Addis Ababa University

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

'Productivity Improvement through Line Balancing:

Case Study of Nazareth Garment Share Company'

A Thesis Submitted to the School of Mechanical and Industrial Engineering in partial fulfillment of the Degree of Master of Science in Mechanical Engineering (Industrial Engineering Stream)

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May, 2019

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This is to certify that the thesis prepared by Tesfaye Bayeh, entitled: Productivity Improvement through Line Balancing: Case Study of Nazareth Garment SC and submitted in partial fulfillments of the requirements for the degree of Master of Science (Mechanical and Industrial Engineering) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Declaration

I hereby declare that the work which is being presented in this thesis entitled "Productivity Improvement through Line Balancing: Case Study of Nazareth Garment SC" is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged.

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Acknowledgment

First and foremost, it is my pleasure to express my heart-felt appreciation and special gratitude to my Advisor **Dr. Gulelat Gatew** for his unreserved support and supervision during the thesis work. I treasure his advises which, have contributed a great deal to the success of this work.

I am also very grateful to Co-Advisor **Wegene Tesfaye** (PhD candidate) for his timely, encouraging, genuine, valuable and unreserved support during the thesis work. I learnt a lot from him and thank him for his friendly approach and dedicated effort in order to complete the thesis.

I would like to extend my gratitude to all Nazareth Garment SC workers, departmental heads and supervisors for their time, efforts, voluntariness and cooperation throughout the thesis work by availing themselves for an interview, questionnaire and provided very valuable data.

Last but not least, grateful acknowledgement to all my family and friends for their unconditional love and support.

Abstract

Apparel industries must produce large quantities in shorter lead times in order to stay alive and compete in the current fashion market. Apparel production needs high level of productivity and production lines should be balanced to get shorter lead time in effective way.

This work aimed at improving the productivity of garment manufacturing through line balancing with case factory of Nazareth garment Share Company. Time study data was collected from the real system of the factory trouser export production line. Data analysis was accomplished with arena input analyzer to develop a simulation model representing the real garment production process which also assisted to identify the bottlenecks for improvement.

Finally, alternative improved models were proposed. The outcomes of the proposed alternative models showed improvement in results of the output, capacity utilization, productivity per operator, number of operator/resources, lead time, waiting time in queue, takt time and make span which predicted an increase in productivity through balanced lines.

Keywords: Productivity, Line Balancing, Simulation

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List of Acronyms

ALB………………………………. Assembly Line Balancing

ALs……………………………….. Assembly Lines

GDP………………………………. Gross Domestic Product

GPSS………………………………General Purpose Systems Simulator

GSD………………………………. General Stich Data

IBM…………………………….…. International Business Machines

MLT………………………………. Manufacturing Lead Time

NGSC………………………………Nazareth Garment Share Company

PBS………………………………...Progressive Bundle Production System

SAM……………………………… Standard Allocated Minute

SEM………………………………...Structural Estimating Modeling

SMV………………………………. Standard Minute Value

TLT………………………………. Total Lead Time

WIP………………………………. Work in Process

CHAPTER ONE

INTRODUCTION

1.1 Background and Justification of the Study

Textile and Apparel industry is one of the priority sectors of Ethiopian manufacturing sector having a substantial contribution in GDP of the economy. Most of the apparel factories of Ethiopia are export oriented earning highly demanded foreign exchange (Admasu,2017).

Garment manufacturing is a mass production system of transforming fabric into garment. Garment products are assembled as it passes through a series of workstations in a line. In today's competitive global market, companies are mostly striving to strengthen themselves as much as possible in all competiveness dimensions of business; these demands for optimal production systems, which increases the overall performance of the companies (F Sarwar, 2013).

