PRODUCTIVITY IMPROVEMENT IN READYMADE GARMENTS INDUSTRY -A CASE STUDY

By

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DECLARATION

It is hereby declared that, this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Sumon Mazumder

This work is dedicated
to my loving parents

Bhabesh Mazumder
&
Shadhona Mazumder

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ABSTRACT

In case of readymade garments (RMG) industries, productivity improvement is a vital to decrease the production lead time as well as manufacturing cost. For productivity improvement it becomes essential to decrease the waiting time, process bottlenecks and increase the production line efficiency. Time study and line balancing are effective techniques to reduce the operation time and improve the productivity. Time study was performed in a furniture industry to increase its production efficiency and reduce the operation time and associated cost. Assembly line balancing technique was also used in some manufacturing industries for single production line to identify and remove the non-value added activities and increase the productivity. But, it becomes essential to apply time study and line balancing techniques for the number of production lines of various products in small and large RMG industries to improve its productivity.

In this work, time study is performed on four different products of RMG industries and production lines are balanced through the distribution of works among the work stations by line balancing. Thus, new production layouts are modeled with the balanced capacity combining both modular line and traditional manufacturing system together. In new production systems, 6-64% production lead time is decreased for 27-78% reduction of waiting time, 10-179% improvement of labor productivity and 6-130% improvement of machine productivity for four products. Possible problem areas in the industries are identified by fishbone analysis and strength, weakness, opportunities and threats for productivity improvement were also identified by SWOT analysis. This research report provides pragmatic guidelines for the garments manufacturers to improve their industrial productivity and capacity by applying some essential tools like time study, line balancing and fishbone analysis.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

RMG	:	Readymade Garments
ILO	:	International Labor Organization
BSI	:	British Standard Institute
SMV	:	Standard Minute Value
SAM	:	Standard Allowable Time
MMR	:	Man to Machine Ratio
PMTS	:	Pre-determined Motion Time Systems
GSD	:	General Sewing Data
VA	:	Value Adding
NVA	:	Non Value Adding
NNVA	:	Necessary but Non Value Adding
CT	:	Cycle Time
BT	:	Basic Time
ST	:	Standard Time
PTS	:	Pre-determined Time Standard
TQM	:	Total Quality Management
TPM	:	Total Productive Maintenance
TPS	:	Toyoda Production System
AQL	:	Accepted Quality Control
KAIZEN	:	Continuous Improvement
PDCA	:	Plan, Do, Check and Act
JIT	:	Just in Time
SMED	:	Single Minute Exchange of Dies
VSM	:	Value Stream Mapping
WIP	:	Work in Process
RCA	:	Root Cause Analysis
ZQC	:	Zero Quality Control
CAD	:	Computer Aided Design
CAM	:	Computer Aided Manufacturing
IE	:	Industrial Engineering

CONTENTS

Chapter-1

Introduction

1.1 Introduction

Readymade garments (RMG) sector has experienced an outstanding export growth in Bangladesh by the last two decades [**Mukul et al. 2013**]. In recent years, many RMG industries have been installed in Bangladesh to meet the extended demands of the customers globally and locally. Now-a-days, it becomes vital to maximize utilization of the resources and increase production capacity of the industries to meet the growing demands. For this reason, RMG 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 RMG industries. There are several issues associated to increases the labor productivities and among those, labor incentives is one of the major factor point [**Islam[a] 2013**]. RMG factories in Srilanka operate at 80-90% efficiency, whereas in Bangladesh, productivity lies between 35-55% of efficiency with very few exceptions according to some experts [**Shumon et al. 2010**]. 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 [**Islam[b] et al. 2013**].

The demand for higher value at lower price is increasing and to survive, garment manufacturers must need to improve their operations through producing right first time quality and waste reduction [**Islam[c] et al. 2013**]. The demands for low cost garments are increased by the clients who forced suppliers to deliver low cost garments within short timeframe. Because of many high cost factors in Bangladesh, most of the companies faced difficulties in getting orders and some companies are even closed down. 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.

Few researches in the respective arena have been conducted in small extent at Bangladesh, but it is necessary to study and compare the results for number of large and small industries after applying various effective tools and techniques. This research report provides empirical suggestive remarks to the RMG manufacturers about their industrial productivity improvement and cost reduction along with the implemented tools.

Chapter-2

Literature Review

2.1 Literature Review

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 readymade garments industry, “output” can be taken as the number of products manufactured, whilst “input” is the people, 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. Productivity gains are vital to the economy because they allow us to accomplish more with less. The apparel industries need to produce momentous quantities in shorter lead times as apparel product is highly correlated with high level of productivity. In Bangladeshi apparel industry 22% labor productivity was increased by applying line balancing technique [**Shumon et al. 2010**].

A garment production system is a way how fabric is being transformed into a garment in a manufacturing system. Production systems are named according to the various factors such as number of machine used to make a garment, machines layout, total number of operators involved to sew a complete garment and number of pieces moving in a line during making a garment. Among the various production systems progressive bundle system and one piece flow system are most commonly found in the readymade garments industries. In Bangladeshi apparel industry, single product line balancing proposed to use the new production system that combines traditional and modern modular manufacturing systems both together in order to improve the productivity [**Shumon et al. 2010**].

Facility layout is the most effective physical arrangement of machines, processing equipment and service departments to have maximum co-ordination and efficiency of man, machine and material in a plant. A good layout scheme would contribute to the overall efficiency of operations. Layouts can be classified into four classes such as product layout, process layout, group technology layout and fixed position layout. Among those product layout is mostly used in the readymade garments industries. In product layout machines are arranged according to the product manufacturing sequences. It is a layout in where workstations or departments are arranged in a linear path. This strategy is also known as line flow layout. Advantages of product layout are as follows-

- Lower production time.
- Less material handling cost.
- Smaller floor area of production.
- Simpler production control.

Besides, product layout also has some following disadvantages-

- Duplication of the processing equipment and machine tool.
- More investment cost.

Flow pattern can be classified as straight line (chain), U-shaped, convoluted, circular and zigzag type. But all types of flow patterns are not suitable for RMG industries. In this perspective, U shaped product layout can be used to improve material flow across the entire production line. Design of the workstation layout widely vary from one operation to another depending on size of work, number of components to be worked on and type of machine to handle during operation. In Chinese manufacturing workshops, facility lean layout system of a production line was researched and designed to improve the production efficiency [**Zhenyuan and Xiaohong 2011**]. An efficient layout in Indian plant could help to reduce the production cycles, work-in-progress, idle times, number of bottlenecks, material handling times and increase the productivity [**Vaidya et al. 2013**]. In Bangladeshi apparel industry, for tee shirt manufacturing 21% line efficiency was improved by the balanced production layout [**Shumon et al. 2010**].

2.1.1 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 RMG sector productivity improvement is defined as the improvement of the production time and reduction of the wastage. Sometimes specific problems such as machine break down, machine set up time, imbalanced line, continuous feeding to the line, quality problems, performance level and absenteeism of workers may hamper the productivity in RMG industries. Productivity of a RMG industry can be improved by following steps [**Babu 2011**]:

- 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 work station 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 RMG 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 work stations. Thus, it helped to maximize the production rate in the industry [**Kumar and Mahto 2013**].

2.1.2 Time and Motion Study

Besides other sectors work study can also be used in readymade garments sector which includes method study and work measurement. 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), normal time (NT) or basic time (BT) and standard time (ST). The basics 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 [**Jannat et al. 2009**]. 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 [**Babu 2011**]. 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 Bangladeshi furniture industry to measure the standard time for manufacturing of products [**Jannat et al. 2009**].

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.

2.1.3 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 work station 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 Fig. 1.1.

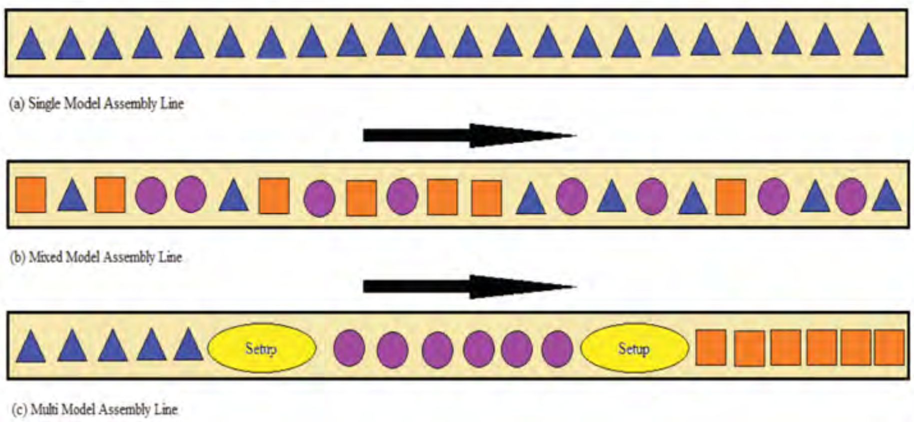

Fig. 2.1 Assembly lines for single and multiple products [**Amardeep et al. 2013**]

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 work stations [**Kumar and Mahto 2013**].

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 [**Babu 2011**]:

- **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.
- **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 bottle necks in the line. Capacity studies conducted on the line also help the line balancing process.
- **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 break downs, 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 RMG industry.
- **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. In Indian industries, assembly line was designed with a number of operations by simulation and heuristic method to minimize the balancing loss and system loss. [**Roy and Khan 2010**]. Line balancing is very effective technique as a well managed apparel factory could improve its productivity level by 22% thorough line balancing [**Shumon et al. 2010**].

2.1.4 Lean Manufacturing Tools and Techniques

After World War II Japanese manufacturers were faced with the dilemma of vast shortages of material, financial and human resources. The problems that Japanese manufacturers were faced with differed from those of their Western counterparts. These conditions resulted in the birth of the "lean" manufacturing concept. In the 1950's Toyota Motor Corporation created Toyota Production System (TPS), then it formatted a new kind of management concept 'Lean thinking' [**Rameez and Inamdar 2010**]. Agile manufacturing, just-in-time manufacturing, synchronous manufacturing, world-class manufacturing and continuous flow are all terms that are used in parallel with lean manufacturing. Lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality system, work teams, cellular manufacturing, supplier management, etc. in an integrated system [**Kuo et al., 2008**]. Benefits of lean manufacturing system are improved productivity, overall wastage or 'muda' (the Japanese word for waste) reduction, cost reduction, reduces defects and overall quality improvement [**Chahal 2012**]. In the face of fierce competition resulting from the rapid globalization of businesses in Bangladesh, some companies across the garment industry sector have been practicing lean production to remain globally competitive and create a strong market position. There is a lack of research evidence regarding the impact of lean practices on manufacturing performance improvement in Bangladeshi garment firms. Researchers are mostly soundless on this very important area of production philosophy. The entire field of lean remains unexplored in Bangladesh [**Ferdousi and Ahmed 2009**]. So, it is essential to apply lean tools in Bangladeshi RMG industries.

For any industry waste is unwanted because it increases the product cost. Waste is anything that creates no value for the owner/client/end-user. Waste elimination is a by-product of lean process, lean design and lean production management. In a company, lean design and lean production can eliminate the seven wastes to create value for the supplier as well as for the client. According to one paper published, creating value and only value is the best way as it can eliminate wastes in design and construction [**Mossman 2009**]. For any industry cost and time related to production and quality management or wastes reductions have important impact on overall factory economy. Internal cost spent by a company and savings made by eliminating non productive works and time are important for management to keep the industry economically sound and safe. By applying lean tools in the manufacturing industry, seven lean wastes such as overproduction, re-processing (re-work), excess motion, transport, excess inventory, waiting time and defects can be reduced to a great extent which in turn improves the productivity of the organization [**Islam[d] et al. 2013**].

The basic purpose of Lean Manufacturing is to manufacture the product with minimal wastage, optimal usage of available resources and at the least cost. To doing this, it uses various techniques like SMED, one-piece flow, kanban, poka-yoke, 5S, total productive maintenance, visual management, line optimization and synchronous manufacturing [**Satao et al. 2012**]. Lean thinking focused on value-added lean and consists of best practices, tools and techniques from the Indian industry with the aims of reducing waste and maximizing the flow and efficiency of the overall system to achieve the ultimate customer satisfaction [**Chakrabortty and Paul 2011**].

Cellular manufacturing is a concept of lean manufacturing that increases the combination of products with minimal wastes. A cell consists of equipment and workstations that are arranged in an order that maintains a smooth flow of materials and components through the process. It also assigns operators who are qualified and trained to work at that cell. There are lots of benefits of cellular manufacturing over long assembly lines [**Heizer and Render 2007**]. Some of these are as follows:

- Reduced work in process inventory because the work cell is set up to provide a balanced flow from machine to machine.
- Reduced direct labor cost because of improved communication between employees, better material flow, and improved scheduling.
- High employee participation is achieved due to added responsibility of product quality monitored by themselves rather than separate quality persons.

- Increased use of equipment and machinery, because of better scheduling and faster material flow.
- Allows the company higher degrees of flexibility to accommodate changes in customer demand.
- Promotes continuous improvement as problems are exposed to surface due to low WIP and better communication.
- Reduces throughput time and increases velocity for customer orders from order receipt through production and shipment.
- Enhances the employee's productive capability through multi-skilled operators.

Apart from these substantial benefits, there is a very important advantage of cellular manufacturing over the linear flow model. Due to the closed loop arrangement of machines, the operators inside the cell are familiar with each other's operations and they understand each other better. This improves the relation between the operators and helps to improve productivity.

5S is the first step for the implementation of the TQM on the operation level. 5S is a Japanese concept for increasing quality and productivity which belongs five Japanese terms. 5S is the essential tool for acquiring continuous improvement in the organization. In any organization improvement begins with 5S and it is a lean tool which is implemented for obtaining a clean, effective and pleasant work environment. The implementation of 5S in Indian organization helped to achieve its continuous improvement and higher performance [**Ghodrati and Zulkifli 2013**]. By applying 5S system in a company it helps to organize a workplace with efficiency and decrease wastes and optimize quality and productivity through monitoring an organized environment. The application of 5S tool in Indian manufacturing industry provided the useful visual evidences to minimize the manufacturing cost and increase the work area [**Lingareddy et al. 2013**].

Continuous improvement is another elementary principle of lean manufacturing. Kaizen is a Japanese technique for "improvement", or "change for the better" refers to philosophy or practices that focus upon continuous improvement of processes in manufacturing, engineering and business management. Kaizen is a multifaceted word that involves two concepts such as 'Kai' means change and 'Zen' for the better. The term comes from Gemba Kaizen meaning ‘Continuous Improvement’ (CI). Kaizen is also known as the Shewhart cycle, Deming cycle or PDCA (Plan do check and Act). Kaizen is essential for the reduction of throughput time, addition of workstation to meet the takt time, and elimination of unnecessary operations, activities and workstations. According to the case study presented, the implementation of Kaizen and other techniques helped one Indian company to survive with lower manufacturing cost and better product quality [**Gautam et al. 2012**].

Just in time (JIT) is closely coupled with lean manufacturing system and is a vital to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. One of the most documented reasons for JIT implementation is the reduction of non-value added (NVA) activities that increase throughput time. JIT is important as it enhances the long-run performance and competitiveness of the firm. By adopting JIT practices in a firm many substantial benefits can be experienced such as quality improvements, time-based responses, employee flexibility, improved workers’ efficiency, reduced production lead time, accounting simplification, firm profitability, and inventory reductions [**Fullerton and Mc Watters 2001**]. JIT based approaches has potential to improve the product quality and productivity to significant level but organizations must adopt its principles in way that meet their own organizational structure, design and processes [**Kumar 2010**]. According to the paper presented, there are seven important elements for successful implementation of the JIT production strategy in order to provide feed backs and control at all levels of the organization and all through the procurement - production - distribution environment [**Bandyopadhyay 1995**]. JIT can be used in supply chain in order to achieve a precise production, i.e. an efficient product in a proper place and time and with the least costs. Using JIT in supply chain, one can increase flexibility and productivity of products and s/he can meet customers' needs. As a widespread JIT application lead to high outcome and economical production process and customer satisfaction, those companies which get use of JIT in their production system, have more competitive power in comparison with others [**Asiabi and Ve Asiabi 2012**].

TPM is a unique Japanese philosophy, which has been developed based on the productive maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971. Total productive maintenance is a modern approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce. 5S tool is a basis for the implementation of TPM and henceforth, it starts with 5S. It is a systematic process of housekeeping to achieve a tranquil environment in the work place involving the employees with a commitment to sincerely implement and practice housekeeping. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement. TPM involves workers in all departments and levels, from the plant-floor to senior executives, to ensure effective equipment operation. The ultimate goals of TPM are zero product defects, which lead to improve utilization of production assets and plant capacity. There are three main components of a total productive maintenance program which are preventive maintenance, corrective maintenance and maintenance prevention. TPM contributed in an Ethiopian malt manufacturing industry by improving its manufacturing performance [**Wakjira and Singh 2012**]**.**

Value stream mapping (VSM) originally developed by Toyota is used to first map the current state and then to identify the sources of waste and to identify lean tools to eliminate the waste. Diverging from other conventional recording approaches value stream mapping helps to visualize and record cycle times, inventories held, changeover times, modes of transportation, manpower deployment, utilization of resources etc. Beyond the advantages, VSM is unable to handle multiple products that do not have identical maps and tends to bias a factory designer to consider only continuous flow, assembly line layouts, kanban-based pull scheduling, etc. that are suitable mainly for high volume and low variety manufacturing systems. Value stream improvement is not an event but it is an unending incrementally favorable process. In an internal manufacturing situation, three types of activities are taken into consideration. These are non-value adding (NVA), necessary but non-value adding (NNVA) and value-adding (VA). VSM is a lean or quality management tool which assists in establishing the current state of a process while aiding to uncover opportunities for improvement. The first of these is pure waste and involves unnecessary actions which should be eliminated completely by seven value stream mapping tools in the industries [**Hines and Rich 2005**]. Importance of enthusiastically vested cross-functional team work is vital to success of VSM process in the industry [**Gill 2012**]. VSM technique was used in the garments industry of Bangladesh to help in the visualization of material and information flow, cycle time and best utilization of the resources [**Islam[d] and Sultana 2011**].

The technique that makes the JIT principles practical is called Kanban. Kanban is a Japanese word meaning signboard or billboard in where 'Kan' means visual and 'Ban' means card. Kanban is a signal to replace what has been used and it is therefore a way of controlling inventory. In earlier days it was the special manufacturing system proposed by Toyota. The word Kanban has come to stand for a variety of items ranging from shelves, bins, electronic messages and order slips to the entire reorder point system. This system guides everyone in an industry from machine operator to trolley driver to know what the next process to be carried out. The kanban system is based on use of cards called 'Kanbans'. In this system three kinds of cards can be used which are move kanban, production kanban and supplier kanban. Kanban system was used in the engine valve machining cell of auto components manufacturing industry of south India to eliminate the wastes those are identified by value stream mapping [**Ramnath et al. 2010**].

Poka-Yoke is a technique for waste reduction. The term Poka-Yoke is derived from the Japanese, which was developed by Shingo, is an autonomous defect control system that is put on a machine and inspects all parts to make sure that there are zero defects. Poka-Yoke can nearly be translated as mistake or fool proofing. It is derived from the term 'Poka' means inadvertent mistake and the term 'yoke' means circumvent. Poka-Yoke or mistake proofing is the basis of Zero Quality Control (ZQC) approach, which is a technique for avoiding and eliminating mistakes. This type of technique can be used in the manufacturing industries but also has much wider uses in offices, hospitals and in case of aircraft maintenance to control quality of the products [**Satao et al. 2012**]. The goal of zero defects or ZQC is to ensure that products are fault free all the way, through continuous improvement of the manufacturing process. Human beings almost invariably will make errors. When errors are made and are not caught then defective parts will appear at the end of the process. If the errors can be identified and prevented before they happen then the production of defective parts can be avoided. In short, Poka-Yoke is to observe the defective parts at the source, detect the cause of the defect, and to avoid moving the defective part to the next workstation.

