192	208	208	200	104	208	160	208	208	100	96	96	48	207.96	208	208	200	200	100	192	208	3744
Total SMV	2935	6448	6934	6934	8392	1944	6448	0	6448	6934	648	0	0	0	5476	6448	6934	7420	7906	2268	5408	5888	101808
EFF	27%	56%	56%	56%	70%	31%	52%	0%	52%	56%	11%	0%	0%	0%	44%	52%	56%	62%	66%	38%	47%	47%	45%

Table B.3. Daily Tracker Data for May of Sample Line

Item	2	3	4	6	7	8	9	10	11	13	14	15	16	17	20	21	22	23	24	25	27	28	29	30	31	Average
	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Tue	Fri	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	
SMV	3.17	3.17	2.79	2.79	2.79	2.79	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	3.50	3.50	3.50	2.90	2.90	2.90	2.90	2.90	2.90	2.90	
Target Output	2271	2362	1342	2581	2581	2581	2483	2582	2582	2905	2905	2905	2570	2570	2185	2139	1810	1810	2284	2681	2334	2334	2334	2632	2334	
Output	1600	2310	1000	2310	2310	1390	1800	1800	1900	2225	2225	2225	2025	2225	1000	1400	1400	1900	1800	2000	2100	2200	2200	2200	2200	
Attendance	22	23	23	22	22	22	22	23	23	23	23	23	23	23	22	26	22	22	23	27	23	23	23	26	23	
Working Hours	200	208	104	200	200	200	200	208	208	234	234	234	207	207	176	208	176	176	184	216	188	188	188	212	188	4944
Total SMV	5072	7323	2790	6445	6445	3878	5220	5220	5510	6453	6453	6453	5873	6453	2900	4900	4900	6650	5220	5800	6090	6380	6380	6380	6380	141565.1
EFF	42%	59%	45%	54%	54%	32%	44%	42%	44%	46%	46%	46%	47%	52%	27%	39%	46%	63%	47%	45%	54%	57%	57%	50%	57%	48%

Table B.4. Daily Tracker Data for June of Sample Line

Item	1	3	4	5	6	7	8	10	11	12	13	14	15	17	18	19	20	21	22	24	25	26	27	28	29	Average
	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	
SMV	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.9	2.9	2.9	2.9	2.9	2.9	2.9	
Target Output	2334	2619	2619	2323	2605	2604	2328	2613	2502	2605	2136	2264	2222	2129	2078	2037	2037	2037	2284	2681	2266	2234	2570	2570	2185	
Output	2300	2525	2525	2300	2525	2525	2300	2525	2525	2525	2025	2025	1800	2025	2025	1500	2025	1400	1800	1600	2025	2025	1400	2025	1200	
Attendance	23	23	23	23	23	23	23	23	22	23	23	24	24	23	23	22	22	22	23	24	21	20	23	23	22	
Working Hours	188	211	211	187	210	210	188	211	202	210	208	220	216	207	202	198	198	198	184	216	183	180	207	207	176	5025.44
Total SMV	6670	7323	7323	6670	7323	7323	6670	7323	7323	7323	7088	7088	6300	7088	7088	5250	7088	4900	5220	4640	5873	5873	4060	5873	3480	158173
EFF	59%	58%	58%	59%	58%	58%	59%	58%	61%	58%	57%	54%	49%	57%	58%	44%	60%	41%	47%	36%	54%	54%	33%	47%	33%	52%

Table B.5. Daily Tracker Data for July of Sample Line

Item	1	2	3	4	5	6	8	9	10	11	12	13	15	17	18	20	22	23	24	25	26	27	29	30	31	Average
	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Wed	Thu	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	
SMV	2.90	2.90	2.90	2.90	2.90	3.04	3.04	3.04	3.04	3.04	3.04	3.04	2.90	2.90	2.90	3.50	3.42	3.50	3.50	3.50	3.50	3.16	3.50	3.50	3.50	
Target Output	2222	2346	2346	2570	2284	2301	2025	2084	2238	2345	2345	2179	2570	2570	2570	1893	2002	2129	2037	2129	2129	2099	2037	2129	2037	
Output	2025	2025	2025	2025	622	400	900	500	1800	1800	1800	1700	2025	2025	2025	1100	2025	2025	2125	2125	2225	2200	2525	2525	2025	
Attendance	19	21	21	23	23	25	19	19	21	22	22	23	23	23	23	23	22	23	22	23	23	23	22	23	22	
Working Hours	179	189	189	207	184	194	171	176	189	198	198	184	207	207	207	184	190	207	198	207	207	184	198	207	198	4859
Total SMV	5873	5873	5873	5873	1804	1214	2736	1520	5472	5472	5472	5168	5873	5873	5873	3850	6917.6	7088	7438	7438	7788	6943.4	8838	8838	7088	142189
EFF	55%	52%	52%	47%	16%	10%	27%	14%	48%	46%	46%	47%	47%	47%	47%	35%	61%	57%	63%	60%	63%	63%	74%	71%	60%	49%