Apparel is a seasonal demand; to place order with garment factories international buyer needs short production lead-time in order to meet their customer demand. (Shahriare and Pekka,2016) The apparel industry must produce momentous quantities in shorter lead times. Apparel production needs high level of productivity; production lines should be balanced to get shorter possible time and effective way for each style as well as quantity. As cited by Mazharul *et al*., (2015), Pritchard (1995) defines assembly line productivity as how well a production system uses its resources to achieve production goals at optimal costs. The focal constraint against the higher productivity is the variation in individual capacity which is the cause of improper line balancing which can lead to bottleneck process including increase of labor cost, work in process (WIP), cycle time and poor throughput (Mahmud *et al*., 2017)

Many researchers have reported various productivity techniques and performance measures with the aim of increasing manufacturing productivity. Some of the major techniques and methods are technology-based, employee-based task-based, product-based techniques, and material-based techniques. Line balancing-is one of the task-based techniques that can increase productivity, machine utilization, material and labor utilization in a manufacturing industry (Mazharul *et al*., 2015)

Assembly line balancing in garment is usually undertaken to minimize imbalance between workers and workloads in order to achieve required run rate and productivity while meeting a required output from the line. It is a tool to improve the throughput of a work cell or line which at the same time reducing manpower and cost needed. It is often used to develop product-based layout. Well-designed production lines balance reduces manufacturing lead-time, improve space utilization, improve labor productivity, reduce material flow path and indirectly improve quality and workers' satisfaction (Mohamad, 2008).

In garment industries, to examine the real production lines is very expensive and sometimes difficult due to many operations which done manually. Furthermore, the rate at which the whole operations process takes place, the interaction between workers and the different transition times between works makes difficult and costly to observe the real garment manufacturing system closely. A simulation model is an easier helpful way to build up models representing real production system. The model will assist to identify production line bottlenecks also to get insight in terms of production output, queues, resources utilization, etc.

This research focuses on garment manufacturing productivity improvement through line balancing to analyze the production line bottlenecks and propose productivity improvement alternative models by taking Nazareth garment SC. export dressed trouser line as case study.

1.2 Statement of the Problem

Nazareth garment is one of the garment factories in Ethiopia working for local and export markets. The factory produces nested suits, formal and casual jackets, blazers, formal trousers, shirts and work wears. The factory is working for different international buyers such as H&M, Hagar and Bagir Group.

Seven export production lines are running in the factory; three lines setup for export products and the rest four lines for local markets. Currently trouser is the export product of the factory running with 57 workstations and 96 workers per line. The export lines have a planned capacity to produce 2000 pcs /day, but the current average output is below 800 pcs/day, it is less than the planned. while the average overall efficiency of the lines presenting below 36% which is less by half from the factory's plan and for daily production; productivity per operator is not more than 3 pcs per operator compared to the average factory plan 7.18 pcs per operator.

Factory is facing difficulty to meet the order delivery time as buyers or customers demand. The planned production lead time given by buyer is averagely eight weeks; however, the actual production time of the orders is ten to twelve weeks. If production delays happened buyers cannot catch up the seasonal demand and this will affect both price and delivery schedule. To meet the delivery time, the factory is implementing overtimes that leads to high manufacturing cost. Work in process (WIP) was seen on the lines which will have an impact on cycle time.

By considering all the mentioned above problems of low output production, lower productivity per operator, longer lead time and work in Process on the export lines which shows that there are productivity problems on production lines. Therefore, this research aims to improve productivity of the export production lines through line balancing. Improved productivity for export lines will help to be competitive on the international market and also to get an advantage of foreign currency exchange for Ethiopian textile business sector.

Hence, the basic research questions derived for this thesis are:

1. What critical bottlenecks in the assembly lines are responsible for lower productivity?
2. How can the productivity be improved through line balancing?
3. To what extent the productivity will be improved through line balancing?

1.3 Objective of the Research

1.3.1 General Objective:

The general objective of this research is to improve the productivity of the export garment production lines through line balancing.

1.3.2 Specific Objectives:

The specific objectives of the research include:

- To assess existing production line performances along with identifying the production process bottleneck.
- To model productivity improvement system for the production lines using suitable tool.
- To verify the modeling assumption and validate the model with the real productivity measures from the factory.
- To suggest balance production lines with the proposed model parameters that will improves the productivity of the lines.

1.4 Scope of the Study

The case factory produces different product types such as nested suits, jackets, blazers, trousers, shirts and work wears for both local and export markets. The scope of this research focuses on export lines of the factory by assessing, reviewing and analyzing garment production assembly lines and propose improvement model to the line productivity through the line balancing process.