Single Minute Exchange of Die (SMED) is another technique of waste reduction. During 1950's Ohno devised this system. The basic idea of SMED is to reduce the setup time on a machine. There are two types of setups such as internal and external. Internal setup activities are those that can be carried out only when the machine is stopped, while external setup activities are those that can be done during machining. Once all activities are identified then the next step is to try to simplify these activities. By reducing the setup time many benefits can be realized. First, die-changing specialists are not needed. Second, inventory can be reduced by producing small batches and more variety of product mix can be run. It is also called as quick change over. Some of the lean manufacturing practitioners are saying that all machine setups are technically non-value added. According to the paper published, this tool was used in the green manufacturing to eliminate waste such as movements or work that does not contribute to the process of changing over the machine [**Satao et al. 2012**].

2.1.5 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 [**Bose 2012**]. 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

[**Mahto and Kumar 2008**]. 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 [**Gautam et al. 2012**].

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 [**Bose 2012**].

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 [**Ilie and Ciocoiu 2010**]. Root-cause analysis was done to identify the defects and eliminates those defects in cutting operation in CNC oxy flame cutting machine [**Kumar and Mahto 2008**].

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

2.1.6 SWOT Analysis

SWOT analysis is a framework and very important tool which can be used in marketing management as well as other business applications [**Ahamed 2013**]. It is a strategic planning tool that segregates influences on a business’s future gains into internal and external factors. Environmental factors internal to the company usually can be classified as strengths (S) or weaknesses (W), and those external to the company can be classified as opportunities (O) or threats (T). Such an analysis of the strategic environment is referred to as a SWOT analysis as shown in Fig. 1.3.

In a company, weaknesses are the constraints to pick the opportunities and again strengths resist the vulnerability of the threats. SWOT analysis allows businesses to define realistic goals, improve capability, overcome weaknesses with strengths and identify threats than can be turned into opportunities. The SWOT analysis provides information that is helpful in matching the firm's resources and capabilities to the competitive environment in which it operates.

SWOT analysis helped to identify the challenges, opportunities and threats of textile sector in Bangladesh. According to the analysis, many problem areas were identified in the mill which is related to the global challenges of textile industry such as high prices of quality products, high rated gas, electricity and oil prices, political unrest and inadequate sales centre for the local market etc. [**Mostafa 2006**]. Textile industries of Bangladesh must need to overcome these challenges to expand its market growth locally and internationally.

In India, SWOT analysis was practiced to throw light on it's present retail scenario and to identify weakness such as multi-diversified business, no bargaining markets etc. and various threats such as increasing competitors, government and local policies, unrecognized modern retailing etc. The analysis also discussed some customer-centric initiatives to be taken in future by the retailers [**Archana 2012**].

SWOT analysis also identified the weakness such as poor infra structure, poor quality standards, less productivity, unstable political situation etc. in the Pakistan's textile industries and recommended alternative solutions and remedies to make the industries more competitive and efficient against its biggest challengers and competitors [**Akhlaq 2009**].

Readymade garment is a leading sector in Bangladesh economy and SWOT analysis should be done on RMG industries to identify the strengths, weakness, opportunities and threats for productivity improvement.

2.2 Objectives of the Present Work

The objectives of the present work are as follows:

i) Observation of cycle time during garment making and calculation of standard minute value (SMV) for garments manufacturing by considering allowances in different RMG industries.

ii) Assessment of existing capacity and productivity of selected RMG industries in Bangladesh by considering calculated SMV.

iii) Identification of bottlenecks in process and it’s minimization through line balancing.

iv) Identification of problem areas for less production, more wastage and higher cost through fishbone diagram analysis in RMG industries.

v) Comparison of labor efficiency, production line efficiency and factory efficiency among the large and small industries.

2.3 Outlines of the Methodology

The methodologies are as follows:

i) Four readymade garments (RMG) industries of Bangladesh (Appendix-A) have been selected and visited for the research purpose. By the time study SMV is calculated from the cycle time of every process for four different garment products. For the determination of total SMV, basic time and SMV for each operation is calculated separately. Process wise production capacity and worker’s efficiency are calculated by using calculated SMV (Appendix-C). After that, benchmarked production target is set for line balancing.

ii) After applying line balancing technique, four production lines are balanced (Appendix-D) considering existing bottlenecks in the processes. After line balancing new manpower setup is proposed and final capacity of each process is also reallocated. Finally, new production layouts (Appendix-E) are modeled with the balanced capacity to increase the productivity in RMG industries.

iii) Actual problem areas and causes for less productivity in the industries are identified and represented by Fish bone diagram.

iv) SWOT analysis is practiced on the present situation of RMG industries to identify the possible strength, weakness, opportunity and threat for productivity improvement.

v) One structured questionnaire (Appendix-F) was also used to conduct a survey on 100 production people in the RMG industries to identify other factors those are indirectly related to the productivity.

2.4 Scope of the Thesis

The purpose of this work was to improve the productivity and decrease the garments manufacturing cost in the RMG industries. In this report, various types of relevant contents such as introduction, literature review, research objectives and methodology, data analysis and results, discussion on results and conclusion with scopes for future work are arranged chapter wise here.

Chapter 1 includes introduction part of the research report.

Chapter 2 covers literature review, research objectives and outlines of the methodology.

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

Chapter 4 contains discussions on the results found after the time study and line balancing. The chapter also includes comparisons between existing and proposed situation of the RMG industries to evaluate the improvements after applying various tools and techniques.

Chapter 5 contains conclusion part of the research report which is followed by scopes for future work.

Chapter-3

Data Analysis and Results

3.1 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 on several production lines and in case of variety products. For the calculation of SMV, allowance (for machine, personal & bundle) 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 stop watch by standing side of every worker 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 0-100 (whereas 0 for no activity and 100 for standard performance) based on British Standard Institute (BSI) and ILO. Besides, allowance factor was considered from 15%-20% based on machine, personal and bundle allowance according to paper presented [**Shumon et al. 2010**]. Table 2.1 shows the average workers' performance rating and allowance factor which are assumed in this work. Equation (1.1) and (1.2) are used to calculate the SMV and basic time for the four products.

Table 3.1 Product category with workers' performance rating and allowance factor

Product	Product Name	Average Worker's Performance Rating	Allowance Factor
Product-1	Ladies Tank Top	90%	15%
Product-2	Mens Tee Shirt	90%	15%
Product-3	Mens Polo Shirt	75%	20%
Product-4	Mens Half Shirt	75%	20%

$$\text{SMV for individual process} = \text{Basic time } (1 + \text{Allowance factor}) \quad [1.1]$$

$$\text{Basic time} = \text{Cycle time X Performance rating} \quad [1.2]$$

Process capacity and worker's efficiency were also determined by using SMV. Capacity of every process and working efficiency of all operators and helpers in a line were calculated by using Equation (1.3) and (1.4). Equation (1.5), (1.6) and (1.7) were used for the calculation of production line efficiency:

$$\text{Capacity/hour (Pieces)} = \frac{\text{Total work force} \times \text{Total minutes attended}}{\text{SMV}} \quad [1.3]$$

$$\text{Worker's efficiency} = \frac{\text{Total minutes produced}}{\text{Total minutes attended}} \times 100 \quad [1.4]$$

$$\text{Line efficiency} = \frac{\text{Total output (minutes)}}{\text{Total input (minutes)}} \times 100 \quad [1.5]$$

$$\text{Total output (minutes)} = \text{Total output (piece) per day} \times \text{SMV} \quad [1.6]$$

$$\text{Total input (minutes)} = \text{Total work force per day} \times \text{Total minutes attended} \quad [1.7]$$

Waiting time can be calculated by using Equation (1.8). Equation (1.9), (1.10) and (1.11) were used to calculate the man-machine ratio, labor productivity and machine productivity respectively.

$$\text{Waiting time/hr/line} = (\text{Process capacity - Actual output}) \times \text{SMV} \quad [1.8]$$

$$\text{Man to machine ratio} = \frac{\text{Total workforce}}{\text{Total no. of available machines}} \quad [1.9]$$

$$\text{Labor productivity/day/line} = \frac{\text{Total output (Pieces)}}{\text{Total workforce}} \qquad [1.10]$$

$$\text{Machine productivity/day/line} = \frac{\text{Total output (Pieces)}}{\text{Total no. of machines}} \qquad [1.11]$$

The data for existing production (pieces per hour) and cycle time (min) of different products have been collected from four selected RMG industries (as shown in Appendix-A and Appendix-B). Fig.3.1and Fig.3.2 shows the variation of existing production and cycle time with that of process number for different products.

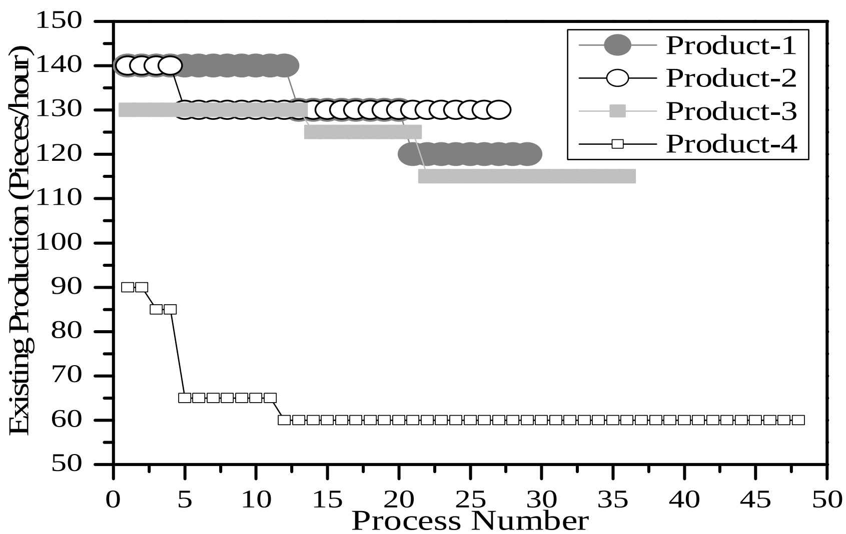

Fig.3.1 Variation of existing production with process number for different products

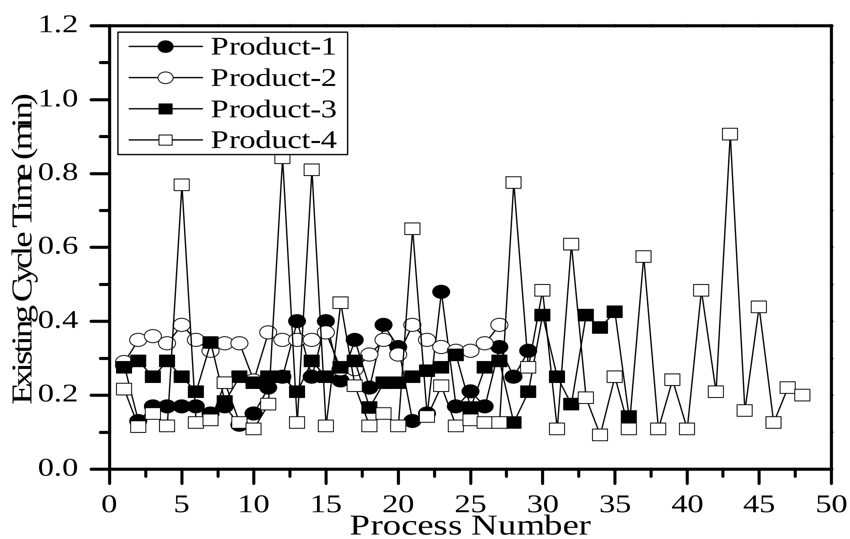

Fig.3.2 Variation of existing cycle time with process number for different products

Based on collected data, SMV, production capacity and waiting time have been calculated (Appendix-C) and the variation of SMV, production capacity and waiting time with process number for different product are shown in Fig.3.3, Fig.3.4 and Fig.3.5.

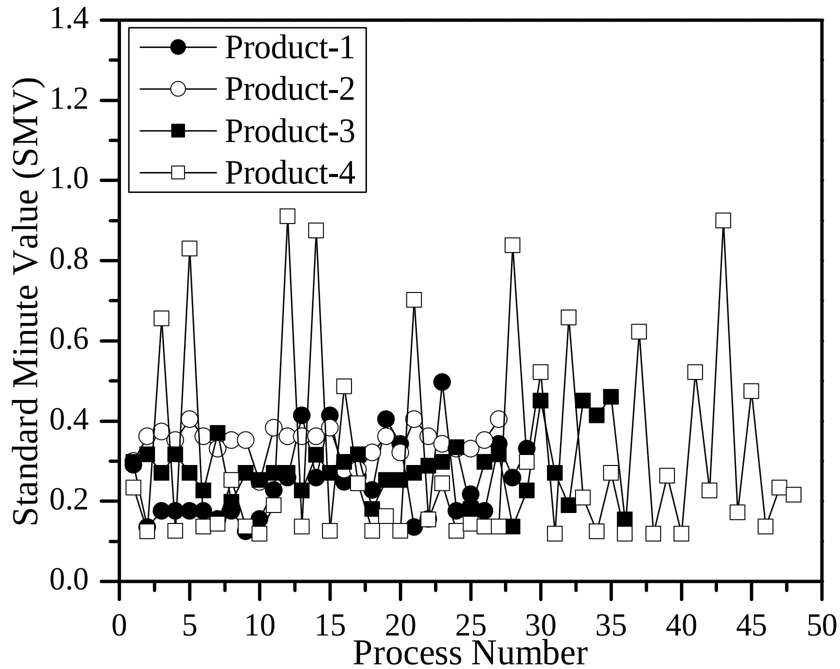

Fig.3.3 Variation of SMV with process number for different products

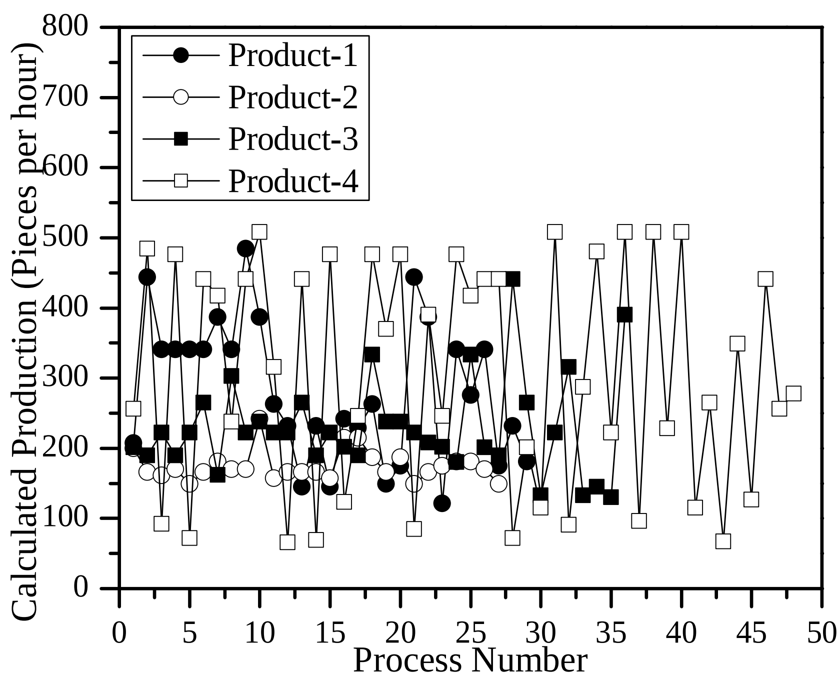

Fig.3.4 Variation of calculated production with process number for different products

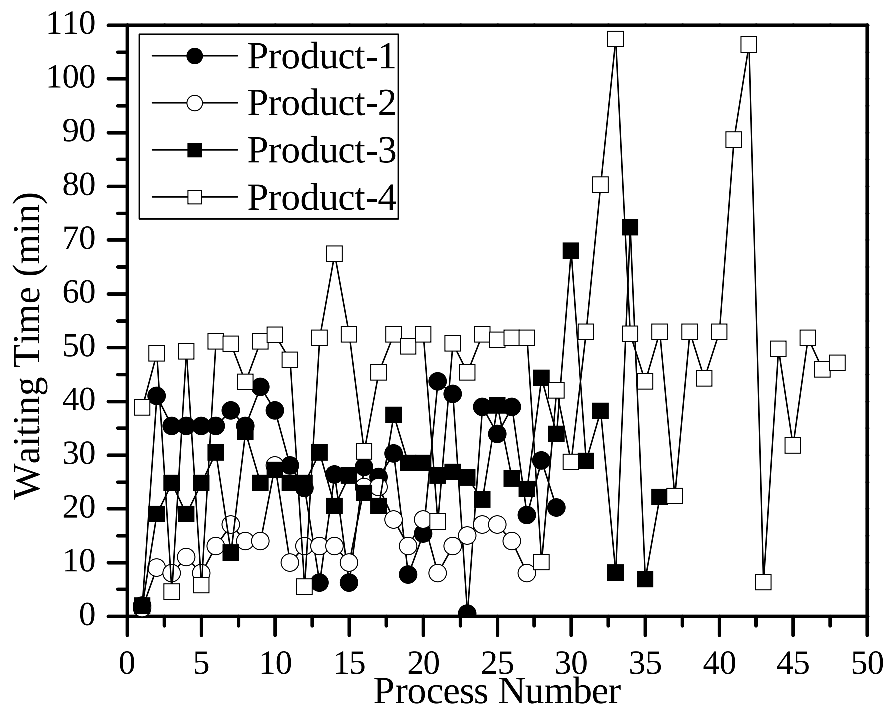

Fig.3.5 Variation of waiting time with process number for different products

3.2 Production Lines Balancing

Line balancing is an effective technique to distribute balanced workload among the workers in a production line and to maintain uniform production flow. By line balancing selected production lines were balanced considering identified bottlenecks and waiting time in where the balancing process has shared the excess time in the bottleneck process after achieving it's benchmarked target production. For line balancing work sharing distance, type of machine and worker's efficiency have been taken into consideration. According to Shumon et al. (**2010**), the benchmarked production target is assumed to be 80% for RMG. After line balancing new manpower setup is proposed and final capacity of each process is also reallocated. Finally, a new production layout is modeled with the balanced capacity. Equation (1.12) is used to calculate the theoretical manpower. The data required for line balancing of four products are shown in Table 3.2.

$$\text{Theoretical manpower} = \frac{\text{Benchmarked target capacity/hour/line}}{\text{Process capacity/hour/line}} \quad [1.12]$$

Table 3.2 Required data for line balancing of four products

Parameter	Product-1	Product-2	Product-3	Product-4
Total SMV	7.1	9.4	10.2	15
Calculated production capacity at 100% efficiency	245	172	241	212
Calculated production capacity at 80% efficiency (benchmarked production target)	196	138	193	170

After line balancing, production capacity is balanced and waiting time of the processes is reduced. After line balancing SMV, calculated production and waiting time for four products are changed and shown in Fig.3.6, Fig.3.7 and Fig.3.8. Besides, for four products comparisons are made among the existing process capacity, benchmarked target and proposed capacity as shown in Fig.3.9, Fig.3.10, Fig.3.11 and Fig.3.12 respectively.