Table B.6. Loss Time Data for April

Date	Total Loss Minutes	Available Minutes	Major problem	Loss Minutes Due to Major Problem	Loss Time Percentage
1.4.19	505	10560	Absenteeism	505	5%
2.4.19	217	10560	Machine Breakdown	90	2%
3.4.19	151	10560	Machine Breakdown	151	1%
4.4.19	39	10560	Re-Work Due to Poor Quality	39	0%
5.4.19	27	10560	Re-Work Due to Poor Quality	27	0%
6.4.19	131	5280	Electricity Cut Off	96	2%
8.4.19	120	10560	Electricity Cut Off	120	1%
9.4.19	2971	10560	Absenteeism	2880	28%
10.4.19	38	10560	Re-Work Due to Poor Quality	38	0%
11.4.19	38	10560	Re-Work Due to Poor Quality	38	0%
22.4.19	161	10560	Electricity Cut Off	120	2%
23.4.19	183	10560	Re-Work Due to Poor Quality	138	2%
24.4.19	160	10560	Electricity Cut Off	120	2%
25.4.19	5	10560	Re-Work Due to Poor Quality	5	0%
26.4.19	260	10560	Electricity Cut Off	240	2%
27.4.19	245	5280	Absenteeism	240	5%
29.4.19	186	10560	Electricity Cut Off	138	2%
30.4.19	495	10560	Machine Breakdown	325	5%

Table B.7. Loss Time Data for May

Date	Total Loss Minutes	Available Minutes	Major problem	Loss Minutes Due to Major Problem	Loss Time Percentage
2.5.19	258	10560	Electricity Cut Off	120	2%
3.5.19	172	10560	Electricity Cut Off	72	2%
4.5.19	24	5760	Re-Work Due to Poor Quality	24	0%
6.5.19	535	11520	Absenteeism	480	5%
7.5.19	1345	11520	Input Delay	600	12%
8.5.19	638	11520	Absenteeism	480	6%
9.5.19	39	11520	Re-Work Due to Poor Quality	39	0%
10.5.19	55	11520	Re-Work Due to Poor Quality	55	0%
11.5.19	198	11520	Electricity Cut Off	138	2%
13.5.19	189	11520	Electricity Cut Off	138	2%
14.5.19	180	11520	Electricity Cut Off	115	2%
15.5.19	137	11520	Electricity Cut Off	72	1%
16.5.19	185	11520	Electricity Cut Off	120	2%
17.5.19	65	11520	Re-Work Due to Poor Quality	65	1%
20.5.19	650	11520	Absenteeism	480	6%
21.5.19	609	11520	Absenteeism	480	5%
22.5.19	170	11520	Electricity Cut Off	110	1%
23.5.19	716	11520	Absenteeism	480	6%
24.5.19	635	11520	Absenteeism	480	6%
25.5.19	170	5760	Electricity Cut Off	110	3%
27.5.19	124	11520	Electricity Cut Off	69	1%
28.5.19	165	11520	Electricity Cut Off	115	1%
29.5.19	55	11520	Re-Work Due to Poor Quality	55	0%
30.5.19	170	11520	Electricity Cut Off	115	1%
31.5.19	129	11520	Electricity Cut Off	69	1%