1.5 Significance of the Study

Nazareth Garment Share Company is the target company which is intended to benefit from the results of this research. Productivity improvement in the garment industry helps to make competitive for the global market demand by responding to the questions on market demands of high production volume with short lead time and flexibility in sustainable way.

Also, hopefully this thesis work will be helpful on fulfilling the literature gaps and also as starting point to further enhance the research activities.

1.6 Organization of the study

The paper is organized in six chapters. The preceding chapter is an introductory part, which contains the statement of the problem, objectives, scope, and significance of the study. Chapter two is the literature review on productivity improvement on garment manufacturing, assembly line balancing, modeling and simulation also highlights review of studies on line balancing and gap of the literature. Chapter three focuses on the methodology tool and method of data analysis and data source discussed. The fourth chapter deals with data collection and analysis as well as simulation model formulation, verification and validation. Chapter five consists result and discussion mainly on simulation model result analysis and alternative model development. Finally, the conclusion and recommendation addressed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Garment Manufacturing Process

Today's apparel manufacturing is characterized by short product life cycles, volatile and unpredictable customer demands, tremendous product varieties and long supply process Sen (2007) as referenced by Mohammed (2010). In the face of the increasingly fierce competition and fast changing customer demands, today apparel enterprises must keep looking for ways to produce various types of products in shorter lead-time with less production costs and higher production quality.

Garment manufacturing use light weight machines which are easily moved during a line changeover. The practice is to rearrange the manufacturing line depending on the style required to produce. The same machine arrangement may prevail for several years for large order quantities or it may last for a few days for very low quantities and specialized fashion tailored styles. As the fashion change rapidly, today's trend of garment industry is to move towards fast change order and fashion quantities. Hence manufacturing lines should react fast for rapid changeovers.

Garment industry is one of the most labor-intensive industries where the raw textile materials, by manipulating though workstations, are converted first to semi products and then to final products. By its nature, garment industry is very similar to other product assembly industries, for instance the automotive industry. However, garment industry has its own characteristics that make it different from other industries. The big variety of raw materials with different properties is one of the characteristics that distinguish garment industry from other industries. Consequently, a high level of skills is required by the workers in order to manipulate efficiently with the machines and materials used. Furthermore, mainly manual skills are required from the workers in garment industry in the process of machine and material manipulation (Mohammed, 2010).

As a supply chain of textile industry, garment industry is one of the major industries of the world. The production process of garments is separated into four main phases: designing/ clothing pattern generation, fabric spreading & cutting, sewing and ironing & packing. The most critical phase is sewing phase. As the sewing is the heart of apparel industry, proper design of the sewing line is needed to achieve the best output at maximum efficiency and productivity (Mazharul, 2015).

Apparel is a mass production system in which assembly line production systems are developed to meet the requirements of mankind, which continue to grow day by day. The demand for greater product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines.

Assembly line is an industrial arrangement of machines, equipment’s and workers for continuous flow of work pieces in mass production operation. Manufacturing a product in an assembly line requires partitioning the total amount of work into a set of elementary operations called tasks. Tasks are assigned to operators depending on constrains of different labor skill levels. Finally, several workstations in sequence are formed as a sewing line.

The sewing process includes a set of workstations, at each of which a specific task is carried out in a restricted sequence, with hundreds of employees and thousands of bundles of sub-assemblies producing different style simultaneously. Therefore, this process is of critical importance and needs to be planned more carefully. Consequently, good line balancing with small stocks in the sewing line has to be drawn up to increase the efficiency, productivity and quality. So, the aim of assembly line balancing in sewing line is to assign tasks to the workstations, so that the machines of the workstation can perform the assigned task with a balanced loading with different labor skill levels (Mazharul, 2015).