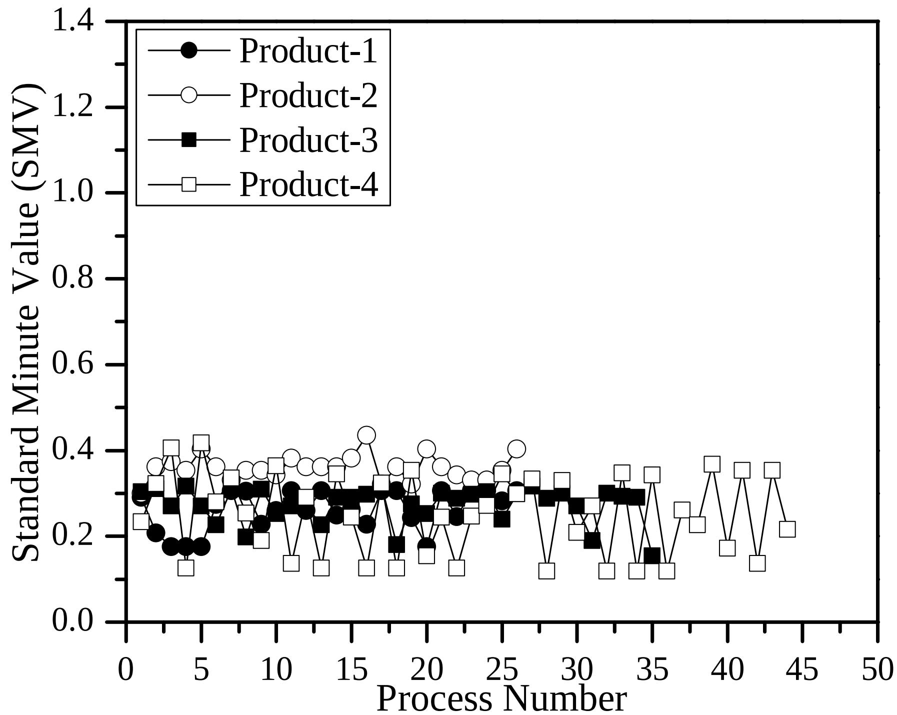

Fig.3.6 Variation of SMV with process number **after line balancing**

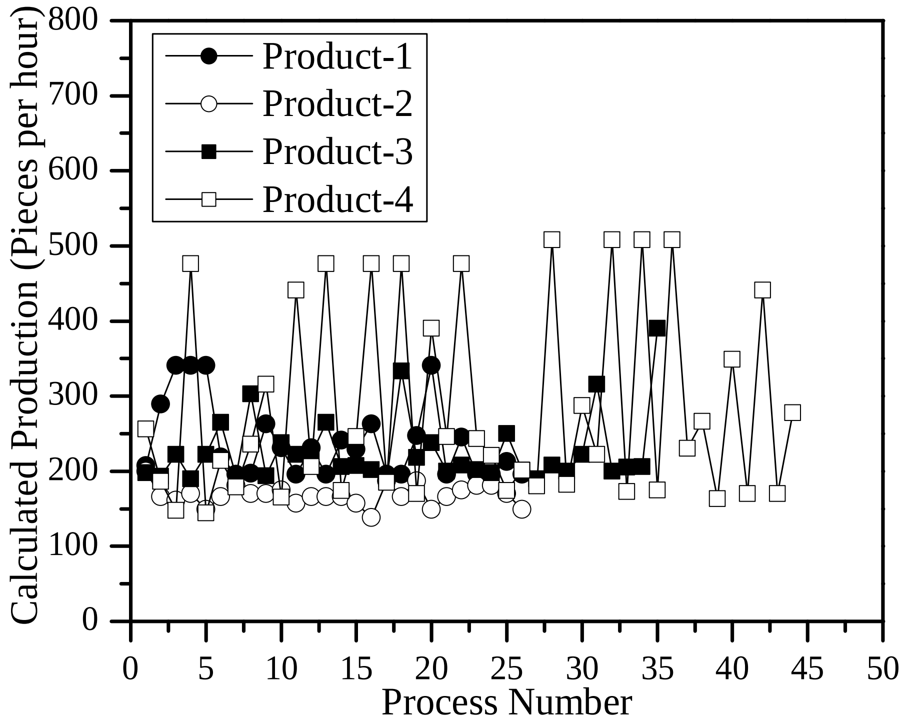

Fig.3.7 Variation of calculated production with process number after **line balancing**

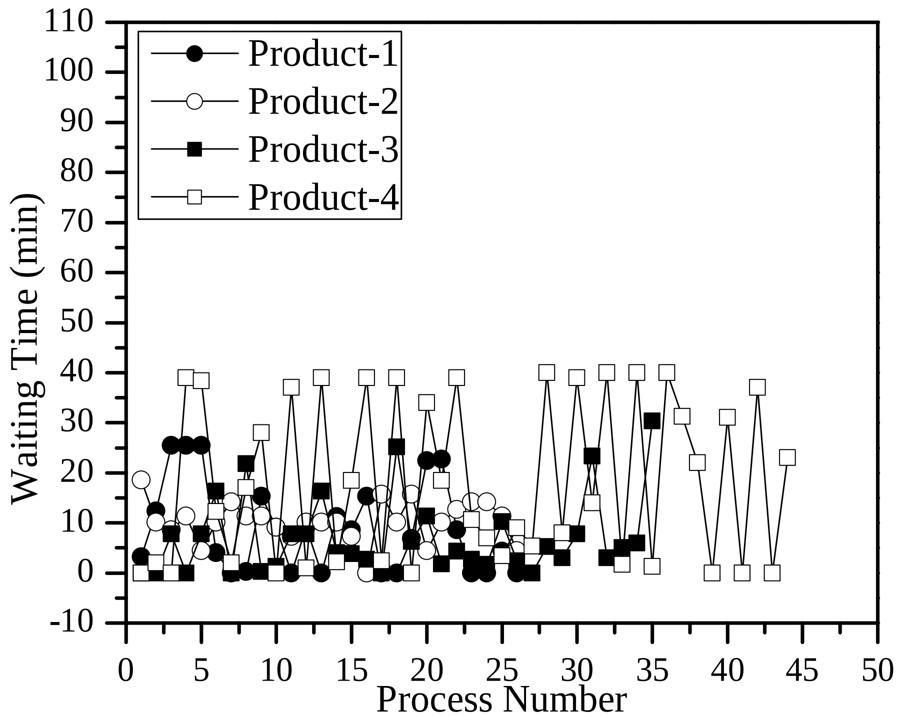

Fig.3.8 Variation of waiting time with process number after **line balancing**

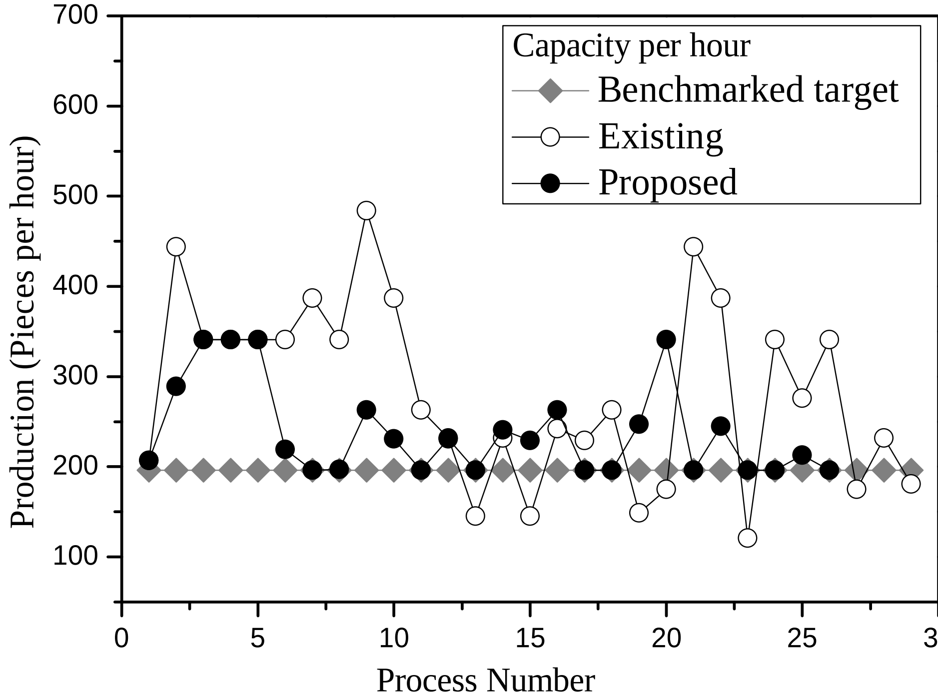

Fig.3.9 Variation in production with process number under different condition for product-1

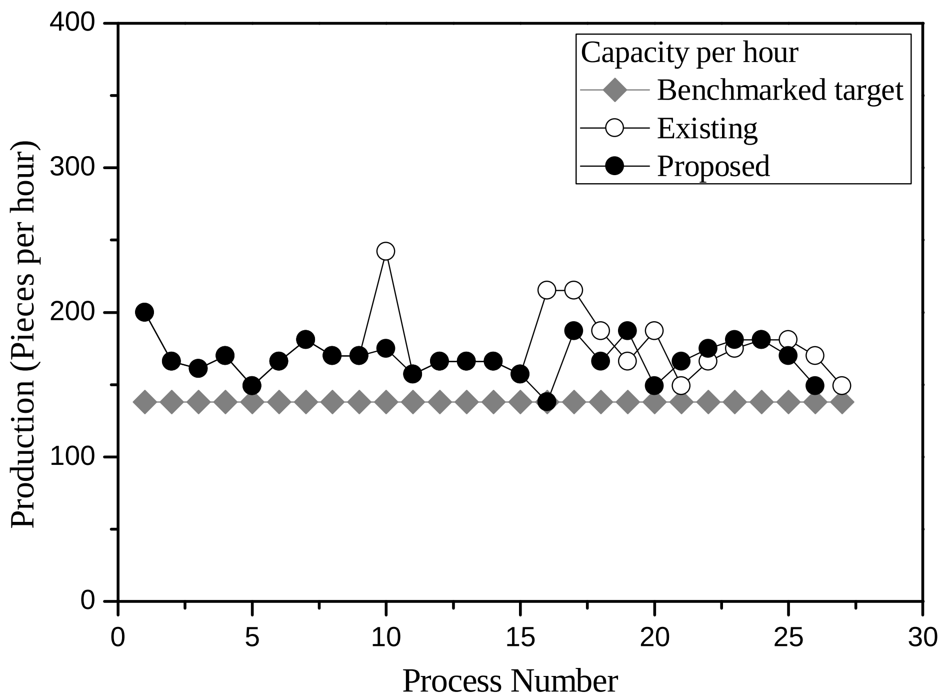

Fig.3.10 Variation in production with process number under different condition for product-2

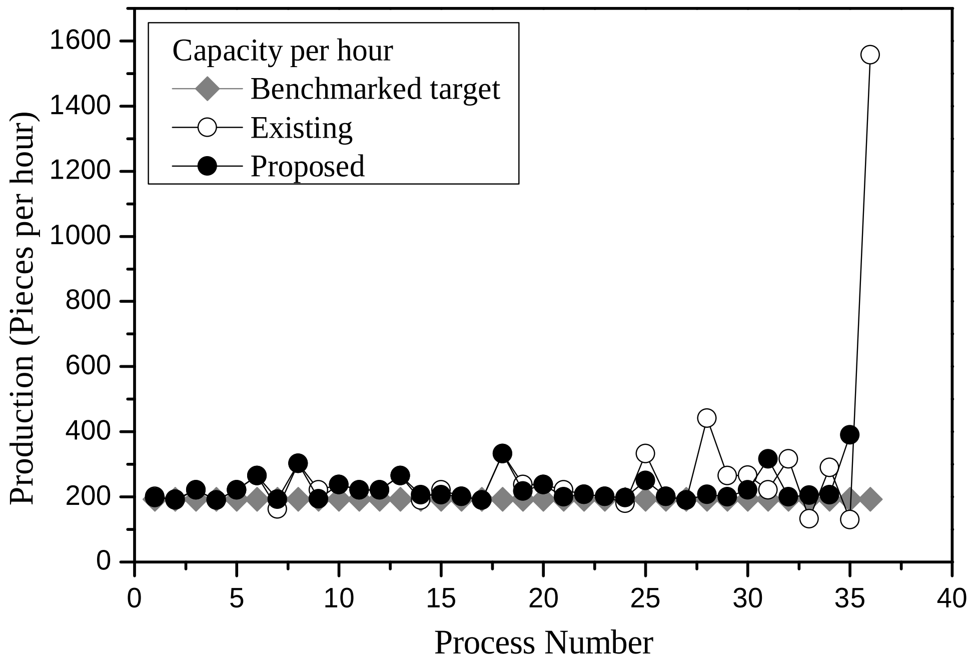

Fig.3.11 Variation in production with process number under different condition for product-3

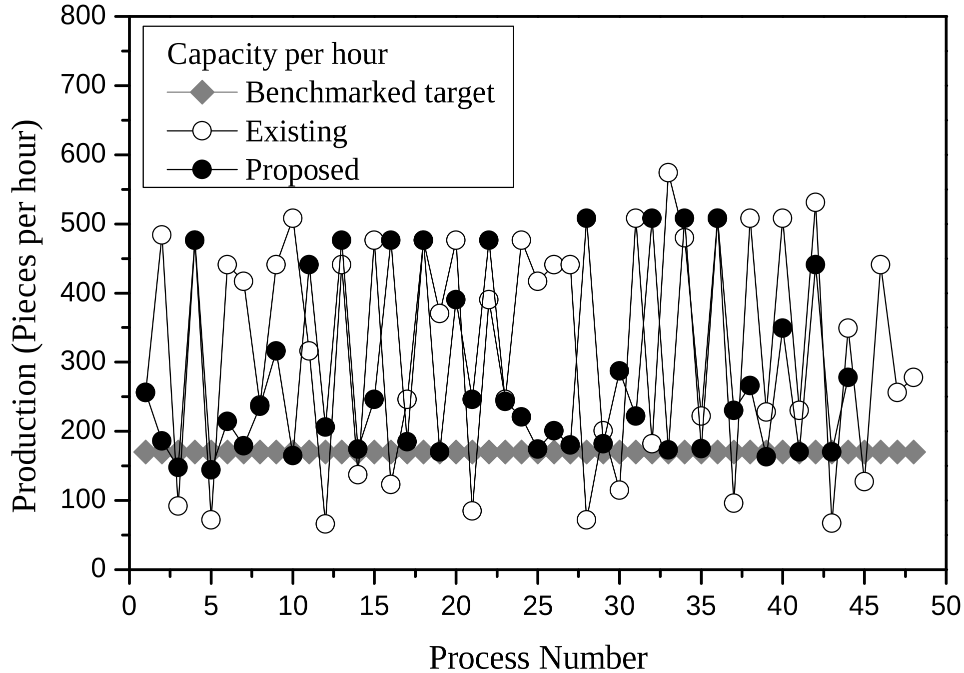

Fig.3.12 Variation in production with process number under different condition for product-4

3.3 Fishbone Diagram Analysis

Fish bone diagram is also known as cause-effect diagram which identifies actual causes for any result. The problem areas in RMG industries were closely noticed and identified during working time in the production floors and after discussion with the supervisors, operators and helpers in the industries. In this work, different problem areas for less productivity, more wastage and more production time are found in RMG industries as shown in Fig.3.13.

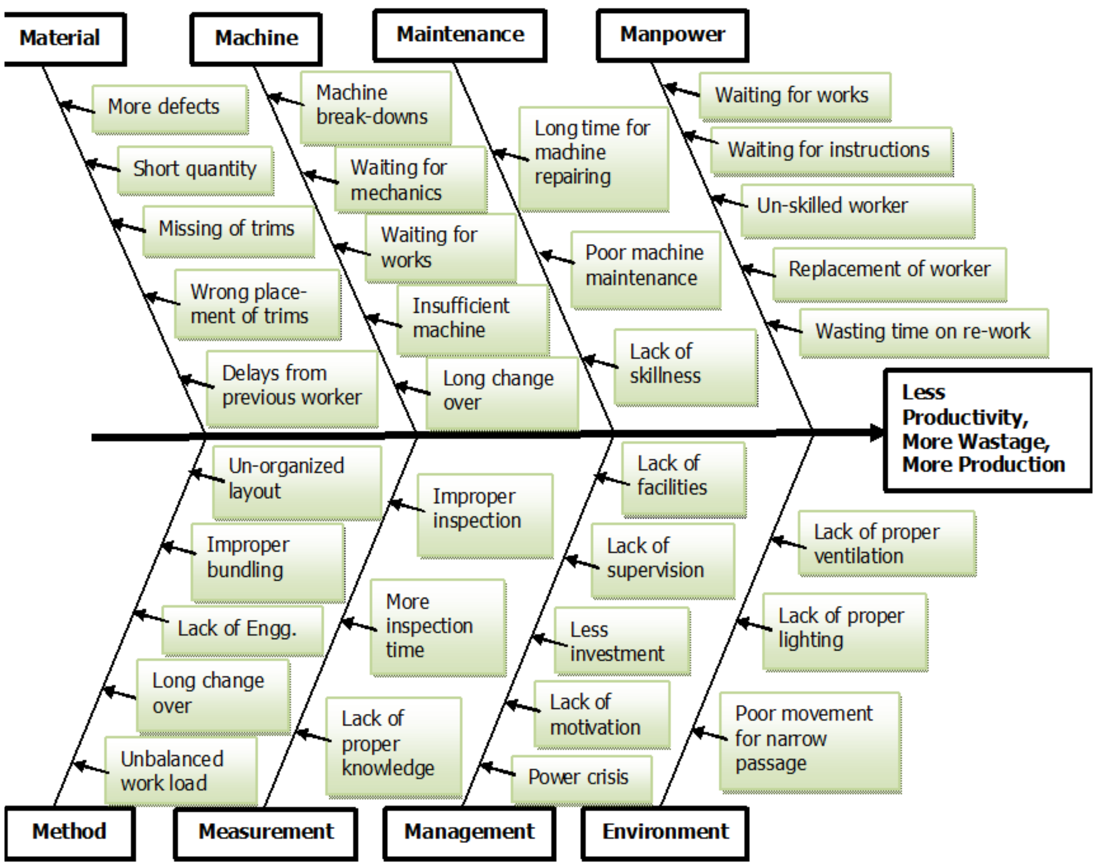

Fig.3.13 Fishbone diagram for less productivity, more wastage and more production time in RMG industries

Chapter-4

Discussion on Results

4.1 Production Lines Balancing

Fig.3.1 shows the variation of existing production with process number for different products in where the production is decreased after some processes and becomes constant. Fig.3.2 shows the variation of existing cycle time with process number for four different production lines in where cycle time is slight to moderate fluctuated for first three products and for product-4 the cycle time is fluctuated more. So, time study and line balancing is necessary to apply to increase the production.

Fig.3.3 shows the standard minute value (SMV) with process number for variety of products after time study. In the figure, the variation in process wise SMV for manufacturing of product-1, 2 and 3 are found similar with few exceptions. But, large variation in SMV is found for manufacturing of product-4 due to having many critical operations in the line as compare to other production lines. Fig.3.4 represents the variation of calculated production with process number for different products manufacturing in where production capacity is fluctuated more in case of product-1, 2 and 3. But, more variations in capacity are found in manufacturing of product-4, because of processes having huge variation in SMV. In case of all types of products, higher and lower process SMV results variations in the waiting time and process bottlenecks, those finally affect the efficiency and productivity of the lines. In case of four products, variations in production capacity leads more waiting time and bottlenecks in the processes according to Fig.3.5, those must be reduced to improve the line efficiency and productivity.

Fig.3.7 shows the variation of calculated production with process number after line balancing in where process wise production capacity is balanced and fluctuated less as compare to Fig.3.4. As a result, waiting time in the processes is reduced according to

Fig.3.8 due to work sharing among the processes. Though, production lines still contain some variations in process capacity and waiting time that can also be reduced by adding extra manpower and machine in the line and to do this will add more cost to the manufacturing. Finally, process wise SMV is decreased to increase the production rate according to Fig.3.6 in where the standard minute value is fluctuated less after line balancing for four products.