Table B.8. Loss Time Data for June

Date	Total Loss Minutes	Available Minutes	Major problem	Loss Minutes Due to Major Problem	Loss Time Percentage
1.6.19	244	12480	Electricity Cut Off	184	2%
3.6.19	239	12480	Electricity Cut Off	184	2%
4.6.19	239	12480	Electricity Cut Off	184	2%
5.6.19	249	12480	Electricity Cut Off	184	2%
6.6.19	285	12480	Electricity Cut Off	230	2%
7.6.19	60	12480	Re-Work Due to Poor Quality	60	0%
8.6.19	244	12480	Electricity Cut Off	184	2%
10.6.19	180	12480	Re-Work Due to Poor Quality	65	1%
11.6.19	175	12480	Electricity Cut Off	110	1%
12.6.19	60	12480	Re-Work Due to Poor Quality	60	0%
13.6.19	60	12480	Re-Work Due to Poor Quality	60	0%
14.6.19	60	12480	Re-Work Due to Poor Quality	60	0%
15.6.19	505	12480	Line Balancing	360	4%
17.6.19	1025	12480	Absenteeism	960	8%
18.6.19	1010	12480	Absenteeism	720	8%
19.6.19	1055	12480	Re-Work Due to Poor Quality	960	8%
20.6.19	1505	12480	Absenteeism	1440	12%
21.6.19	1615	12480	Absenteeism	1440	13%
22.6.19	1610	12480	Absenteeism	1440	13%
24.6.19	1135	12480	Absenteeism	960	9%
25.6.19	2285	12480	Absenteeism	1920	18%
26.6.19	2015	12480	Absenteeism	1920	16%
27.6.19	1597	12480	Absenteeism	1440	13%
28.6.19	1008	12480	Absenteeism	960	8%
29.6.19	46	12480	Electricity Cut Off	46	0%

Table B.9. Loss Time Data for July

Date	Total Loss Minutes	Available Minutes	Major problem	Loss Minutes Due to Major Problem	Loss Time Percentage
1.7.19	1527	12960	Absenteeism	1440	12%
2.7.19	615	12960	Absenteeism	480	5%
3.7.19	1105	12960	Absenteeism	960	9%
4.7.19	1125	12960	Absenteeism	960	9%
5.7.19	485	12960	Absenteeism	480	4%
6.7.19	970	12960	Absenteeism	960	7%
8.7.19	2454	12960	Absenteeism	2400	19%
9.7.19	2400	12960	Absenteeism	2400	19%
10.7.19	1440	12960	Absenteeism	1440	11%
11.7.19	1040	12960	Absenteeism	960	8%
12.7.19	980	12960	Absenteeism	960	8%
13.7.19	558	12960	Absenteeism	480	4%
15.7.19	604	12960	Absenteeism	480	5%
17.7.19	620	12960	Absenteeism	480	5%
18.7.19	651	12960	Absenteeism	480	5%
20.7.19	176	12960	Electricity Cut Off	156	1%
22.7.19	640	12960	Absenteeism	480	5%
23.7.19	187	12960	Electricity Cut Off	182	1%
24.7.19	617	12960	Absenteeism	480	5%
25.7.19	660	12960	Absenteeism	480	5%
26.7.19	1085	12960	Absenteeism	960	8%
27.7.19	615	12960	Absenteeism	480	5%
29.7.19	342	12960	Electricity Cut Off	540	3%
30.7.19	411	12960	Electricity Cut Off	500	3%
31.7.19	383	12960	Electricity Cut Off	480	3%

Table B.10. Example SMV Data Bank-1

Part	Stich Per Inch	Fabric Type	Stitch Length	Machine	Folder	RPM	Thread Type	SMV
Pocket	-			HP	-		Count-40/2 Spun Polyster Thread	0.23
Waist	-			BT	-		Count-40/2 Spun Polyster Thread	0.17
Pocket	11			OV	-		Count-40/2 Spun Polyster Thread	0.04
Pocket	9			S	-		Count-40/2 Spun Polyster Thread	0.32
Pocket	10			S	-		Count-40/2 Spun Polyster Thread	0.55
Pocket	11			OV	-		Count-40/2 Spun Polyster Thread	0.13
Pocket	9			S	-		Count-40/2 Spun Polyster Thread	0.44
Trousers Joint	9			OV	-		Count-40/2 Spun Polyster Thread	0.30
Trousers Joint	9			S	-		Count-40/2 Spun Polyster Thread	0.17
Waist	11			S	-		Count-40/2 Spun Polyster Thread	0.31
Trousers Joint	11			OV	-		Count-40/2 Spun Polyster Thread	0.29
Waist	9			S	-		Count-40/2 Spun Polyster Thread	0.31
Waist	10			KS	-		Count-40/2 Spun Polyster Thread	0.21