Stepwise garments manufacturing sequence on industrial basis is shown in ***Fig2.1***: (www.textilelearner.blogspot.com)

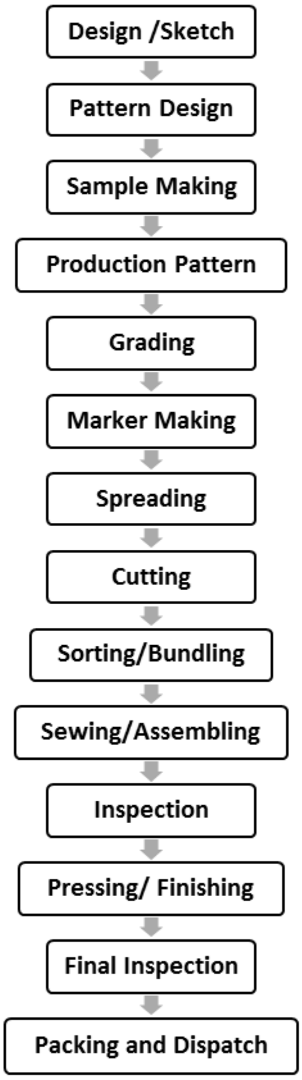

Fig. 2.1: - Garment manufacturing process flow diagram

Table 2.1 describes each process involved in garment manufacturing.

Table 2.1: - Process description of the garment manufacturing steps

Steps	Operation	Job	Method
01	Design/Sketch	It is given by buyers to manufacturers containing sketches including measurements of particular styles	Manual/Computerized
02	Basic Block	Basic block is an individual component of garments without any style of design (without Allowance, Style, Design)	Manual/Computerized
03	Working Pattern	When a pattern is made for a particular style with net dimension regarding the basic block along with allowance then it is called working pattern.	Manual/Computerized
	Sample Garments	To make a sample, this will be approved by	

04		buyer. After making a sample, it is sent to buyer for approval to rectify the faults	Manual
05	Approved Sample	After rectifying the faults, sample is again sent to buyers. If it is ok then, then it is called approved sample	Manual
06	Costing	• Fabric Costing • Making Charged • Trimmings • Profit	Manual
07	Production Pattern	Making allowance with net dimension for bulk production	Manual/Computerized
08	Grading	If the buyer requires different sizes, so should be grade as Small, Medium, Large, Extra Large, Extra Extra Large	Manual/Computerized
09	Marker Making	Marker is a thin paper which contains all the components for different sizes for a particular style of garments	Manual/Computerized
10	Fabric Spreading	To spread the fabrics on table properly for cutting	Manual/Computerized
11	Cutting	To cut fabric according to marker dimension	Manual/Computerized
12	Sorting & Bundling	Sort out the fabric according to size and for each size make in individual bundles	Manual
13	Sewing	To assemble a full garment	Manual
14	Ironing & Finishing	After sewing we will get a complete garment which is treated with steam ironing & also several finishing processes are done for example extra loose thread cutting	Manual
15	Inspection	Should be approved as initial sample	Manual
16	Packing	Treated by Polyethylene bag	Manual
17	Cartooning	After packing, it should be placed in cartooning for export	Manual
18	Dispatching	Ready for export	Manual

2.2 Manufacturing Productivity

Productivity of a manufacturing system can be defined as the amount of work that can be accomplished per unit time using the available resources. (Swapnil, 2014) According to Durdyev, (2011) productivity is an effective utilization of the resources to achieve set objectives or it can be defined as "quantity of output of a process per unit of resource input", which aligns with several approaches.

Productivity, with its widely used definition, is a relation between output which is produced by a production process or service system and input which is used to produce output. Productivity is one of the major determinants that enable manufacturing organizations to compete in the global market. One of the most important factors which increase competitive capacity of companies is to use their production bases in the most effective way. Therefore, to minimize loss of the factors related to labor, machine and material provides opportunity to increase productivity. In apparel companies, the sewing room is a production department where the most of the labors operate and the size of apparel companies are considered with their sewing capacity. Besides quickness and productivity of apparel production is also determined by considering sewing room. Consequently, the studies which are applied to increase productivity in sewing department substantially affect productivity of companies (Herbert *et al.*, 2016).

$$Productivity = \frac{Output}{Input}$$

Productivity is also confused with terms like efficiency and effectiveness and these terms are wrongly considered synonymous to productivity. Efficiency and effectiveness are two different terms such that efficiency indicates how well the resources are utilized to accomplish a result. 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 (Swapnil, 2014).

2.3 Productivity Improvement on Garment Manufacturing

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. 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 garment industries. [Santosh et al., 2015]

Many researchers have reported various improvement techniques and performance measures with the aim of increasing garment manufacturing productivity.