In this work, all graphs have shown the results at 80% benchmarked production target to decrease the waiting time and increase the productivity. For the change of further benchmarked target of production the graphs will show different results. After balancing four production lines a comparison is made between existing and proposed system to observe the variations of various parameters like productivity, waste (waiting time), production time etc. as shown in Table 4.1, Table 4.2, Table 4.3 and Table 4.4.

Table 4.1 Percentage of variation of various parameters after line balancing of product-1

Sl. No.	Parameters	Line Balancing		% of Variation
		Before	After	
1	Manpower	29	27	-7.0
2	Work Stations	29	26	-10.3
3	Machine	14	15	+7.1
4	Man Machine Ratio	2.1	1.7	-19.0
5	Total Waiting Time (min)	800	230	-71.3
6	Total Bottlenecks (min)	5.5	0	-100.0
7	Output/Hour/Line (pieces)	120	196	+63.3
8	Labour Productivity	41.4	72.6	+75.4
9	Machine Productivity	85.7	130.7	+52.5
10	Line Efficiency (%)	49	86	+75.5
11	Production lead time (days)	37	23	-37.8

After line balancing 10.3% work stations and 7% manpower (3 helpers) are decreased from the production line. This reduced manpower may be shifted to another production line to decrease the total labor cost. Fig.3.9 shows some variations in the existing process capacity as compare to the benchmarked target and the lower capacity from the benchmarked target is identified as the bottleneck process as production flow would be trapped at those points. Comparing with the 80% bench marked production target, process no.-7, 11, 13, 17, 18, 21, 23, 24 and 26 (Appendix-D) are identified as bottleneck process in where total production has been blocked and large work in process has been stuck at those processes. Line balancing is an efficient method to make the production flow almost smoother while compare to the existing layout. Workers having extra time after completing their regular works can share works with other work stations containing bottlenecks. In case of product-1, production line was found with bottleneck processes which have been balanced through sharing of works by the process no.-2, 6, 8, 19, 20, 22 and 25 (Appendix-D). Fig.3.9 also shows process wise proposed capacity per hour after balancing all processes. Besides, for the removal of process bottlenecks and to maintain smooth production, it is recommended to place additional 1 operator and 1 flat lock (FL) machine in process no.-21 (Appendix-D). Man machine ratio is also decreased from 2.1 to 1.7 after balancing the processes. For line balancing, total waiting time is decreased in a significant amount (71.3%) and thus, 37.8% production time is reduced for order completion. Finally, Labor productivity, machine productivity and line efficiency have been increased as 75.4%, 52.5% and 75.5% respectively. After line balancing outputs have been increased from 1200 to 1960 pieces a day. Before line balancing 44000 pieces of garments have been produced by 37 days where only 23 days are required to complete the same order quantity for line balancing. So, it is possible to save 14 days lead time for manufacturing of product-1 (Tank Top). Besides, it is also possible to save the working time of two helpers (600x2=1200 minutes) per day which decreases total labor cost of the industry.

Table 4.2 Percentage of variation of various parameters after line balancing of product-2

Sl. No.	Parameters	Line Balancing		% of Variation
		Before	After	
1	Manpower	27	26	-3.7
2	Work Stations	27	26	-3.7
3	Machine	19	19	0
4	Man Machine Ratio	1.42	1.37	-3.5
5	Total Waiting Time (min.)	370	267	-27.8
6	Total Bottlenecks (min.)	4	0	-100.0
7	Output/Hour/Line (pieces)	130	138	+6.2
8	Labor Productivity	48.2	53.1	+10.4
9	Machine Productivity	68.4	72.6	+6.1
10	Line Efficiency (%)	75.4	83.2	+10.3
11	Production lead time (days)	34	32	-6.0

After line balancing 3.7% work stations and manpower (1 operator) are decreased from the production line. Fig.3.10 shows some variations in the existing process capacity as compare to the benchmarked target. Comparing with the 80% bench marked production target, process no.-16 (Appendix-D) is identified as bottleneck process in where total production has been blocked and work in process has been stuck at that process. In case of product-2, production line was found with bottleneck processes which have been balanced through sharing of works by the process no.-10 (Appendix-D). Fig.3.10 also shows process wise proposed capacity per hour after balancing all processes. Man machine ratio is also decreased from 1.42 to 1.37 after line balancing. For line balancing, total waiting time is decreased to 27.8% and thus, 6% production time is reduced for order completion. Finally, labor productivity, machine productivity and line efficiency have been increased as 10.4%, 6.1% and 10.3% respectively. After line balancing outputs have been increased from 1300 to 1380 pieces a day. Before line balancing 44000 pieces of garments have been produced by 34 days where 32 days are required to complete the same order quantity for line balancing. So, it is possible to save 2 days lead time for manufacturing of product-2 (T-Shirt). Besides, it is also possible to save the working time of one worker (600x1=600 minutes) per day which decreases total labor cost of the industry.

Table 4.3 Percentage of variation of various parameters after line balancing of product-3

Sl. No.	Parameters	Line Balancing		% of Variation
		Before	After	
1	Manpower	41	37	-9.8
2	Work Stations	36	35	-2.8
3	Machine	26	26	0
4	Man Machine Ratio	1.6	1.4	-12.5
5	Total Waiting Time (min)	1193	255	-78.6
6	Total Bottlenecks (min)	4.5	3	-33.3
7	Output/Hour/Line (pieces)	115	193	+67.8
8	Labor Productivity	28	52.2	+86.4
9	Machine Productivity	44.2	74.2	+68.0
10	Line Efficiency (%)	47.7	88.7	+86.0
11	Production Lead time (days)	12.3	7.3	-40.7

After line balancing, 2.8% work stations and 9.8% manpower (4 helpers) are decreased from the production line. Fig.3.11 shows some variations in the existing process capacity as compare to the benchmarked target. Comparing with 80% bench marked production target, process no.-2, 7, 14, 24, 28, 32 and 34 (Appendix-D) are identified as bottleneck processes in where total production has been blocked and work in process has been stuck at those processes. In case of product-3, production line was found with bottleneck processes which have been balanced through sharing of works by the process no.-1, 15, 19, 21, 25, 29 and 33 (Appendix-D). Fig.3.11 also shows process wise proposed capacity per hour after balancing the bottleneck processes. Man machine ratio is also decreased from 1.6 to 1.4 after balancing the processes. After line balancing 78.6% waiting time is decreased and finally labor productivity, machine productivity and line efficiency have been increased as 86.4%, 68% and 86% respectively. After line balancing outputs have been increased from 1150 to 1930 pieces a day. Before line balancing 14000 pieces of garments have been produced by 12.3 days whereas 7.3 days are required to complete the same order quantity for line balancing. So, it is possible to save 5 days lead time for manufacturing of product-3 (Polo Shirt). Besides, it is also possible to save the working time of four workers (600x4=2400 minutes) per day which decreases total labor cost of the industry.

Table 4.4 Percentage of variation of various parameters after line balancing of product-4

Sl. No.	Parameters	Line Balancing		% of Variation
		Before	After	
1	Manpower	53	54	+2.0
2	Work Stations	48	44	-8.0
3	Machine	30	37	+23.0
4	Man Machine Ratio	1.8	1.5	-17.0
5	Total Waiting Time (min)	2244	812	-64.0
6	Total Bottlenecks (min)	50	40	-20.0
7	Output/Hour/Line (pieces)	60	170	+183.0
8	Labor Productivity	11.3	31.5	+179.0
9	Machine Productivity	20	46	+130.0
10	Line Efficiency (%)	28.3	78.7	+178.0
11	Production lead time (days)	6.7	2.4	-64.0

After line balancing, 23% machines are increased and 8% work stations are reduced from the production line. 6 helpers are shifted from the process no.-6, 8, 24, 30 and 38 (Appendix-D) but 7 new operators are added to the process no.-5, 10, 19, 25, 27, 33 and 39 (Appendix-D) to meet 80% benchmarked production target. So, total 2% workers are newly attached with the production line after line balancing. Fig.3.12 shows some variations in the existing process capacity as compare to the benchmarked target. Comparing with the 80% bench marked production target, process no.-5, 10, 12, 14, 25, 39 and 41(Appendix-D) are identified as bottleneck processes in where total production has been blocked and work in process has been stuck at those processes. In case of product-4, production line was found with bottleneck processes which have been balanced through sharing of works by the process no.-2, 7, 17, 23, 27, 33, 35 and 43 (Appendix-D). Fig.3.12 also shows process wise proposed capacity per hour after balancing the processes. Man machine ratio is also decreased from 1.8 to 1.5 after balancing the process. After line balancing 64% waiting time and 20% bottlenecks were decreased and finally labor productivity, machine productivity and line efficiency have been increased as 179%, 130% and 178% respectively. After line balancing outputs have been increased from 600 to 1700 pieces a day. Before line balancing 4000 pieces of garments have been produced by 6.7 days whereas 2.4 days are required to complete the same order quantity for line balancing. So, it is possible to save 4.3 days production lead time for manufacturing of product-4 (Men's half shirt). Exception is found for product-4 as production line needed to add and exchange some operators and helpers which increase the manufacturing cost about $213. It is only happened due to meet the same benchmarked production target with other three products. Table 4.5 shows the percentage variation of various parameters of different production lines after line balancing.

Table 4.5 Percentage variation of various parameters of different production lines after line balancing

Sl. No.	Parameters	Percentage variation			
		Product-1	Product-2	Product-3	Product-4
1	Manpower	-7%	-3.7%	-9.8%	+2%
2	Work Stations	-10.3%	-3.7%	-2.8%	-8%
3	Machine	+7.1%	0	0	+23%
4	Man Machine Ratio (MMR)	-19%	-3.5%	-12.5%	-17%
5	Total Waiting Time (min)	-71.3%	-27.8%	-78.6%	-64%
6	Total Bottlenecks (min)	-100%	-100%	-33.3%	-20%
7	Output/Hour/Line (pieces)	+63.3%	+6.2%	+67.8%	+183%
8	Labor Productivity	+75.4%	+10.4%	+86.4%	+179%
9	Machine Productivity	+52.5%	+6.1%	+68%	+130%
10	Line Efficiency (%)	+75.5%	+10.3%	+86%	+178%
11	Production Lead Time (days)	-37.8%	-6%	-40.7%	-64%

Following points have been noted after comparing the percentage variation of various parameters of four balanced production lines:

- After line balancing total manpower is reduced for product-1, 2 and 3 but is increased for product-4 due to increase in productivity to meet the same benchmarked production target.
- Total work satiations are minimized for all types of products.
- Man machine ratio is decreased for all types of products.
- Total waiting time and bottlenecks are minimized from four production lines in where even no bottlenecks are found to remain present in the lines for product-1 and 2.

- Line efficiency, labor productivity and machine productivity are increased in momentous amount in case of product-1, 3 and 4 as compare to product-2.
- For all kinds of products production lead time is reduced to deliver four products in required quantity.
- To meet 80% benchmarked production target line required to add extra machine and manpower to increase the productivity. This is only happened because of having more critical and time consuming operations in the production line.

4.2 Fishbone Diagram Analysis

Different problem areas in RMG industries coupled with eight variables such as manpower, machine, material, method, maintenance, measurement, 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 four RMG industries for less productivity are:

- Production time is enlarged due to more waiting time for work, machine, mechanic, maintenance and machine setting. Besides waiting time, more defects (fabric and sewing) and re-works 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 inspector in the production lines.

- Lack of engineering and unorganized production layout impeded well distribution of work load among the workers. As a result, more waiting time and bottlenecks were resulted in the production lines, which maximized the production time and minimized the productivity.

- Workers' concentration towards the work is reduced due to poor ventilation and lighting facilities, which were also accountable for less productivity.

- Lack of motivation, supervision, overall co-ordination and power crisis in the RMG industries were some obstacles for productivity improvement.

4.3 SWOT Analysis

SWOT means strength, weakness, opportunity and threats. This type of analysis was done on the overall situation of four RMG industries to identify the strength, weakness, opportunity and threats for productivity improvement. Table 4.6 shows the SWOT analysis for productivity improvement in RMG industries.

One structured questionnaire (Appendix-F) was also used to conduct a survey on 100 people including supervisors, operators and helpers of different sections in four readymade garments (RMG) industries. The aim of this survey was to study and investigate various parameters pertaining to workers' personal information as well as overall working environment of the industries which may have indirect impacts on the productivity of the RMG industries.

After study of the questionnaire following points have been identified and recorded which may also decrease workers' performance as well as overall productivity of the RMG industries:

- Lack of skillness of the workers
- Lack of provision of training facilities by the industries
- Lack of consistent workers in the RMG industries
- Marital status and no. of children of the workers
- Lack of active baby daycare facilities
- Lower salary structure and less satisfaction of the workers
- Improper working conditions like ventilation and lighting

Table 4.6 SWOT analysis for productivity improvement in RMG industries

Strengths (S)	Weaknesses (W)
➢ Low-cost power generation by using gas as fuel. ➢ Cheap labor force	➢ Lack of training opportunities. ➢ Lack of skilled manpower. ➢ Lack of quality management ➢ Excessive defects and more re-work. ➢ More waiting time and too much bottlenecks. ➢ Lack of engineering. ➢ More production time. ➢ Imbalanced work load distribution ➢ Long changeover time. ➢ Purchasing of wrong materials. ➢ Lack of supervision. ➢ Poor salary structure of workers. ➢ Lack of worker's motivation. ➢ Lack of incentive scheme. ➢ Poor working conditions.
Threats (T)	**Opportunities (O)**
➢ Political imbalance ➢ Labor unrest. ➢ Interrupted utility supply.	➢ Increase of customer relation. ➢ More production orders from customers. ➢ Increase of business growth in global market especially in USA, Canada, Australia and EU countries. ➢ Export opportunity in Japan and CIS countries. ➢ Increase of profit margin.

Chapter-5

Conclusions and Recommendation

5.1 Conclusions

By the time study, SMV and production capacity of the processes were calculated separately (Appendix-B) for four different production lines. Line balancing has decreased 3-10% workforce for product-1, 2 and 3 but 2% workforce had to increase for product-4 to meet the same benchmarked production target. After line balancing 2-10% of work stations, 27-78% of waiting time and 20-100% of process bottlenecks are reduced from four production lines.

After line balancing four production systems (Appendix-D) are newly proposed for four products which have finally reduced 6-64% of production lead time for the improvement of 10-179% of labor productivity and 6-130% of machine productivity.

Extra machinery and manpower are attached with two production lines (for product-1 and 4) for productivity improvement at the same benchmarked production target with other two production lines (for product-2 and 3). It is only happened because of having some critical, time consuming and excessive bottleneck processes in the production lines. The reduced workforce after line balancing can be shifted to other production lines to minimize the total labor cost.

Different problem areas associated to man, machine, maintenance, material, method, measurement, management and environment were recognized during observation and are obviously indicated by fishbone or cause-effect diagram. These problem areas (causes) are also accountable to enlarge the production time as well as hamper overall productivity (effect). As a result, RMG industries require more lead time for order completion which becomes hard to manage in maximum cases.

By SWOT analysis it becomes possible to identify various internal factors such as strength, and weakness and external factors such as opportunity and threats of RMG industries to improve its productivity, capacity and export growth in global markets.

Now-a-days, RMG manufacturers of Bangladesh are seeking ways to maximize their resources utilization, increase productivity and minimize production cost. In this respective point of view, this study becomes more important to provide the technical overview about the productivity improvement and reduction of waiting time and production cost.

5.2 Recommendation

One piece flow production system was found in the existing production layouts of product-1, 2 and 3 whereas section production system linked with one piece flow was found for product-4. After line balancing new production layout models (Appendix-D) are proposed for four products in where combination of both modular and traditional manufacturing systems (one piece flow/group) are recommended to use for the reduction of waiting time, and bottlenecks and to maximize the productivity. The workers having skillness on multi-tasks should be integrated with the proposed systems to share the works of other work centers.

Only skilled workers should be entitled for the production processes and that’s why proper training and supervision must necessary to achieve the optimum improvements in productivity and efficiency.

Time study and line balancing techniques are only used in the sewing section and the application of those techniques in the cutting and finishing sections will further increase more productivity in the RMG industries. Besides time studies, line balancing and fishbone analysis other effective lean tools like 5S, KAIZEN, JIT, KANBAN, SMED, TPM, VSM etc. may also be employed to the RMG industries for the reduction of excessive wastes, and more production time and to increase the productivity which will help Readymade garments (RMG) industries to compete and survive with less manufacturing cost and higher product quality.

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Appendix-A: RMG Industry Profile

Name of the Industry

Style Garden Ltd.

Location	: Mirpur-12, Dhaka-1216.
Type	: Only garment making
Nature	: Supporting industry
IE Activities	: None
Certification	: None
Clients	: Exposures Ltd.
Production Lines	: 01
Production capacity/day	: 550 pieces
Workforce	: 150
Type of Products	: Ski Jacket and Long Pant

Fakir Apparels Ltd.

Location	: BSCIC, Hosiery Industrial Estate, Narayangonj.
Type	: Composite (Knitting, Dyeing, Printing & Garment)
Nature	: 100% export oriented industry
IE Activities	: Yes
Certification	: Oeko-Tex and WRAP
Clients	: H & M, Gap, Levi's, Esprit, S.Oliver, Tesco etc.
Production Lines	: 90
Production capacity/day	: 1, 40, 000 pieces
Workforce	: 7,500
Type of Products	: T-Shirt, Polo Shirt, Tank Top, Mens Shorts etc.

AJI Apparels Industry Ltd.

Location	: 226, Singair Road, Hemayetpur, Savar, Dhaka.
Type	: Composite (Knitting, Dyeing, Printing & Garment)
Nature	: 100% export oriented industry
IE Activities	: Yes
Certification	: ISO
Clients	: Carrefour, Tesco, Wal-Mart, Sears, K mart etc.
Production Lines	: 44
Production capacity/day	: 48, 600 pieces
Workforce	: 2, 200
Type of Products	: Mens Polo Shirt

MIM Dresses Ltd.