Table B.11. Example SMV Data Bank-2

Process Name	Part	Stich Per Inch	Fabric Type	Stitch Length	Machine	Folder	RPM	Thread Type	SMV
Waist Kansai	Waist	8			Kansai	-		Count-40/2 Spun Polyster Thread	0.27
Sides Seam x 2	Side Seam (Trousers)	10			OV	-		Count-40/2 Spun Polyster Thread	0.32
Join Waist Band	Waist	9			OV	-		Count-40/2 Spun Polyster Thread	0.62
Waist Label x 2	Label	9			S	-		Count-40/2 Spun Polyster Thread	0.17
Waist Band Label x 1	Label	12			S	-		Count-40/2 Spun Polyster Thread	0.27
Tie x 2 and Put Waist Rope	Waist	-			HP	-		Count-40/2 Spun Polyster Thread	0.31
Stitch 1 Parametric Line on Thigh Hole x 2	Thigh	10			KS	-		Count-40/2 Spun Polyster Thread	0.62
Front Pocket Bartack x 4	Pocket	-			Bartack	-		Count-40/2 Spun Polyster Thread	0.68
Thigh Hole Bartack x 4	Thigh	-			Bartack	-		Count-40/2 Spun Polyster Thread	1.02
Cut Waist Rope	Waist	-			HP	-		Count-40/2 Spun Polyster Thread	0.24
Cut Rubber Band	Waist	-			HP	-		Count-40/2 Spun Polyster Thread	0.41

APPENDIX C

Table C.1. Studied Product Data

Studied Garments	Photo	Style Number	SMV
Product 1 - Short Boxer		235385 - 7988	2.9
Product 2 - Long Boxer		280771 - 7988	3.5

APPENDIX D

TIME STUDIES AND CALCULATIONS

Table D.1. Rating Scale

British Standard Rating Scale (0-100)	Description
0	No activity
50	Very slow, clumsy, fumbling movements, operative appears half asleep, with no interest in the job
75	Steady, deliberate, unhurried performance, as of a worker not on piece work but under proper supervision, looks slow, but time is not being intentionally wasted while under observation
100	Brisk, business like performance, as of an average qualified worker on piece work, necessary standard on quality and accuracy achieved with confidence
125	Very fast, operative exhibits a high degree of assurance, dexterity and coordination of movement, well above that of an average trained worker
150	Exceptionally fast, requires intense effort and concentration and is unlikely to be kept up for long periods, a “Virtuoso” performance achieved only by a few outstanding workers.

Table D.2. Time Study Sheet (1st Time)