Location	: Baishaki Super Market (2nd Floor), Mirpur-1, Dhaka.
Type	: Only garment making
Nature	: Sub-contract industry
IE Activities	: None
Certification	: None
Clients	: New Yorker
Production Lines	: 02
Production capacity/day	: 2, 400 pieces
Workforce	: 200
Type of Products	: Mens Half Shirt and Ladies Skirt

Appendix-B: Collected Data

Table B.1 Existing production and cycle time with process number

Process No.	Product-1		Product-2		Product-3		Product-4	
	Production (pieces/ hour)	Cycle Time (min)	Production (pieces/ hour)	Cycle Time (min)	Production (pieces/ hour)	Cycle Time (min)	Production (pieces/ hour)	Cycle Time (min)
1	140	0.28	140	0.29	130	0.28	90	0.22
2	140	0.13	140	0.35	130	0.29	90	0.11
3	140	0.17	140	0.36	130	0.25	85	0.15
4	140	0.17	140	0.34	130	0.29	85	0.12
5	140	0.17	130	0.39	130	0.25	65	0.77
6	140	0.17	130	0.35	130	0.21	65	0.13
7	140	0.15	130	0.32	130	0.34	65	0.13
8	140	0.17	130	0.34	130	0.18	65	0.23
9	140	0.12	130	0.34	130	0.25	65	0.13
10	140	0.15	130	0.24	130	0.23	65	0.11
11	140	0.22	130	0.37	130	0.25	65	0.18
12	140	0.25	130	0.35	130	0.25	60	0.84
13	130	0.4	130	0.35	130	0.21	60	0.13
14	130	0.25	130	0.35	125	0.29	60	0.81
15	130	0.40	130	0.37	125	0.25	60	0.12
16	130	0.24	130	0.27	125	0.28	60	0.45
17	130	0.35	130	0.27	125	0.29	60	0.23
18	130	0.22	130	0.31	125	0.17	60	0.12
19	130	0.39	130	0.35	125	0.23	60	0.15
20	130	0.33	130	0.31	125	0.23	60	0.12
21	120	0.13	130	0.39	125	0.25	60	0.65
22	120	0.15	130	0.35	115	0.27	60	0.14
23	120	0.48	130	0.33	115	0.28	60	0.23
24	120	0.17	130	0.32	115	0.31	60	0.12
25	120	0.21	130	0.32	115	0.17	60	0.13
26	120	0.17	130	0.34	115	0.28	60	0.13
27	120	0.33	130	0.39	115	0.29	60	0.13
28	120	0.25	-	-	115	0.13	60	0.78
29	120	0.32	-	-	115	0.21	60	0.28
30	-	-	-	-	115	0.42	60	0.48
31	-	-	-	-	115	0.25	60	0.11
32	-	-	-	-	115	0.18	60	0.61
33	-	-	-	-	115	0.42	60	0.19
34	-	-	-	-	115	0.38	60	0.09
35	-	-	-	-	115	0.43	60	0.25
36	-	-	-	-	115	0.14	60	0.11
37	-	-	-	-	-	-	60	0.58
38	-	-	-	-	-	-	60	0.11
39	-	-	-	-	-	-	60	0.24
40	-	-	-	-	-	-	60	0.11
41	-	-	-	-	-	-	60	0.48
42	-	-	-	-	-	-	60	0.21

43	-	-	-	-	-	-	60	0.91
44	-	-	-	-	-	-	60	0.16
45	-	-	-	-	-	-	60	0.44
46	-	-	-	-	-	-	60	0.13
47	-	-	-	-	-	-	60	0.22
48	-	-	-	-	-	-	60	0.20

Appendix-C: Time Study Data

Table C.1 Process wise SMV and capacity per hour for product-1 in sewing section

Process No.	Processes	No. of Operator	No. of Helper	M/C Type	Basic Time (min)	SMV	Capacity /Hour (Pieces)
1	Matching and Folding		1	-	0.252	0.290	207
2	Right shoulder joint	1		OL	0.117	0.135	444
3	Trimming		1	-	0.153	0.176	341
4	Loop joint	1		PM	0.153	0.176	341
5	Folding		1	-	0.153	0.176	341
6	Neck piping	1		FL	0.153	0.176	341
7	Trimming		1	-	0.135	0.155	387
8	Shoulder in tucking	1		PM	0.153	0.176	341
9	Trimming and Folding		1	-	0.108	0.124	484
10	Shoulder out tucking	1		PM	0.135	0.155	387
11	Left shoulder joint	1		PM	0.198	0.228	263
12	Trimming		1	-	0.225	0.259	232
13	Arm hole piping	1		FL	0.360	0.414	145
14	Trimming		1	-	0.225	0.259	232
15	Side seam	1		OL	0.360	0.414	145
16	Trimming and Folding		1	-	0.216	0.248	242
17	Side seam	1		OL	0.315	0.262	229
18	Trimming and Folding		1	-	0.198	0.228	263
19	Arm hole in and out tucking	1		PM	0.351	0.404	149
20	Thread cutting		1	-	0.297	0.342	175
21	Bottom hem tucking	1		PM	0.117	0.135	444
22	Trimming		1	-	0.135	0.155	387
23	Body hem tucking	1		FL	0.432	0.497	121
24	Folding		1	-	0.153	0.176	341
25	Hem security tucking	1		PM	0.189	0.217	276
26	Cutting and Folding		1	-	0.153	0.176	341
27	Care label joint	1		PM	0.297	0.342	175
28	Thread cutting		1	-	0.225	0.259	232
29	Turning over		1	-	0.288	0.331	181
		14	**15**	**14**		**7.1**	

Table C.2 Process wise worker's efficiency for Product-1 in sewing section

Process No.	Process	SMV	Total Output /Day (Pieces)	Total Minutes Produced	Total Minutes Attended	Worker's Efficiency (%)
1	Matching and Folding	0.290	1400	406.0	600	68
2	Right shoulder joint	0.135	1400	189.0	600	32
3	Trimming	0.176	1400	246.4	600	41
4	Loop joint	0.176	1400	246.4	600	41
5	Folding	0.176	1400	246.4	600	41
6	Neck piping	0.176	1400	246.4	600	41
7	Trimming	0.155	1400	217.0	600	36
8	Shoulder in tucking	0.176	1400	246.4	600	41
9	Trimming and Folding	0.124	1400	173.6	600	29
10	Shoulder out tucking	0.155	1400	217.0	600	36
11	Left shoulder joint	0.228	1400	319.2	600	53
12	Trimming	0.259	1400	362.6	600	60
13	Arm hole piping	0.414	1300	538.2	600	90
14	Trimming	0.259	1300	336.7	600	56
15	Side seam	0.414	1300	538.2	600	90
16	Trimming and Folding	0.248	1300	322.4	600	54
17	Side seam	0.262	1300	340.6	600	57
18	Trimming and Folding	0.228	1300	296.4	600	49
19	Arm hole in and out tucking	0.404	1300	525.2	600	88
20	Thread cutting	0.342	1300	444.6	600	74
21	Bottom hem tucking	0.135	1200	162.0	600	27
22	Trimming	0.155	1200	186.0	600	31
23	Body hem tucking	0.497	1200	596.4	600	99
24	Folding	0.176	1200	211.2	600	35
25	Hem security tucking	0.217	1200	260.4	600	43
26	Cutting and Folding	0.176	1200	211.2	600	35
27	Care label joint	0.342	1200	410.4	600	68
28	Thread cutting	0.259	1200	310.8	600	52
29	Turning over	0.331	1200	397.2	600	66
		7.1				

Table C.3 Process wise waiting time, bottlenecks and manpower for product-1

Process No.	Process	Total Capacity /Hour (pieces)	Existing Production/ Hour (pieces)	Waiting time (min)	Bottlenecks (min)	Actual Manpower
1	Matching and Folding	207	140	1.50	0.0	1
2	Right shoulder joint	444	140	41.0	0.0	1
3	Trimming	341	140	35.4	0.0	1
4	Loop joint	341	140	35.4	0.0	1
5	Folding	341	140	35.4	0.0	1
6	Neck piping	341	140	35.4	0.0	1
7	Trimming	387	140	38.3	0.0	1
8	Shoulder in tucking	341	140	35.4	0.0	1
9	Trimming and Folding	484	140	42.7	0.0	1
10	Shoulder out tucking	387	140	38.3	0.0	1
11	Left shoulder joint	263	140	28.0	0.0	1
12	Trimming	232	140	23.8	0.0	1
13	Arm hole piping	145	130	6.20	4.1	1
14	Trimming	232	130	25.4	0.0	1
15	Side seam	145	130	6.00	0.0	1
16	Trimming and Folding	242	130	27.8	0.0	1
17	Side seam	229	130	25.9	0.0	1
18	Trimming and Folding	263	130	30.0	0.0	1
19	Arm hole in and out tucking	149	130	7.70	0.0	1
20	Thread cutting	175	130	15.4	0.0	1
21	Bottom hem tucking	444	120	43.7	1.4	1
22	Trimming	387	120	41.4	0.0	1
23	Body hem tucking	121	120	0.50	0.0	1
24	Folding	341	120	38.9	0.0	1
25	Hem security tucking	276	120	33.9	0.0	1
26	Cutting and Folding	341	120	38.9	0.0	1
27	Care label joint	175	120	18.8	0.0	1
28	Thread cutting	232	120	29.0	0.0	1
29	Turning over	181	120	20.2	0.0	1
				800	**5.5**	**29**

Table C.4 SMV and capacity per hour for product-2 in sewing section

Process No.	Processes	No. of Operator	No. of Helper	M/C Type	Basic Time (min)	SMV	Capacity /Hour (pieces)
1	Matching and Folding		1	-	0.261	0.300	200
2	Both shoulder joint	1		OL	0.315	0.362	166
3	Neck piping	1		OL	0.324	0.373	161
4	Back neck piping	1		FL	0.306	0.352	170
5	Back end tacking	1		PM	0.351	0.404	149
6	Front neck top stitching	1		PM	0.315	0.362	166
7	Cutting and Marking		1	-	0.288	0.331	181
8	Back tape top stitching with main label joint	1		PM	0.306	0.352	170
9	Left shoulder joint tacking and Shoulder out tacking	1		PM	0.306	0.352	170
10	Left shoulder joint	1		OL	0.216	0.248	242
11	Sleeve open hemming	1		FL	0.333	0.383	157
12	Sleeve dechain		1	-	0.315	0.362	166
13	Shoulder trimming		1	-	0.315	0.362	166
14	Body matching		1	-	0.315	0.362	166
15	Sleeve join tacking and Folding	1		PM	0.333	0.383	157
16	First sleeve joint	1		OL	0.243	0.279	215
17	Second sleeve joint	1		OL	0.243	0.279	215
18	Side seam one	1		OL	0.279	0.321	187
19	Label joint	1		PM	0.315	0.362	166
20	Side seam two	1		OL	0.279	0.321	187
21	Sleeve in and out tacking	1		PM	0.351	0.404	149
22	Bottom hem tacking and Hem security tacking	1		PM	0.315	0.362	166
23	Bottom hemming	1		FL	0.297	0.342	175
24	Thread cutting		1	-	0.288	0.331	181
25	Care label sewing and joint	1		PM	0.288	0.331	181
26	Sticker removing		1	-	0.306	0.352	170
27	Thread cutting		1	-	0.351	0.404	149
		19	**8**	**19**		**9.4**	

Table C.5 Process wise worker's efficiency for product-2 in sewing section

Process No.	Process	SMV	Total Output /Day (Pieces)	Total Minutes Produced	Total Minutes Attended	Worker's Efficiency (%)
1	Matching and Folding	0.300	1400	420.0	600	70
2	Both shoulder joint	0.362	1400	506.8	600	84
3	Neck piping	0.373	1400	522.2	600	87
4	Back neck piping	0.352	1400	492.8	600	82
5	Back end tacking	0.404	1300	525.2	600	88
6	Front neck top stitching	0.362	1300	470.6	600	78
7	Cutting and Marking	0.331	1300	430.3	600	72
8	Back tape top stitching with main label joint	0.352	1300	457.6	600	76
9	Left shoulder join tacking and Shoulder out tacking	0.352	1300	457.6	600	76
10	Left shoulder joint	0.248	1300	322.4	600	54
11	Sleeve open hemming	0.383	1300	497.9	600	83
12	Sleeve dechain	0.362	1300	470.6	600	78
13	Shoulder trimming	0.362	1300	470.6	600	78
14	Body matching	0.362	1300	470.6	600	78
15	Sleeve join tacking and Folding	0.383	1300	497.9	600	83
16	First sleeve joint	0.279	1300	362.7	600	60
17	Second sleeve joint	0.279	1300	362.7	600	60
18	Side seam one	0.321	1300	417.3	600	70
19	Label joint	0.362	1300	470.6	600	78
20	Side seam two	0.321	1300	417.3	600	70
21	Sleeve in and out tacking	0.404	1300	525.2	600	88
22	Bottom hem tacking and Hem security tacking	0.362	1300	470.6	600	78
23	Bottom hemming	0.342	1300	444.6	600	74
24	Thread cutting	0.331	1300	430.3	600	72
25	Care label sewing and joint	0.331	1300	430.3	600	72
26	Sticker removing	0.352	1300	457.6	600	76
27	Thread cutting	0.404	1300	525.2	600	88
		9.4				

Table C.6 Process wise waiting time, bottlenecks and manpower for product-2

Process No.	Process	Total Capacity /Hour (pieces)	Existing Production/ Hour (pieces)	Waiting time (min)	Bottlenecks (min)	Actual Manpower
1	Matching and Folding	200	140	1.20	0	1
2	Both shoulder joint	166	140	9.00	0	1
3	Neck piping	161	140	7.80	0	1
4	Back neck piping	170	140	11.3	0	1
5	Back end tacking	149	130	7.70	4	1
6	Front neck top stitching	166	130	13.4	0	1
7	Cutting and Marking	181	130	17.0	0	1
8	Back tape top stitching with main label joint	170	130	13.6	0	1
9	Left shoulder join tacking and Shoulder out tacking	170	130	14.2	0	1
10	Left shoulder joint	242	130	27.2	0	1
11	Sleeve open hemming	157	130	9.80	0	1
12	Sleeve dechain	166	130	12.8	0	1
13	Shoulder trimming	166	130	12.7	0	1
14	Body matching	166	130	13.3	0	1
15	Sleeve join tacking and Folding	157	130	10.0	0	1
16	First sleeve joint	215	130	23.8	0	1
17	Second sleeve joint	215	130	24.0	0	1
18	Side seam one	187	130	18.2	0	1
19	Label joint	166	130	13.2	0	1
20	Side seam two	187	130	18.0	0	1
21	Sleeve in and out tacking	149	130	7.80	0	1
22	Bottom hem tacking and Hem security tacking	166	130	13.5	0	1
23	Bottom hemming	175	130	15.0	0	1
24	Thread cutting	181	130	16.5	0	1
25	Care label sewing and joint	181	130	17.0	0	1
26	Sticker removing	170	130	13.8	0	1
27	Thread cutting	149	130	8.20	0	1
				370	**4**	**27**

Table C.7 SMV and capacity per hour for product-3 in sewing section

Process No.	Processes	No. of Operator	No. of Helper	M/C Type	Basic Time (min)	SMV	Capacity /Hour (pieces)
1	Back front matching		1	-	0.248	0.298	201
2	Body marking		1	-	0.263	0.316	190
3	Sleeve scissoring		1	-	0.225	0.270	222
4	Shoulder joint	1		OL	0.263	0.316	190
5	Shoulder top stitch	1		PM	0.225	0.270	222
6	Sleeve matching		1	-	0.188	0.226	265
7	Sleeve joint	1		OL	0.308	0.370	162
8	Matching and Trimming		1	-	0.165	0.198	303
9	Placket rolling	1		PM	0.225	0.270	222
10	Body and Placket joint	1		PM	0.210	0.252	238
11	Placket top stitching	1		PM	0.225	0.270	222
12	Nose tucking	1		PM	0.225	0.270	222
13	Trimming		1	-	0.188	0.226	265
14	Collar tucking	1		PM	0.263	0.315	190
15	Collar joint	1		OL	0.225	0.270	222
16	Cuff joint	1		OL	0.248	0.297	202
17	Back neck piping	1		FL	0.263	0.316	190
18	Marking		1	-	0.150	0.180	333
19	Placket closing	1		PM	0.210	0.252	238
20	Upper placket stitching	1		PM	0.210	0.252	238
21	Lower placket stitching	1		PM	0.225	0.270	222
22	Placket box	1		PM	0.240	0.288	208
23	Back neck top stitching	1		PM	0.248	0.297	202
24	Label joint	1		PM	0.278	0.334	180
25	Trimming		1	-	0.150	0.180	333
26	Opening tuck	1		PM	0.248	0.298	201
27	Bottom hemming	1		FL	0.263	0.316	190
28	Trimming		1	-	0.113	0.136	441
29	Marking		1	-	0.188	0.226	265
30	Side seem	2		OL	0.375	0.450	133
31	Side vent tucking	1		PM	0.225	0.270	222
32	Trimming		1	-	0.158	0.190	316
33	Side vent tuck joint	1		OL	0.375	0.450	133
34	Side vent top stitching	2		PM	0.345	0.414	145
35	Chap tucking	1		PM	0.383	0.460	130
36	Trimming		4	-	0.128	0.154	390
		26	**15**	**26**		**10.2**	

Table C.8 Process wise worker's efficiency for product-3 in sewing section

Process No.	Process	SMV	Total Output /Day (pieces)	Total Minutes Produced	Total Minutes Attended	Worker's Efficiency (%)
1	Back front matching	0.298	1300	387.4	600	65
2	Body marking	0.316	1300	410.8	600	69
3	Sleeve scissoring	0.270	1300	351.0	600	59
4	Shoulder joint	0.316	1300	410.8	600	69
5	Shoulder top stitch	0.270	1300	351.0	600	59
6	Sleeve matching	0.226	1300	293.8	600	49
7	Sleeve joint	0.370	1300	481.0	600	80
8	Matching and Trimming	0.198	1300	257.4	600	43
9	Placket rolling	0.270	1300	351.0	600	59
10	Body and Placket joint	0.252	1300	327.6	600	55
11	Placket top stitching	0.270	1300	351.0	600	59
12	Nose tucking	0.270	1300	351.0	600	59
13	Trimming	0.226	1300	293.8	600	49
14	Collar tucking	0.315	1250	393.8	600	66
15	Collar joint	0.270	1250	337.5	600	56
16	Cuff joint	0.297	1250	371.3	600	62
17	Back neck piping	0.316	1250	395.0	600	66
18	Marking	0.180	1250	225.0	600	38
19	Placket closing	0.252	1250	315.0	600	53
20	Upper placket stitching	0.252	1250	315.0	600	53
21	Lower placket stitching	0.270	1250	337.5	600	56
22	Placket box	0.288	1150	331.2	600	55
23	Back neck top stitching	0.297	1150	341.6	600	57
24	Label joint	0.334	1150	384.1	600	64
25	Trimming	0.180	1150	207.0	600	35
26	Opening tuck	0.298	1150	342.7	600	57
27	Bottom hemming	0.316	1150	363.4	600	61
28	Trimming	0.136	1150	156.4	600	26
29	Marking	0.226	1150	259.9	600	43
30	Side seem	0.450	1150	517.5	600	86
31	Side vent tucking	0.270	1150	310.5	600	52
32	Trimming	0.190	1150	218.5	600	36
33	Side vent tuck joint	0.450	1150	517.5	600	86
34	Side vent top stitching	0.414	1150	476.1	600	79
35	Chap tucking	0.460	1150	529.0	600	88
36	Trimming	0.154	1150	177.1	600	30
		10.2				

Table C.9 Process wise waiting time, bottlenecks and manpower for product-3

Process No.	Process	Total Capacity /Hour (pieces)	Existing Production/ Hour (pieces)	Waiting time (min)	Bottlenecks (min)	Actual Manpower
1	Back front matching	201	130	2.20	0.0	1
2	Body marking	190	130	19.0	0.0	1
3	Sleeve scissoring	222	130	24.8	0.0	1
4	Shoulder joint	190	130	18.0	0.0	1
5	Shoulder top stitch	222	130	24.8	0.0	1
6	Sleeve matching	265	130	30.5	0.0	1
7	Sleeve joint	162	130	10.8	0.0	1
8	Matching and Trimming	303	130	34.3	0.0	1
9	Placket rolling	222	130	24.6	0.0	1
10	Body and Placket joint	238	130	27.2	0.0	1
11	Placket top stitching	222	130	24.8	0.0	1
12	Nose tucking	222	130	24.8	0.0	1
13	Trimming	265	130	30.5	0.0	1
14	Collar tucking	190	125	20.5	1.6	1
15	Collar joint	222	125	26.2	0.0	1
16	Cuff joint	202	125	22.9	0.0	1
17	Back neck piping	190	125	20.5	0.0	1
18	Marking	333	125	37.4	0.0	1
19	Placket closing	238	125	28.5	0.0	1
20	Upper placket stitching	238	125	28.5	0.0	1
21	Lower placket stitching	222	125	26.2	0.0	1
22	Placket box	208	115	26.8	2.9	1
23	Back neck top stitching	202	115	25.8	0.0	1
24	Label joint	180	115	21.7	0.0	1
25	Trimming	333	115	39.2	0.0	1
26	Opening tuck	201	115	25.6	0.0	1
27	Bottom hemming	190	115	23.7	0.0	1
28	Trimming	441	115	44.3	0.0	1
29	Marking	265	115	33.9	0.0	1
30	Side seem (2 persons)	266	115	68.0	0.0	2
31	Side vent tucking	222	115	28.9	0.0	1
32	Trimming	316	115	38.2	0.0	1
33	Side vent tuck joint	133	115	8.10	0.0	1
34	Side vent top stitching (2 persons)	290	115	72.4	0.0	2
35	Chap tucking	130	115	6.90	0.0	1
36	Trimming (4 persons)	1558	115	222	0.0	4
				1193	**4.5**	**41**

Table C.10 SMV and capacity per hour for product-4 in sewing section

Process No.	Processes	No. of Operator	No. of Helper	M/C Type	Basic Time (min)	SMV	Capacity /Hour (pieces)
1	Pair tucking	1		PM	0.195	0.234	256
2	Plate cutting	1		PM	0.103	0.124	484
3	Box plate making	1		PM	0.135	0.655	92
4	Checking & Trimming		1	-	0.105	0.126	476
5	Button plate making	1		RM	0.692	0.830	72
6	Trimming		1	-	0.113	0.136	441
7	Form fitting	1		-	0.120	0.144	417
8	Pocket making	1		PM	0.210	0.252	238
9	Trimming		1	-	0.113	0.136	441
10	Pocket ironing		1	Iron	0.098	0.118	508
11	Pocket marking		1	-	0.158	0.190	316
12	Pocket joint	1		PM	0.758	0.910	66
13	Trimming		1	-	0.113	0.136	441
14	Yoke making	2		PM	0.729	0.875	69
15	Trimming		1	-	0.105	0.126	476
16	Front yoke joint	1		PM	0.405	0.486	123
17	Over locking	1		OL	0.203	0.244	246
18	Trimming		1	-	0.105	0.126	476
19	Top stitching	1		PM	0.135	0.162	370
20	Front back matching	1		-	0.105	0.126	476
21	Front joint	1		PM	0.585	0.702	85
22	Checking & Trimming		1	-	0.128	0.154	390
23	Over locking	1		OL	0.203	0.244	246
24	Trimming		1	-	0.105	0.126	476
25	Top stitching	1		PM	0.120	0.144	417
26	Pulling & Transferring		1	-	0.113	0.136	441
27	Collar matching	1		-	0.113	0.136	441
28	Collar joint	1		PM	0.698	0.838	72
29	Checking & Trimming		1	-	0.248	0.298	201
30	Collar top sewing	1		PM	0.435	0.522	115
31	Trimming		1	-	0.098	0.118	508
32	Sleeve rolling	2		PM	0.548	0.658	91
33	Checking & Trimming		2	-	0.174	0.209	287
34	Sleeve matching	1		-	0.083	0.125	480
35	Sleeve joint	1		OL	0.225	0.270	222
36	Trimming		1	-	0.098	0.118	508
37	Arm hole top Stitching	1		PM	0.518	0.622	96
38	Trimming		1	-	0.098	0.118	508
39	Care label joint	1		PM	0.218	0.263	228
40	Checking		1	-	0.098	0.118	508
41	Side seam	2		OL	0.435	0.522	115
42	Checking & Trimming		2	-	0.188	0.226	265

43	Sleeve tucking	1		PM	0.816	0.900	67
44	Trimming		1	-	0.143	0.172	349
45	Hemming	1		PM	0.395	0.474	127
46	Trimming		1	-	0.113	0.136	441
47	Hemming ¾	1		PM	0.198	0.234	256
48	Transferring		1	-	0.180	0.216	278
		30	**23**	**30**		**15**	

Table C.11 Process wise worker's efficiency for product-4 in sewing section

Process No.	Process	SMV	Total Output /Day (pieces)	Total Minutes Produced	Total Minutes Attended	Worker's Efficiency (%)
1	Pair tucking	0.234	900	210.6	600	40
2	Plate cutting	0.124	900	111.6	600	20
3	Box plate making	0.655	850	556.8	600	90
4	Checking & Trimming	0.126	850	107.1	600	20
5	Button plate making	0.830	650	539.5	600	90
6	Trimming	0.136	650	88.40	600	10
7	Form fitting	0.144	650	93.60	600	20
8	Pocket making	0.252	650	163.8	600	30
9	Trimming	0.136	650	88.40	600	10
10	Pocket ironing	0.118	650	76.70	600	10
11	Pocket marking	0.190	650	123.5	600	20
12	Pocket joint	0.910	600	546.0	600	90
13	Trimming	0.136	600	81.60	600	10
14	Yoke making	0.875	600	525.0	600	90
15	Trimming	0.126	600	75.60	600	10
16	Front yoke joint	0.486	600	291.6	600	50
17	Over locking	0.244	600	146.4	600	20
18	Trimming	0.126	600	75.60	600	10
19	Top stitching	0.162	600	97.20	600	20
20	Front back matching	0.126	600	75.60	600	10
21	Front joint	0.702	600	421.2	600	70
22	Checking & Trimming	0.154	600	92.40	600	20
23	Over locking	0.244	600	146.4	600	20
24	Trimming	0.126	600	75.60	600	10
25	Top stitching	0.144	600	86.40	600	10
26	Pulling & Transferring	0.136	600	81.60	600	10
27	Collar matching	0.136	600	81.60	600	10
28	Collar joint	0.838	600	502.8	600	80
29	Checking & Trimming	0.298	600	178.8	600	30
30	Collar top sewing	0.522	600	313.2	600	50
31	Trimming	0.118	600	70.80	600	10
32	Sleeve rolling	0.658	600	394.8	600	70
33	Checking & Trimming	0.209	600	125.4	600	20
34	Sleeve matching	0.125	600	75.00	600	10
35	Sleeve joint	0.270	600	162.0	600	30
36	Trimming	0.118	600	70.80	600	10
37	Arm hole top Stitching	0.622	600	373.2	600	60
38	Trimming	0.118	600	70.80	600	10
39	Care label joint	0.263	600	157.8	600	30
40	Checking	0.118	600	70.80	600	10
41	Side seam	0.522	600	313.2	600	50
42	Checking & Trimming	0.226	600	135.6	600	20
43	Sleeve tucking	0.900	600	540.0	600	90
44	Trimming	0.172	600	103.2	600	20

45	Hemming	0.474	600	284.4	600	50
46	Trimming	0.136	600	81.60	600	10
47	Hemming ¾	0.234	600	140.4	600	20
48	Transferring	0.216	600	129.6	600	20
		15				

Table C.12 Process wise waiting time, bottlenecks and manpower for product-4

Process No.	Process	Total Capacity /Hour (pieces)	Existing Production/ Hour (pieces)	Waiting time (min)	Bottlenecks (min)	Actual Manpower
1	Pair tucking	256	90	38.8	0.00	1
2	Plate cutting	484	90	48.9	0.00	1
3	Box plate making	92	85	4.60	0.00	1
4	Checking & Trimming	476	85	49.3	0.00	1
5	Button plate making	72	65	5.80	0.00	1
6	Trimming	441	65	51.1	0.00	1
7	Form fitting	417	65	50.7	0.00	1
8	Pocket making	238	65	43.6	0.00	1
9	Trimming	441	65	51.1	0.00	1
10	Pocket ironing	508	65	52.3	0.00	1
11	Pocket marking	316	65	47.7	0.00	1
12	Pocket joint	66	60	5.50	23.6	1
13	Trimming	441	60	51.8	0.00	1
14	Yoke making (2 persons)	137	60	67.4	0.00	2
15	Trimming	476	60	52.4	0.00	1
16	Front yoke joint	123	60	30.6	0.00	1
17	Over locking	246	60	45.4	0.00	1
18	Trimming	476	60	52.4	0.00	1
19	Top stitching	370	60	50.2	0.00	1
20	Front back matching	476	60	52.4	0.00	1
21	Front joint	85	60	17.6	0.00	1
22	Checking & Trimming	390	60	50.8	0.00	1
23	Over locking	246	60	45.4	0.00	1
24	Trimming	476	60	52.4	0.00	1
25	Top stitching	417	60	51.4	0.00	1
26	Pulling & Transferring	441	60	51.8	0.00	1
27	Collar matching	441	60	51.8	0.00	1
28	Collar joint	72	60	10.1	4.20	1
29	Checking & Trimming	201	60	42.0	0.00	1
30	Collar top sewing	115	60	28.7	0.00	1
31	Trimming	508	60	52.9	0.00	1
32	Sleeve rolling (2 persons)	182	60	80.3	0.00	2
33	Checking & Trimming (2 persons)	574	60	107.4	0.00	2
34	Sleeve matching	480	60	52.5	0.00	1
35	Sleeve joint	222	60	43.7	0.00	1
36	Trimming	508	60	52.9	0.00	1
37	Arm hole top Stitching	96	60	22.4	0.00	1
38	Trimming	508	60	52.9	0.00	1
39	Care label joint	228	60	44.2	0.00	1
40	Checking	508	60	52.9	0.00	1
41	Side seam (2 persons)	230	60	88.7	2.60	2
42	Checking & Trimming (2 persons)	531	60	106.4	0.00	2
43	Sleeve tucking	67	60	6.30	14.5	1

44	Trimming	349	60	49.7	0	1
45	Hemming	127	60	31.8	0	1
46	Trimming	441	60	51.8	0	1
47	Hemming ¾	256	60	45.9	0	1
48	Transferring	278	60	47.1	0	1
				2244	**50**	**53**

Appendix-D: Line Balancing Data

Table D.1 Balancing process to equalize the bottleneck process for product -1

Balancing Capacity Per Hour								
	Bottleneck Process				Balancing Process			
Sl. No.	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/ Hour (pieces)	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)
1	13	Side seam joint	145	196	2	Right shoulder joint	444	289
	Process-2 can work for 39 min. and share work with Process-13 for last 21 min.							
2	11	Arm hole piping	144	196	6	Neck piping	341	219
	Process-6 can work for 38.5 min. and share work with Process-11 for last 21.5 min.							
3	7	Trimming & Shoulder in tucking	181	196	8	Trimming, Folding & Shoulder out tucking	215	197
	Process-8 can work for 55 min. and share work with Process-7 for last 5 min.							
4	17	Arm hole in and out tucking	148	196	19	Bottom hem tucking	444	247
	Process-19 can work for 40.6 min. and share work with Process-17 for last 19.4 min.							
5	24	Care label joint	175	196	19	Bottom hem tucking	444	247
	Process-19 can work for 52.8 min. and share work with Process-24 for last 7.2 min.							
6	18	Thread cutting	175	196	20	Trimming	387	341
	Process-20 can work for 52.8 min. and share work with Process-18 for last 7.2 min.							
7	23	Hem security tucking, Cutting & Folding	153	196	22	Folding	341	245
	Process-22 can work for 43.1 min. and share work with Process-23 for last 16.9 min.							
8	26	Turning over	181	196	25	Thread cutting	232	213
	Process-25 can work for 55 min. and share work with Process-26 for last 5 min.							

Table D.2 Existing capacity per hour, waiting time, bottlenecks and proposed manpower after line balancing for product-1

Process No.	Process	SMV	Existing Capacity/Hour (pieces)	Benchmarked Target/Hour (pieces)	Waiting time (min)	Bottlenecks (min)	Theoretical Manpower	Actual Manpower	Proposed Manpower
1	Matching and Folding	0.290	207	196	3.20	0	1.0	1	1
2	Right shoulder joint	0.135	444	196	12.4		0.4	1	1
3	Trimming	0.176	341	196	25.5	0	0.6	1	1
4	Loop joint	0.176	341	196	25.5	0	0.6	1	1
5	Folding	0.176	341	196	25.5	0	0.6	1	1
6	Neck piping	0.176	341	196	4.00	0	0.6	1	1
7	Trimming & Shoulder in tucking	0.331	181	196	0.00	0	1.1	2	1
8	Trimming, Folding & Shoulder out tucking	0.279	215	196	0.30	0	0.9	2	1
9	Left shoulder joint	0.228	263	196	15.3	0	0.7	1	1
10	Trimming	0.259	231	196	9.10	0	0.8	1	1
11	Arm hole piping	0.414	144	196	0.00	0	1.4	1	1
12	Trimming	0.259	231	196	9.10	0	0.8	1	1
13	Side seam	0.414	145	196	0.00	0	1.4	1	1
14	Trimming and Folding	0.248	241	196	11.2	0	0.8	1	1
15	Side seam	0.262	229	196	8.60	0	0.9	1	1
16	Trimming and Folding	0.228	263	196	15.3	0	0.7	1	1
17	Arm hole in and out tucking	0.404	148	196	0.00	0	1.3	1	1
18	Thread cutting	0.342	175	196	0.00	0	1.1	1	1
19	Bottom hem tucking	0.135	444	196	6.90	0	0.4	1	1
20	Trimming	0.155	387	196	22.4	0	0.5	1	1
21	Body hem tucking	0.497	121	196	22.7	0	1.6	1	2
22	Folding	0.176	341	196	8.60	0	0.6	1	1
23	Hem security tucking, Cutting & Folding	0.393	153	196	0.00	0	1.3	2	1
24	Care label joint	0.342	175	196	0.00	0	1.1	1	1
25	Thread cutting	0.259	232	196	4.30	0	0.8	1	1
26	Turning over	0.331	181	196	0.00	0	1.1	1	1
		7.1			**230**	**0**	**23.1**	**29**	**27**

Table D.3 Proposed SMV, Benchmarked target per hour, existing capacity per hour and proposed capacity per hour for product-1

Process No.	Process	Proposed SMV	Benchmarked Target/Hour (pieces)	Existing Capacity /Hour (pieces)	Proposed Capacity/ Hour (pieces)
1	Matching and Folding	0.290	196	207	207
2	Right shoulder joint	0.208	196	444	289
3	Trimming	0.176	196	341	341
4	Loop joint	0.176	196	341	341
5	Folding	0.176	196	341	341
6	Neck piping	0.274	196	341	219
7	Trimming & Shoulder in tucking	0.306	196	**181**	196
8	Trimming, Folding & Shoulder out tucking	0.305	196	215	197
9	Left shoulder joint	0.228	196	263	263
10	Trimming	0.260	196	231	231
11	Arm hole piping	0.306	196	**144**	196
12	Trimming	0.260	196	231	231
13	Side seam	0.306	196	**145**	196
14	Trimming and Folding	0.249	196	241	241
15	Side seam	0.262	196	229	229
16	Trimming and Folding	0.228	196	263	263
17	Arm hole in and out tucking	0.306	196	**148**	196
18	Thread cutting	0.306	196	**175**	196
19	Bottom hem tucking	0.243	196	444	247
20	Trimming	0.176	196	387	341
21	Body hem tucking	0.306	196	**121**	196
22	Folding	0.245	196	341	245
23	Hem security tucking, Cutting & Folding	0.306	196	**153**	196
24	Care label joint	0.306	196	**175**	196
25	Thread cutting	0.282	196	232	213
26	Turning over	0.306	196	**181**	196

Table D.4 Balancing process to equalize the bottleneck process for product-2

Balancing Capacity Per Hour								
Sl. No.	Bottleneck Process				Balancing Process			
	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)
1	16	First & Second sleeve joint	108	138	10	Left shoulder joint	242	175
	Process-10 can work for 43.3 min. and share work with Process-1 for last 16.7 min.							

Table D.5 Existing capacity per hour, waiting time, bottlenecks and proposed manpower after line balancing for product-2

Process No.	Process	SMV	Existing Capacity/Hour (pieces)	Benchmarked Target/Hour (pieces)	Waiting time (min.)	Bottlenecks (min.)	Theoretical Manpower	Actual Manpower	Proposed Manpower
1	Matching and Folding	0.300	200	138	18.6	0	0.7	1	1
2	Both shoulder joint	0.362	166	138	10.1	0	0.8	1	1
3	Neck piping	0.373	161	138	8.60	0	0.9	1	1
4	Back neck piping	0.352	170	138	11.3	0	0.8	1	1
5	Back end tacking	0.404	149	138	4.40	0	0.9	1	1
6	Front neck top stitching	0.362	166	138	10.1	0	0.8	1	1
7	Cutting and Marking	0.331	181	138	14.2	0	0.8	1	1
8	Back tape top stitching with main label joint	0.352	170	138	11.3	0	0.8	1	1
9	Left shoulder join tacking and Shoulder out tacking	0.352	170	138	11.3	0	0.8	1	1
10	Left shoulder joint	0.248	242	138	9.10	0	0.6	1	1
11	Sleeve open hemming	0.383	157	138	7.30	0	0.9	1	1
12	Sleeve dechain	0.362	166	138	10.1	0	0.8	1	1
13	Shoulder trimming	0.362	166	138	10.1	0	0.8	1	1
14	Body matching	0.362	166	138	10.1	0	0.8	1	1
15	Sleeve join tacking and Folding	0.383	157	138	7.30	0	0.9	1	1
16	First & Second sleeve joint	0.558	108	138	0.00	0	1.2	2	1
17	Side seam one	0.321	187	138	15.7	0	0.7	1	1
18	Label joint	0.362	166	138	10.1	0	0.8	1	1
19	Side seam two	0.321	187	138	15.7	0	0.7	1	1
20	Sleeve in and out tacking	0.404	149	138	4.40	0	0.9	1	1
21	Bottom hem tacking and Hem security tacking	0.362	166	138	10.1	0	0.8	1	1
22	Bottom hemming	0.342	175	138	12.7	0	0.8	1	1
23	Thread cutting	0.331	181	138	14.2	0	0.8	1	1
24	Care label sewing and joint	0.331	181	138	14.2	0	0.8	1	1
25	Sticker removing	0.352	170	138	11.3	0	0.8	1	1
26	Thread cutting	0.404	149	138	4.40	0	0.9	1	1
		9.4			**267**	**0**	**21.3**	**27**	**26**

Table D.6 Proposed SMV, Benchmarked target per hour, total capacity per hour and proposed capacity per hour for product-2

Process No.	Process	Proposed SMV	Benchmarked Target/Hour (pieces)	Existing Capacity /Hour (pieces)	Proposed Capacity/ Hour (pieces)
1	Matching and Folding	0.300	138	200	200
2	Both shoulder joint	0.361	138	166	166
3	Neck piping	0.373	138	161	161
4	Back neck piping	0.353	138	170	170
5	Back end tacking	0.403	138	149	149
6	Front neck top stitching	0.361	138	166	166
7	Cutting and Marking	0.331	138	181	181
8	Back tape top stitching with main label joint	0.353	138	170	170
9	Left shoulder join tacking and Shoulder out tucking	0.353	138	170	170
10	Left shoulder joint	0.343	138	242	175
11	Sleeve open hemming	0.382	138	157	157
12	Sleeve dechain	0.361	138	166	166
13	Shoulder trimming	0.361	138	166	166
14	Body matching	0.361	138	166	166
15	Sleeve join tacking and Folding	0.382	138	157	157
16	First & Second sleeve joint	0.435	138	108	138
17	Side seam one	0.321	138	187	187
18	Label joint	0.361	138	166	166
19	Side seam two	0.321	138	187	187
20	Sleeve in and out tacking	0.403	138	149	149
21	Bottom hem tacking and Hem security tacking	0.361	138	166	166
22	Bottom hemming	0.343	138	175	175
23	Thread cutting	0.331	138	181	181
24	Care label sewing and joint	0.331	138	181	181
25	Sticker removing	0.353	138	170	170
26	Thread cutting	0.403	138	149	149