Process Name	Name of the Operator	CT (Sec)					Observed Average Time (Sec)	Rating	BT (Min)	SMV	Hourly Capacity (Pcs)		Minute Lost per Hour
		1	2	3	4	5							
Waist Rubber Ring Marking	Thin Thin Swe	7.44	8.35	10.06	9.37	9.71	8.99	80	0.12	0.14	348	348	41.31
Front Inner 2 Covers and Outer 2 Covers Attach	May Thu Kyine	26.16	26.21	25.72	25.44	24.15	25.54	70	0.30	0.34	123	226	25.36
	Ei Shwe Sin	32.66	30.19	29.53	28.84	30.52	30.35	65	0.33	0.38	103		20.63
Front Covers Join (Left and Right)	Yu Nandar Aye	26.37	25.02	26.24	26.05	24.58	25.65	80	0.34	0.39	122	368	28.89
	Thi Thi Win	41.18	42.24	39.02	38.83	40.51	40.36	65	0.44	0.50	78		14.58
	Tin Htay	43.84	45.11	43.97	48.36	43.74	45.00	60	0.45	0.52	70		10.86
	Aye Thuzar Aung	31.62	31.74	33.24	30.79	31.27	31.73	75	0.40	0.46	99		22.84
Front Covers Topstitch (Left and Right)	May Yu Hlaing	14.40	14.40	14.46	17.12	17.06	15.49	80	0.21	0.24	202	410	36.46
	May Zin Win	15.12	15.43	16.21	13.90	14.74	15.08	80	0.20	0.23	208		36.77
Front and Back Sides Attach x 2	Su Myat Mon	21.07	19.38	22.20	21.48	22.66	21.36	75	0.27	0.31	147	427	30.08
	Moe Sa Pal	27.51	23.29	25.32	26.97	24.66	25.55	70	0.30	0.34	123		25.35
	Hnin Phyu Soe	20.26	19.82	21.26	19.66	18.35	19.87	75	0.25	0.29	158		31.12
Lower Joint Attach	Su Mon	9.92	11.67	13.11	12.21	11.65	11.71	80	0.16	0.18	267	405	39.28
	Tin Moe Khine	22.27	24.76	20.68	23.61	22.69	22.80	65	0.25	0.28	137		25.20
Lower Thigh Edge Hem x 2	Phyu Thwe	52.16	56.26	54.80	56.62	55.73	55.11	65	0.60	0.69	57	300	5.64
	Lay Lay New	53.04	55.69	54.23	56.34	54.29	54.72	65	0.59	0.68	57		5.88
	Khine Thazin Oo	48.91	50.34	47.11	46.57	45.27	47.64	70	0.56	0.64	66		10.95
	Ei Ei Lin	45.73	42.54	41.72	45.41	44.35	43.95	73	0.53	0.61	71		13.93
	Ya Min Thet Wai Khine	62.34	67.31	64.11	65.38	63.05	64.44	60	0.64	0.74	49		0.00
Waist Rubber Ring Attach	Win Mar	23.99	21.68	24.48	21.76	24.15	23.21	75	0.29	0.33	135	366	28.79
	San San Mar	27.52	22.80	25.68	21.52	23.61	24.23	72	0.29	0.33	129		26.96
	Nwe Nwe Win	30.80	27.87	32.46	30.36	31.65	30.63	68	0.35	0.40	102		21.41
Waist Label x 2	Mya Thanar Soe	12.08	12.82	10.22	12.22	12.07	11.88	75	0.15	0.17	263	263	36.70

Table D.3. Time Study Sheet (2nd Time)

Process Name	Name of the Operator	CT (Sec)					Observed Average Time (Sec)	Rating	BT (Min)	SMV	Hourly Capacity (Pcs)		Minute Lost per Hour
		1	2	3	4	5							
Waist Rubber Ring Marking	Thin Thin Swe	9.59	8.23	10.81	12.44	9.45	10.10	75	0.13	0.15	310	310	37.59
Front Inner 2 Covers and Outer 2 Covers Attach	May Thu Kyine	22.66	22.32	22.22	22.84	23.03	22.61	80	0.30	0.35	138	258	30.31
	Ei Shwe Sin	28.37	26.53	28.22	24.15	23.97	26.25	77	0.34	0.39	119		26.43
Front Covers Join (Left and Right)	Yu Nandar Aye	22.27	18.24	21.97	23.05	23.38	21.78	80	0.29	0.33	144	394	30.96
	Thi Thi Win	37.90	36.14	33.99	32.90	33.02	34.79	70	0.41	0.47	90		18.18
	Tin Htay	51.47	50.24	51.11	53.21	50.41	51.29	65	0.56	0.64	61		6.40
	Aye Thuzar Aung	30.27	32.62	31.45	30.15	33.14	31.53	75	0.39	0.45	99		21.88
Front Covers Topstitch (Left and Right)	May Yu Hlaing	12.40	13.15	12.80	12.24	10.27	12.17	80	0.16	0.19	257	476	38.48
	May Zin Win	15.15	15.06	13.46	13.71	14.02	14.28	78	0.19	0.21	219		35.91
Front and Back Sides Attach x 2	Ei Myat Mon	22.88	26.81	24.40	24.03	23.31	24.29	75	0.30	0.35	129	388	27.19
	Moe Sa Pal	23.59	25.06	25.37	24.31	24.06	24.48	75	0.31	0.35	128		27.04
	Hnin Phyu Soe	23.03	25.80	23.93	22.55	23.58	23.78	75	0.30	0.34	132		27.56
Lower Joint Attach	Su Mon	9.92	11.67	13.11	12.21	11.65	11.71	80	0.16	0.18	267	405	38.84
	Tin Moe Khine	22.27	24.76	20.68	23.61	22.69	22.80	65	0.25	0.28	137		24.50
Lower Thigh Edge Hem x 2	Phyu Thwe	52.16	56.26	54.80	56.62	55.73	55.11	65	0.60	0.69	57	295	3.96
	Lay Lay Nwe	53.04	55.69	54.23	56.34	54.29	54.72	65	0.59	0.68	57		4.21
	Khine Thazin Oo	48.91	50.34	47.11	46.57	45.27	47.64	70	0.56	0.64	66		9.38
	Ei Ei Lin	47.98	50.51	48.04	45.41	51.34	48.66	73	0.59	0.68	64		9.06
	Ya Min Thet Wai Khine	62.17	59.57	62.34	61.68	60.98	61.35	60	0.61	0.71	51		0.00
Waist Rubber Ring Attach	Win Mar	24.58	21.80	23.73	21.27	20.87	22.45	80	0.30	0.34	139	361	30.43
	San San Maw	27.27	28.03	25.80	25.77	27.50	26.87	75	0.34	0.39	116		25.29
	Nwe Nwe Win	29.54	27.87	31.80	32.13	27.47	29.76	70	0.35	0.40	105		21.62
Waist Label x 3	Mya Thanar Soe	12.88	9.79	9.67	10.82	12.58	11.15	80	0.15	0.17	281	281	39.28