Table D.7 Balancing process to equalize the bottleneck process for product-3

Balancing Capacity Per Hour								
Sl. No.	Bottleneck Process				Balancing Process			
	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)
1	2	Body marking	190	193	1	Back front matching	201	198
	Process-1 can work for 59 mins and share work with process-2 for last 1 min							
2	7	Sleeve joint	162	193	9	Placket rolling	222	194
	Process-9 can work for 52.5 mins and share work with process-2 for last 7.5 mins							
3	7	Sleeve joint	162	193	15	Collar joint	222	207
	Process-15 can work for 56 mins and share work with process-7 for last 4 mins							
4	14	Collar tucking	190	206	19	Placket closing	238	218
	Process-19 can work for 55 mins and share work with process-14 for last 5 mins							
5	24	Label joint	180	198	21	Lower placket stitching	222	200
	Process-21 can work for 54 mins and share work with process-24 for last 6 mins							
6	28	Trimming & Marking	166	208	25	Trimming	333	250
	Process-25 can work for 45 mins and share work with process-28 for last 15 mins							
7	32	Side vent tuck joint	133	200	29	Side seem	266	200
	Process-29 can work for 30 mins and share work with process-32 for last 30 mins							
8	34	Chap tucking	130	206	33	Side vent top stitching	290	205
	Process-33 can work for 25 mins and share work with process-34 for last 35 mins							

Table D.8 Existing capacity per hour, waiting time, bottlenecks and proposed manpower after line balancing for product-3

Process No.	Process	SMV	Existing Capacity/Hour (pieces)	Benchmarked Target/Hour (pieces)	Waiting time (min.)	Bottlenecks (min.)	Theoretical Manpower	Actual Manpower	Proposed Manpower
1	Back front matching	0.298	201	193	0.00	0	1.0	1	1
2	Body marking	0.316	190	193	0.00	0	1.0	1	1
3	Sleeve scissoring	0.270	222	193	7.80	0	0.9	1	1
4	Shoulder joint	0.316	190	193	0.00	1	1.0	1	1
5	Shoulder top stitch	0.270	222	193	7.80	0	0.9	1	1
6	Sleeve matching	0.226	265	193	16.3	0	0.7	1	1
7	Sleeve joint	0.370	162	193	0.00	0	1.2	1	1
8	Matching and Trimming	0.198	303	193	21.8	0	0.6	1	1
9	Placket rolling	0.270	222	193	0.30	0	0.9	1	1
10	Body and Placket joint	0.252	238	193	1.30	0	0.8	1	1
11	Placket top stitching	0.270	222	193	7.80	0	0.9	1	1
12	Nose tucking	0.270	222	193	7.80	0	0.9	1	1
13	Trimming	0.226	265	193	16.3	0	0.7	1	1
14	Collar tucking	0.315	190	193	4.00	0	1.0	1	1
15	Collar joint	0.270	222	193	3.80	0	0.9	1	1
16	Cuff joint	0.297	202	193	2.70	0	1.0	1	1
17	Back neck piping	0.316	190	193	0.00	1	1.0	1	1
18	Marking	0.180	333	193	25.2	0	0.6	1	1
19	Placket closing	0.252	238	193	6.30	0	0.8	1	1
20	Upper placket stitching	0.252	238	193	11.3	0	0.8	1	1
21	Lower placket stitching	0.270	222	193	1.80	0	0.9	1	1
22	Placket box	0.288	208	193	4.30	0	0.9	1	1
23	Back neck top stitching	0.297	202	193	2.70	0	1.0	1	1
24	Label joint	0.334	180	193	1.70	0	1.1	1	1
25	Trimming	0.180	333	193	10.2	0	0.6	1	1
26	Opening tuck	0.298	201	193	2.40	0	1.0	1	1
27	Bottom hemming	0.316	190	193	0.00	1	1.0	1	1
28	Trimming & Marking	0.362	166	193	5.20	0	1.1	2	1
29	Side seem	0.450	266	193	3.00	0	1.5	2	2
30	Side vent tucking	0.270	222	193	7.80	0	0.9	1	1
31	Trimming	0.190	316	193	23.3	0	0.6	1	1
32	Side vent tuck joint	0.450	133	193	3.00	0	1.5	1	1
33	Side vent top stitching	0.414	290	193	5.00	0	1.3	2	2
34	Chap tucking	0.460	130	193	6.00	0	1.5	1	1
35	Trimming	0.154	390	193	30.3	0	0.5	4	1
		10.2			**255**	**3**	**33**	**41**	**37**

Table D.9 Proposed SMV, Benchmarked target per hour, total capacity per hour and proposed capacity per hour for product-3

Process No.	Process	Proposed SMV	Benchmarked Target/Hour (pieces)	Existing Capacity /Hour (pieces)	Proposed Capacity/ Hour (pieces)
1	Back front matching	0.303	193	201	198
2	Body marking	0.311	193	**190**	193
3	Sleeve scissoring	0.270	193	222	222
4	Shoulder joint	0.316	193	190	190
5	Shoulder top stitch	0.270	193	222	222
6	Sleeve matching	0.226	193	265	265
7	Sleeve joint	0.311	193	**162**	193
8	Matching and Trimming	0.198	193	303	303
9	Placket rolling	0.309	193	222	194
10	Body and Placket joint	0.252	193	238	238
11	Placket top stitching	0.270	193	222	222
12	Nose tucking	0.270	193	222	222
13	Trimming	0.226	193	265	265
14	Collar tucking	0.291	193	**190**	206
15	Collar joint	0.290	193	222	207
16	Cuff joint	0.297	193	202	202
17	Back neck piping	0.316	193	190	190
18	Marking	0.180	193	333	333
19	Placket closing	0.275	193	238	218
20	Upper placket stitching	0.252	193	238	238
21	Lower placket stitching	0.300	193	222	200
22	Placket box	0.288	193	208	208
23	Back neck top stitching	0.297	193	202	202
24	Label joint	0.303	193	**180**	198
25	Trimming	0.240	193	333	250
26	Opening tuck	0.299	193	201	201
27	Bottom hemming	0.316	193	190	190
28	Trimming & Marking	0.288	193	**166**	208
29	Side seem	0.300	193	266	200
30	Side vent tucking	0.270	193	222	222
31	Trimming	0.190	193	316	316
32	Side vent tuck joint	0.300	193	**133**	200
33	Side vent top stitching	0.293	193	290	205
34	Chap tucking	0.291	193	**130**	206
35	Trimming	0.154	193	390	390

Table D.10 Balancing process to equalize the bottleneck process for product-4

Balancing Capacity Per Hour								
Sl. No.	Bottleneck Process				Balancing Process			
	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)	Process No.	Process Name	Total Capacity/Hour (pieces)	Balanced Capacity/Hour (pieces)
1	3	Box plate making	92	148	2	Plate cutting	484	186
	Process-2 can work for 23 mins and share with Process-3 for last 37 mins							
2	10	Pocket joint	132	165	7	Pocket making	238	179
	Process-7 can work for 45 mins and share with Process-10 for last 15 mins							
3	12	Yoke making	137	206	17	Top stitching	370	185
	Process-17 can work for 30 mins and share with Process-12 for last 30 mins							
4	14	Front yoke joint	123	174	23	Top stitching	417	243
	Process-23 can work for 35 mins and share with Process-14 for last 25 mins							
5	25	Collar joint	143	174	27	Collar top sewing	230	180
	Process-27 can work for 34 mins and share with Process-25 for last 26 mins							
6	39	Sleeve tucking	134	163	33	Arm hole top Stitching	192	173
	Process-33 can work for 48 mins and share with Process-39 for last 12 mins							
7	39	Sleeve tucking	134	163	35	Care label joint	228	175
	Process-35 can work for 46 mins and share with Process-39 for last 14 mins							
8	41	Hemming	127	170	43	Hemming 3/4	256	170
	Process-43 can work for 40 mins and share with Process-41 for last 20 mins							

Table D.11 Existing capacity per hour, waiting time, bottlenecks and proposed manpower after line balancing for product-4

Process No.	Process	SMV	Existing Capacity/Hour (pieces)	Benchmarked Target/Hour (pieces)	Waiting time (min.)	Bottlenecks (min.)	Theoretical Manpower	Actual Manpower	Proposed Manpower
1	Pair tucking	0.234	256	170	0.00	0.00	0.7	1	1
2	Plate cutting	0.124	484	170	2.00	0.00	0.4	1	1
3	Box plate making	0.655	92	170	0.00	14.0	1.8	1	1
4	Checking & Trimming	0.126	476	170	39.0	0.00	0.4	1	1
5	Button plate making	0.830	144	170	38.4	0.00	2.4	1	2
6	Trimming & From fitting	0.280	214	170	12.3	0.00	0.8	2	1
7	Pocket making	0.252	238	170	2.00	0.00	0.7	1	1
8	Trimming & Pocket ironing	0.254	236	170	17.0	0.00	0.7	2	1
9	Pocket marking	0.190	316	170	28.0	0.00	0.5	1	1
10	Pocket joint	0.910	132	170	0.00	19.6	2.6	1	2
11	Trimming	0.136	441	170	37.0	0.00	0.4	1	1
12	Yoke making	0.875	137	170	1.00	0.00	2.5	2	2
13	Trimming	0.126	476	170	39.0	0.00	0.4	1	1
14	Front yoke joint	0.486	123	170	2.20	0.00	1.4	1	1
15	Over locking	0.244	246	170	18.5	0.00	0.7	1	1
16	Trimming	0.126	476	170	39.0	0.00	0.4	1	1
17	Top stitching	0.162	370	170	2.40	0.00	0.5	1	1
18	Front back matching	0.126	476	170	39.0	0.00	0.4	1	1
19	Front joint	0.702	170	170	0.00	0.00	2.0	1	2
20	Checking & Trimming	0.154	390	170	34.0	0.00	0.4	1	1
21	Over locking	0.244	246	170	18.5	0.00	0.7	1	1
22	Trimming	0.126	476	170	39.0	0.00	0.4	1	1
23	Top stitching	0.144	417	170	10.6	0.00	0.4	1	1
24	Pulling, Transferring & Collar matching	0.272	221	170	7.00	0.00	0.8	2	1
25	Collar joint	0.838	143	170	3.40	0.00	2.4	1	2
26	Checking & Trimming	0.298	201	170	9.00	0.00	0.8	1	1
27	Collar top sewing	0.522	230	170	5.30	0.00	1.5	1	2
28	Trimming	0.118	508	170	40.0	0.00	0.3	1	1
29	Sleeve rolling	0.658	182	170	8.00	0.00	1.9	2	2
30	Checking, Trimming & Sleeve matching	0.334	287	170	39.0	0.00	1.0	3	1
31	Sleeve joint	0.27	222	170	14.0	0.00	0.8	1	1
32	Trimming	0.118	508	170	40.0	0.00	0.3	1	1
33	Arm hole top Stitching	0.622	192	170	1.70	0.00	1.8	1	2
34	Trimming	0.118	508	170	40.0	0.00	0.3	1	1
35	Care label joint	0.263	228	170	1.30	0.00	0.7	1	1
36	Checking	0.118	508	170	40.0	0.00	0.3	1	1
37	Side seam	0.522	230	170	31.3	0.00	1.5	2	2
38	Checking & Trimming	0.226	266	170	22.0	0.00	0.6	2	1
39	Sleeve tucking	0.9	134	170	0.00	6.4	2.5	1	2

40	Trimming	0.172	349	170	31.0	0.00	0.5	1	1
41	Hemming	0.474	127	170	0.00	0.00	1.3	1	1
42	Trimming	0.136	441	170	37.0	0.00	0.4	1	1
43	Hemming ¾	0.234	256	170	0.00	0.00	0.7	1	1
44	Transferring	0.216	278	170	23.0	0.00	0.6	1	1
		15			**812**	**40**	**42.6**	**53**	**54**

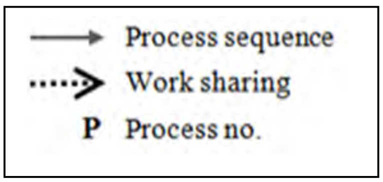
Table D.12 Proposed SMV, Benchmarked target per hour, total capacity per hour and proposed capacity per hour for product-4

Process No.	Process	Proposed SMV	Benchmarked Target/Hour (pieces)	Existing Capacity/ Hour (pieces)	Proposed Capacity/ Hour (pieces)
1	Pair tucking	0.234	170	256	256
2	Plate cutting	0.323	170	484	186
3	Box plate making	0.405	170	**92**	148
4	Checking & Trimming	0.126	170	476	476
5	Button plate making	0.417	170	**144**	144
6	Trimming & From fitting	0.280	170	214	214
7	Pocket making	0.335	170	238	179
8	Trimming & Pocket ironing	0.254	170	236	236
9	Pocket marking	0.190	170	316	316
10	Pocket joint	0.364	170	**132**	165
11	Trimming	0.136	170	441	441
12	Yoke making	0.291	170	**137**	206
13	Trimming	0.126	170	476	476
14	Front yoke joint	0.345	170	**123**	174
15	Over locking	0.244	170	246	246
16	Trimming	0.126	170	476	476
17	Top stitching	0.324	170	370	185
18	Front back matching	0.126	170	476	476
19	Front joint	0.353	170	170	170
20	Checking & Trimming	0.154	170	390	390
21	Over locking	0.244	170	246	246
22	Trimming	0.126	170	476	476
23	Top stitching	0.247	170	417	243
24	Pulling, Transferring & Collar matching	0.271	170	221	221
25	Collar joint	0.345	170	**143**	174
26	Checking & Trimming	0.299	170	201	201
27	Collar top sewing	0.333	170	230	180
28	Trimming	0.118	170	508	508
29	Sleeve rolling	0.330	170	182	182
30	Checking, Trimming & Sleeve matching	0.209	170	287	287
31	Sleeve joint	0.270	170	222	222
32	Trimming	0.118	170	508	508
33	Arm hole top Stitching	0.347	170	192	173
34	Trimming	0.118	170	508	508
35	Care label joint	0.343	170	228	175

36	Checking	0.118	170	508	508
37	Side seam	0.261	170	230	230
38	Checking & Trimming	0.226	170	266	266
39	Sleeve tucking	0.368	170	**134**	163
40	Trimming	0.172	170	349	349
41	Hemming	0.353	170	**127**	170
42	Trimming	0.136	170	441	441
43	Hemming 3/4	0.353	170	256	170
44	Transferring	0.216	170	278	278

Appendix-E: Existing and Proposed Layout

Layout Type	Product
Flow Pattern	Straight
Existing Production System	One piece flow
Proposed Production System	One piece flow and Modular



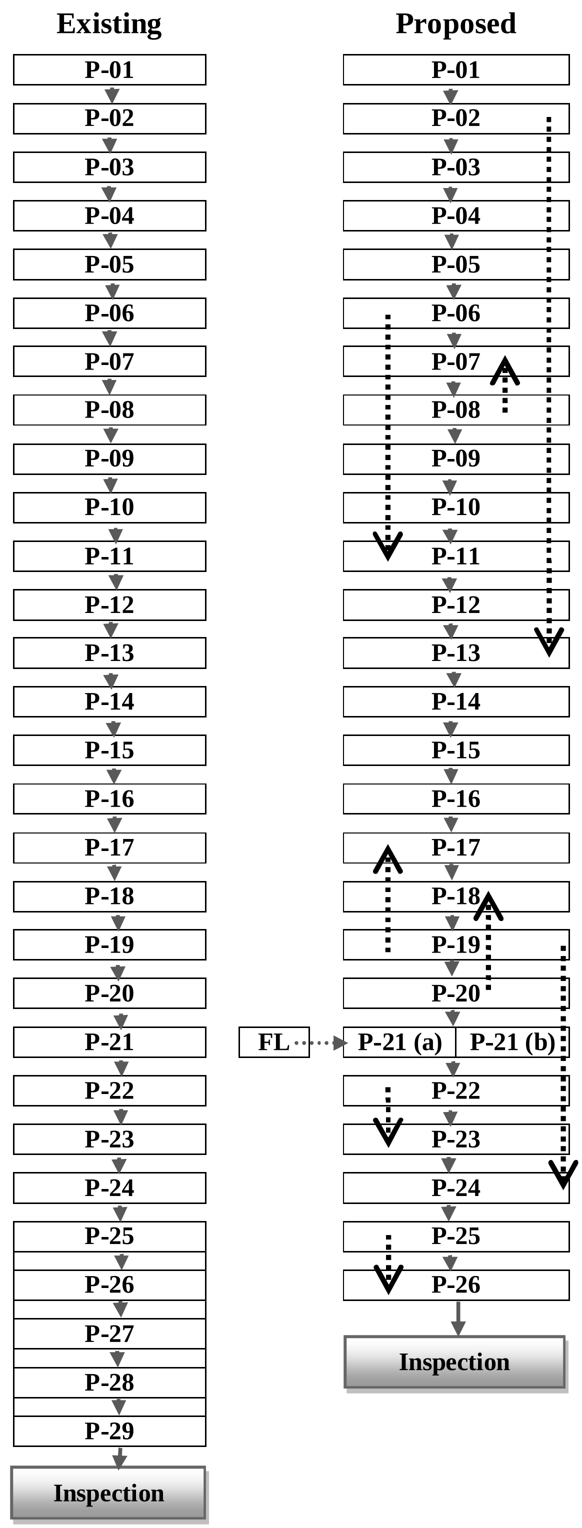
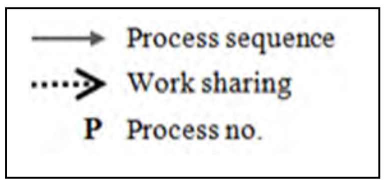


Fig.D.1 Existing and Proposed layout for product-1 manufacturing

Layout Type	Product
Flow Pattern	Straight
Existing Production System	One piece flow
Proposed Production System	One piece flow and Modular



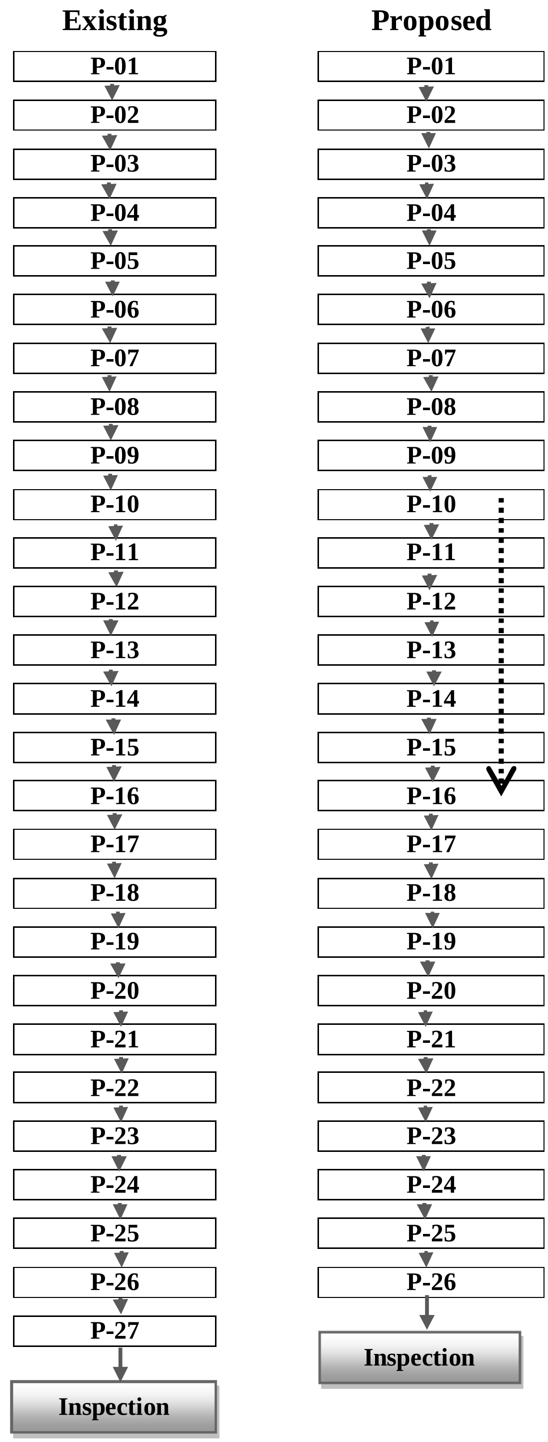
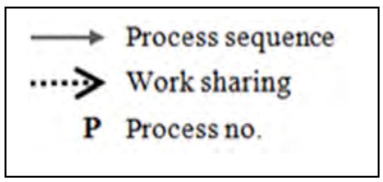


Fig.D.2 Existing and Proposed layout for product-2 manufacturing

Layout Type	Product
Flow Pattern	Zigzag
Existing Production System	One piece flow



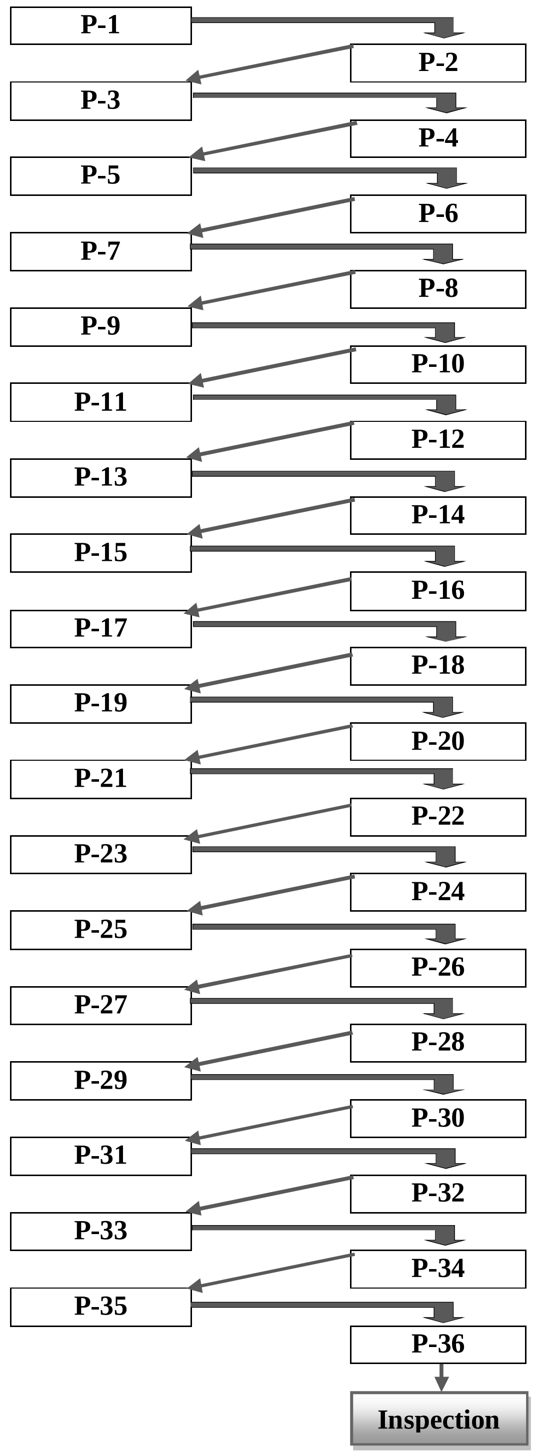
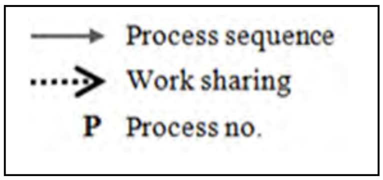


Fig.D.3 Existing layout for product-3 manufacturing

Layout Type	Product
Flow Pattern	Zigzag
Proposed Production System	One piece flow and Modular



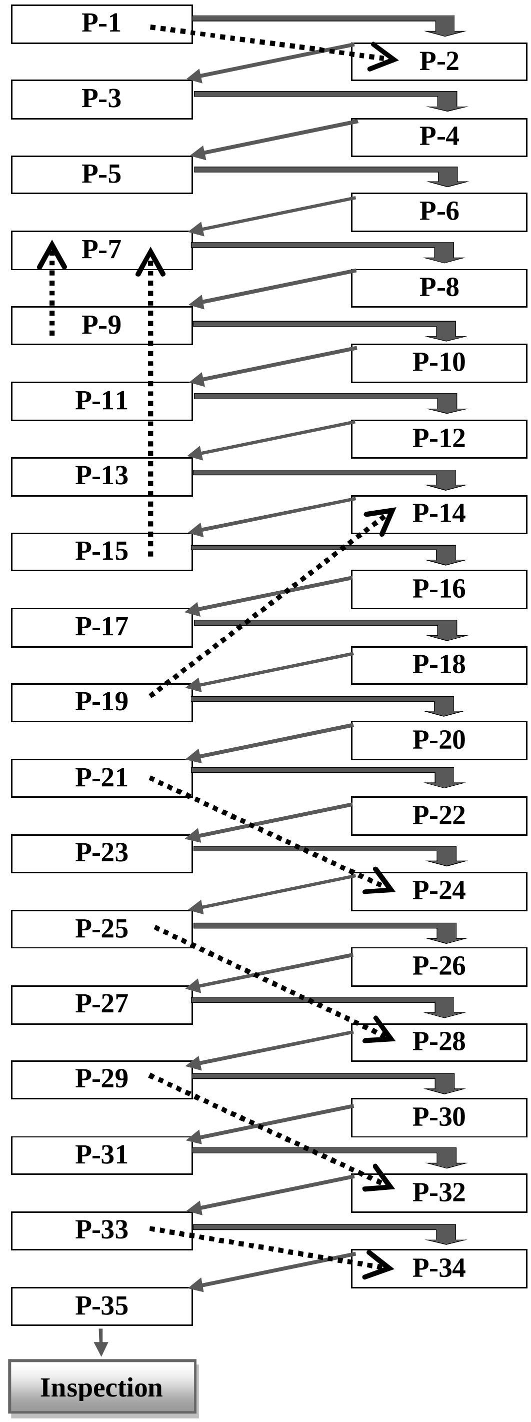
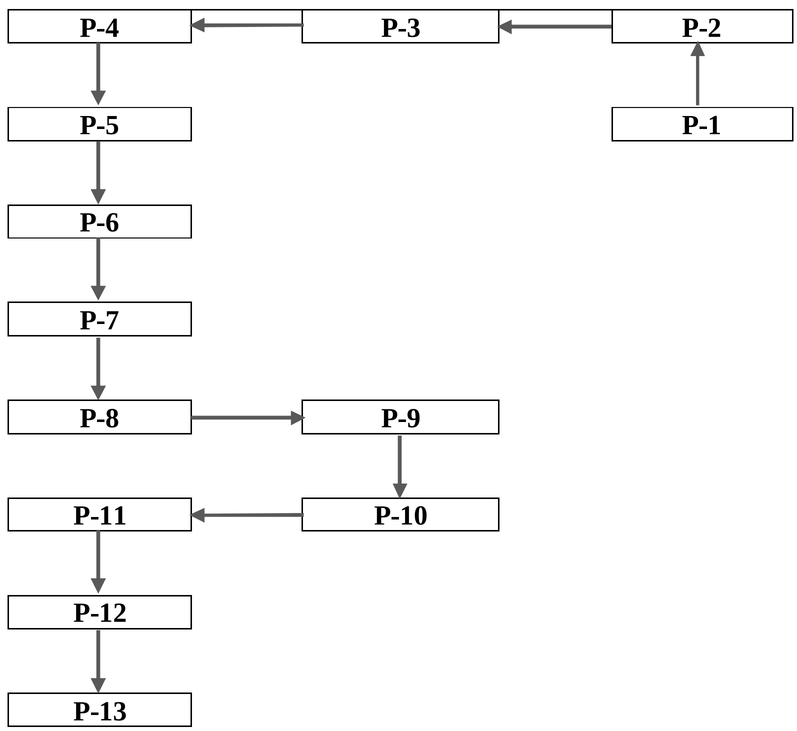


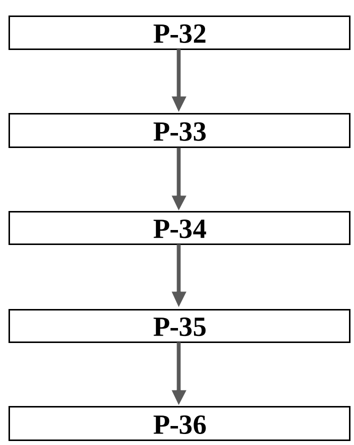
Fig.D.4 Proposed layout for product-3 manufacturing

Layout Type	Product
Flow Pattern	Group and Straight
Existing Production System	One-piece flow and Section

Front Making Section



Sleeve Making Section



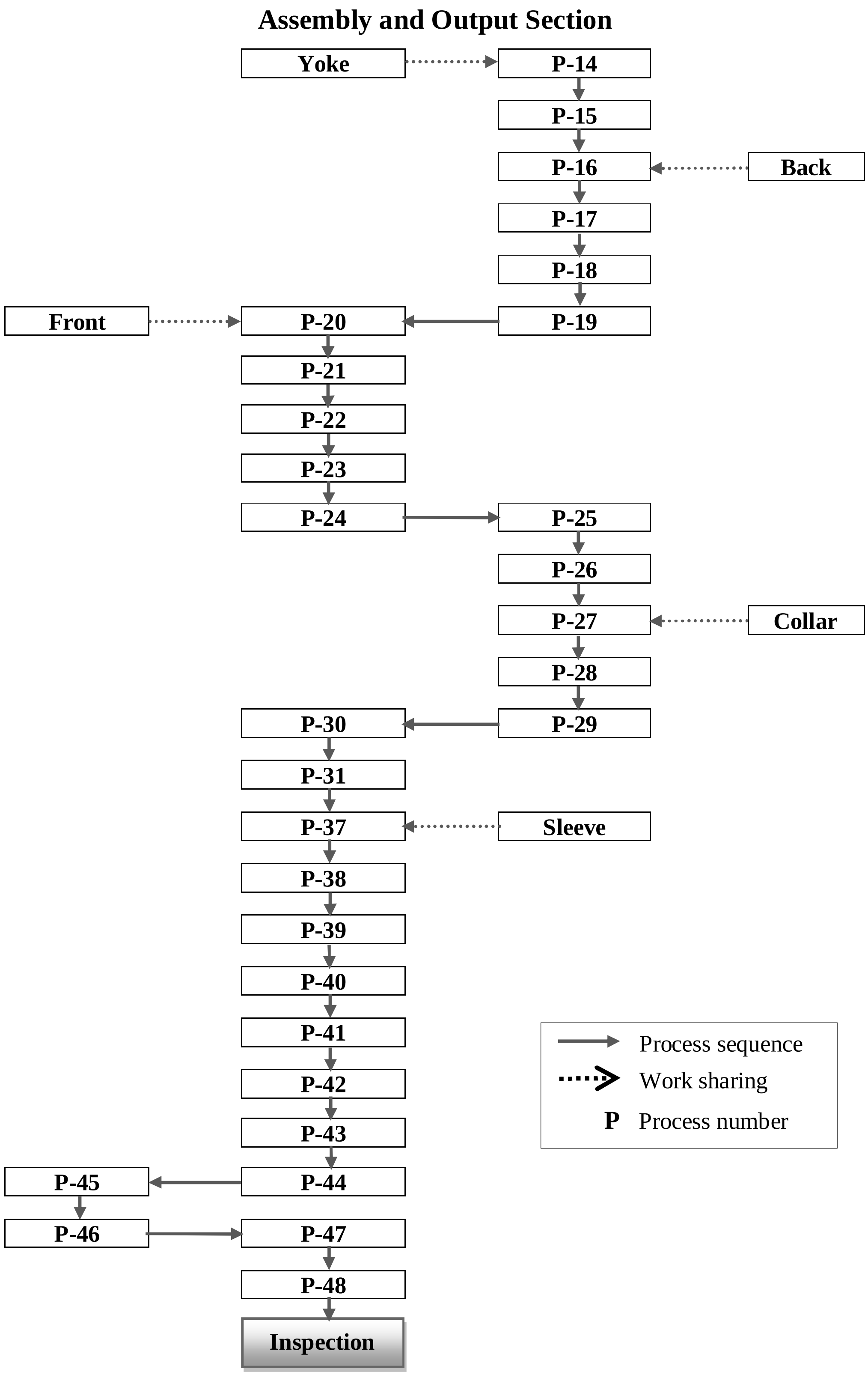
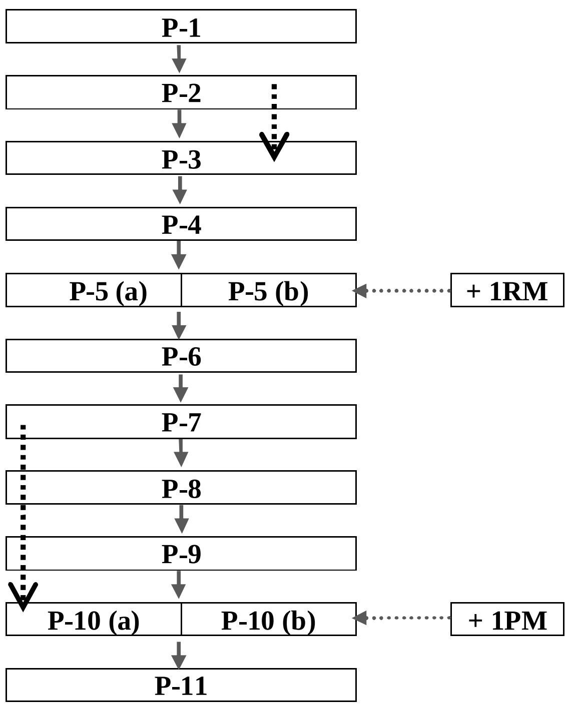


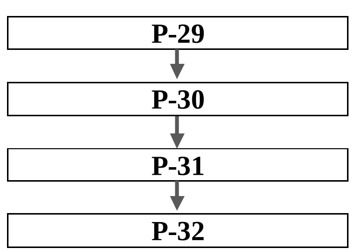
Fig.D.5 Existing layout for product-4 manufacturing

Layout Type	Product
Flow Pattern	Group and Straight
Proposed Production System	One-piece flow, Section and Modular

Front Making Section



Sleeve Making Section



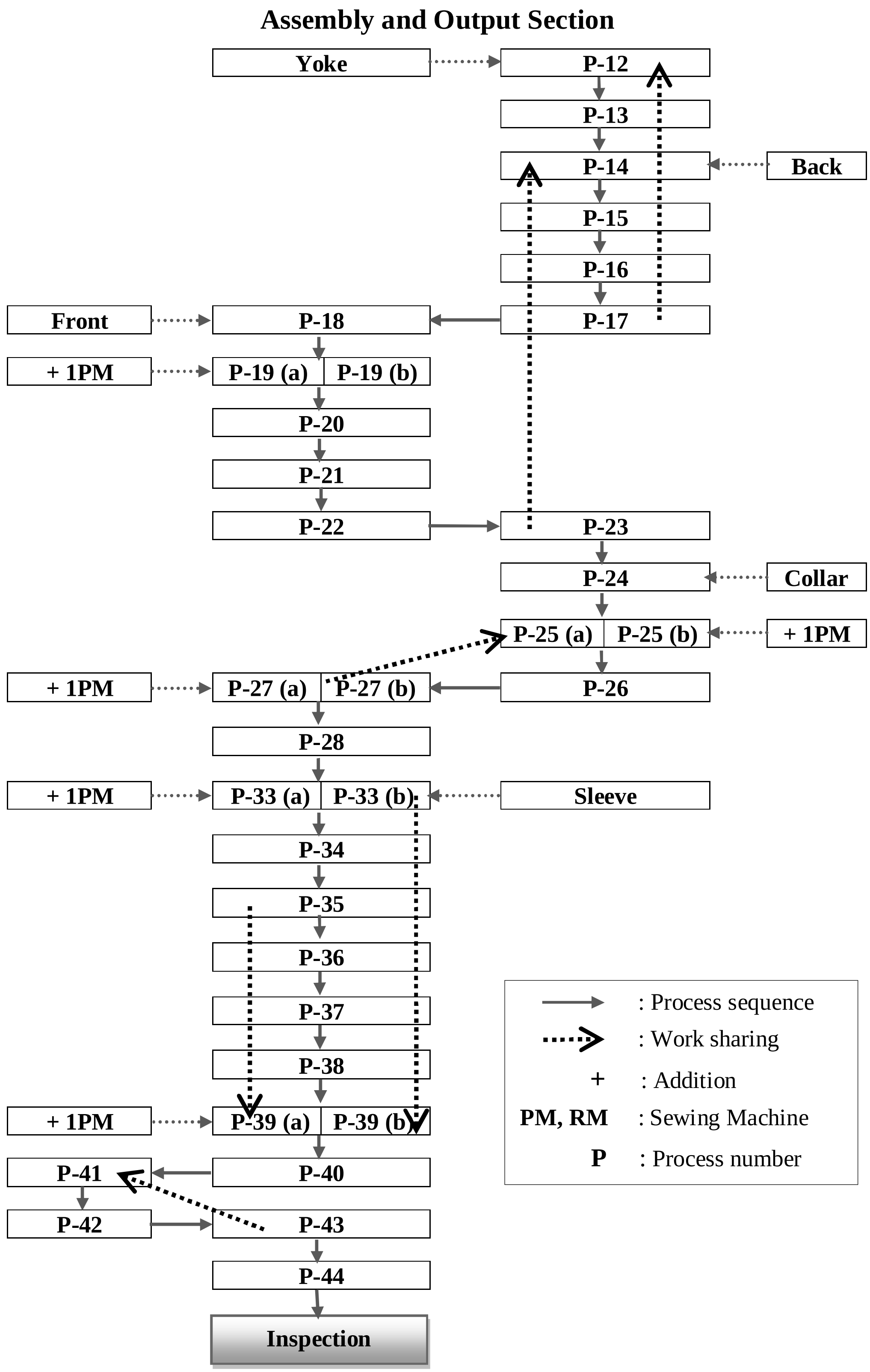


Fig.D.6 Proposed layout for product-4 manufacturing

Appendix-F

Questionnaire for the study on Productivity Improvement in RMG Industries

Name of the Industry			Location	
Address				
	Tel:		Fax:	
Type of products manufactured				
Employee no.				
Name of the employee				
Educational background			Training Achieved	
Sex	☐ Male		☐ Female	
Age (yrs)	☐ Below 15	☐ 15-20	☐ 20-25	☐ > 25
Job designation	☐ Supervisor	☐ Operator	☐ Helper	
Marital status	☐ Unmarried	☐ Married	☐ Separated	☐ Divorce
Number of child	☐ 1-2	☐ 2-3	☐ 3-4	☐ > 4
Placement of child	☐ Babycare	☐ Home	☐ Other place	
Working duration	☐ 0-3	☐ 4-6	☐ 7-9	☐ > 9
Skill level of the worker	☐ Skilled	☐ Semiskilled	☐ Unskilled	
Safety knowledge	☐ Yes		☐ No	
Training facilities	☐ Yes		☐ No	
Repetitive tasks	☐ Yes		☐ No	
Salary (BD Tk.)	☐ 2000-3000	☐ 3000-4000	☐ 4000-5000	☐ > 5000
Satisfaction with the salary	☐ Agree	☐ Neither agree nor disagree		☐ Disagree
Overall satisfaction	☐ Satisfied	☐ Neither satisfied nor dissatisfied		☐ Dissatisfied
Influence of incentives and other benefits in performance	☐ More	☐ Less	☐ No opinion	
Consistency in pace of worker	☐ Yes		☐ No	
Baby daycare facilities	☐ Yes		☐ No	
Ventilation and lighting facilities	☐ Yes		☐ No	