Table D.4. Time Study Sheet (3rd Time)

Process Name	Name of the Operator	CT (Sec)					Observed Average Time (Sec)	Rating	BT (Min)	SMV	Hourly Capacity (Pcs)		Minute Lost per Hour
		1	2	3	4	5							
Front Inner 2 Covers and Outer 2 Covers Attach	May Thu Kyine	20.8	23.1	21.4	22.8	21.1	21.83	80	0.29	0.33	143	389	33.66
	Ei Shwe Sin	30.5	31.4	32.5	29.4	31	30.93	75	0.39	0.44	101		26.4
	Yu Nandar Aye	18.2	22.3	23.4	22.2	22.3	21.67	75	0.27	0.31	144		31.93
Front Covers Join (Left and Right)	Tin Htay	39	36.9	35.9	37.6	33.9	36.64	70	0.43	0.49	85	283	21.56
	Aye Thuzar Aung	28.8	28.1	27.1	28.4	26.3	27.73	80	0.37	0.43	113		30.96
	Thi Thi Win	32.7	35.5	38.2	38.5	39.1	36.8	70	0.43	0.49	85		21.56
Front Covers Topstitch (Left and Right)	May Yu Hlaing	15.7	17.3	16.3	16.7	16	16.39	75	0.2	0.24	191	371	36
	May Zin Win	18	16.9	17.1	17.5	17.3	17.37	75	0.22	0.25	180		34.75
Front and Back Sides Attach x 2	Su Myat Mon	29.8	30.6	29.5	30.6	30.3	30.16	80	0.4	0.46	104	301	28.98
	Moe Sa Pal	32.6	31.2	32.3	32.8	32.2	32.22	70	0.38	0.43	97		24.08
	Hnin Phyu Soe	32.9	32.4	30.5	29.1	32.2	31.42	75	0.39	0.45	100		26.55
Lower Joint Attach	Su Mon	19.6	19.2	21.6	20.1	21.4	20.36	80	0.27	0.31	154	242	35.03
	Tin Moe Khine	36	36	35.9	33.3	35.4	35.3	70	0.41	0.47	89		22.56
Waist Rubber Ring Attach	Win Mar	25.1	24.4	27.2	28.3	26	26.19	77	0.34	0.39	120	339	30.81
	San San Maw	25	27.4	24.1	25.7	24.8	25.39	73	0.31	0.36	123		29.52
	Nwe Nwe Win	33.6	31.1	33.8	29.4	34.3	32.42	75	0.41	0.47	97		26.32
Lower Thigh Edge Hem x 2	Phyu Phyu Thwe	56.8	57.6	56.4	57.6	56.5	56.99	75	0.71	0.82	55	271	11.48
	Lin Lin Nwe	60	56.9	59.3	61.2	56.6	58.81	70	0.69	0.79	53		9.48
	Khine Thazin Oo	53.3	53.9	52.9	51.7	54.3	53.2	75	0.67	0.76	59		13.68
	Ei Ei Lin	50.8	48	50.2	50.6	48.2	49.55	80	0.66	0.76	63		16.72
	Ya Min Thet Wai Khine	73.9	75.6	76.6	76.1	80	76.45	60	0.76	0.88	41		0
Waist Label x 2	Myat Thanar Soe	10.2	9.66	9.13	9.35	10.7	9.82	80	0.13	0.15	319	319	41.7

APPENDIX E

METHOD STUDIES AND IMPROVEMENT PHOTOS

Figure E.1. Waist Rubber Ring Attach (Before)

Figure E.2. Waist Rubber Ring Attach (After)

Figure E.3. Rubber Rings Placed on the Flow Table

Figure E.4. Rubber Rings Put on a Vertical Rod

Figure E.5. Waist Label Attach (Before)

Figure E.6. Waist Label Attach (After)

Figure E.7. Waist Rubber Ring Marking (Removed)

Figure E.8. Waist Rubber Ring Attach Without Marking

Figure E.9. Side Seam

Figure E.10. Joint Attach

Figure E.11. Combined Side Seam and Joint Attach Processes

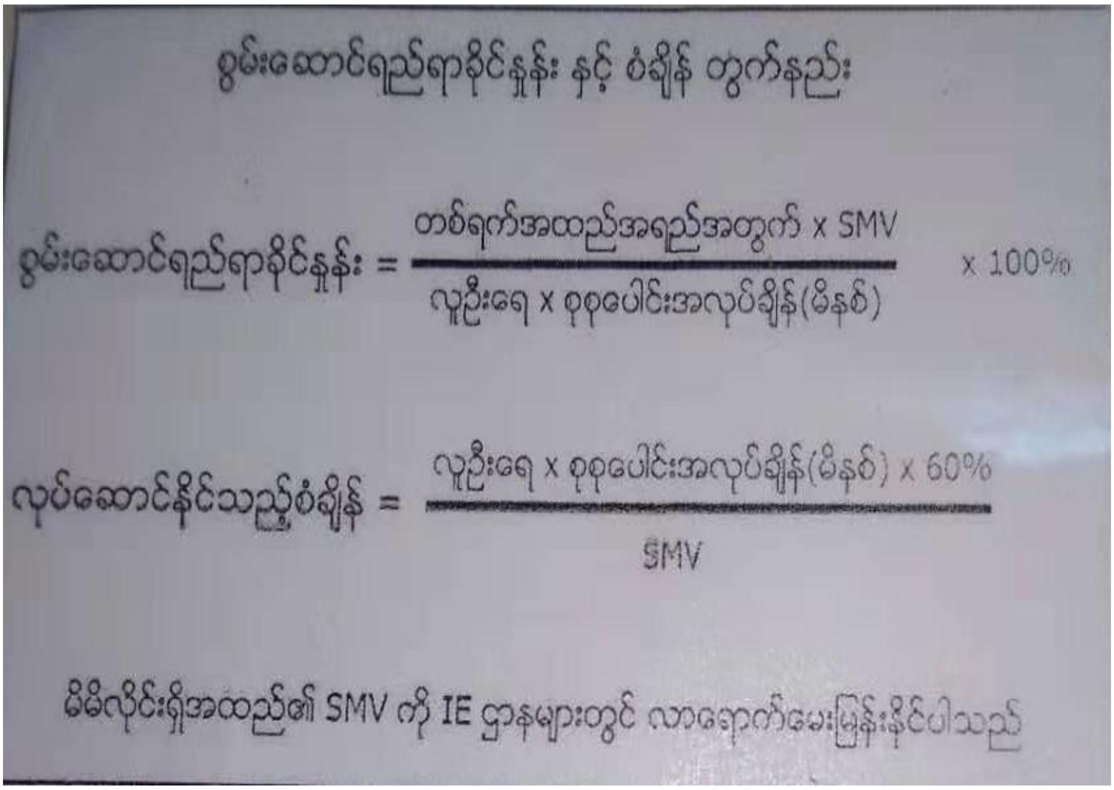

Figure E.12. Efficiency and Target Pocket Card

Figure E.13. Efficiency and Target Board

APPENDIX F
SAMPLE LINE PHOTOS

Figure F.1. Sample Line Photo 1


Figure F.2. Sample Line Photo 2


Figure F.3. Sample Line Photo 3