As described by Herbert Mapfaira (2016) lean manufacturing is a productivity improvement methodology or approach that considers the expenditure of resources on non-value-added activities to be a waste. Value-added activities are activities that are necessary to create value for the end customer. Value is defined as any activity carried out during the course of producing a product/service that the customer would be willing to pay for. Lean manufacturing is therefore focused on the elimination of all activities that do not add value to the end product (Sumon, 2014). Another approach for productivity improvement using lean manufacturing tools is proposed by Rebecca and Aile (2015) aimed to use and apply lean tools as way of improving manufacturing systems that lead to reduction of wastes and standardization of cycle time.

On another research by Balaji Rathod *et al.* (2016), they showed to improve productivity through optimization of Cycle Time by Lean Manufacturing Techniques for reduction of non-value-added activity. Furthermore, Hussain and Ghulam (2012) showed the Role of Productivity Improvement Tools and Techniques in the Textile Sector during manufacturing, mainly focused on time and motion study.

Rupali Biswas (2013) showed to improve productivity through cellular manufacturing approach which is the application of the principles of group technology in manufacturing. Cellular manufacturing helps to create a concept known as single or one-piece flow. Equipment and the workstations are arranged in sequences to allow for a smooth flow of materials and components through the process. The cell is made up of workers and the equipment required performing the steps in creating the product. The layout of the equipment and the workstations is determined by the logical sequence of production. By grouping similar products into families that can then be processed on the same equipment in the same sequence, cellular manufacturing offers companies the flexibility to give customers the variety they require. Factories converted to cellular manufacturing benefit by the reduction of overproduction and waste, shorter lead time, improved quality and productivity, improved teamwork and communication. (Herbert et al., 2016).

Mahmut Kayar *et al.* (2014) shows application of work study to improve the productivity through the systematic analysis of existing operations, processes, work methods and resources.

Another approach to increase productivity is line balancing. Line balancing loss is waiting time, which is caused by unbalanced or inadequate balanced production line, expressed in no. of operators. That means, periods when the operator waits for further work which is coming from workstations in the production line which works in sequential steps. If the line is balanced well, the line balancing loss should be at a minimum. Perfectly balanced lines with a line balancing loss of zero operators are unusual. To find the optimum or an appropriate line balancing loss is certainly an issue companies are focusing on. Planning tools in production line balancing attract notice of an increasing number of companies. To keep the production labor costs per produced piece as low as possible, companies try to increase efficiency in worker's assignment. (Rupali, 2013).

In addition, productivity improvement can also be achieved by various techniques and methods, which consists of technology-based techniques, employee-based techniques task-based techniques, product-based techniques, and material-based techniques. Line balancing-is one of the task-based techniques that can increase productivity, machine utilization, material utilization and labor utilization in a manufacturing industry [Mahmut, 2014]. Rezaul *et al.* (2012) proposed effective productivity improvement model using multi skilled manpower in apparel industries.

As discussed, productivity may improve with lean, cellular manufacturing, work study and line balancing. This research will follow the line balancing approach to improve productivity on the case factory and propose possible solutions to improve productivity.

2.4 Assembly Line Balancing

Assembly lines are production systems developed to meet the requirements of mankind, which continue to grow day by day. The demand for greater product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines. The aims of these systems are to manufacture products at higher production rates in the shortest time, in the most productive way, cheaply and with the quality required.

In 1913, Henry Ford completely changed the general concept of assembly by introducing Assembly Lines (ALs) in automobile manufacturing for the first time. He was the first to introduce a moving belt in a factory, where the workers were able to build the famous Model-T cars, one piece at a time instead of one car at a time. Since then, the AL concept revolutionized the way products were made while reducing the cost of production. Over the years, the design of efficient ALs received considerable attention from both companies and academicians. It had been found from 'that a well-known assembly design problem is assembly line balancing (ALB), which deals with the allocation of the tasks among workstations so that a given objective function is optimized'. ALB has been a focus of interest to academics in operation management for the last decades.

Swapnil (2014) stated that the good assembly line is the line that has high value of line efficiency. Line efficiency can be defined as the percentage of good parts at the end of the line versus the theoretical number that the line should produce in a given time period. Time periods for averaging are determined by the goal of the production. To achieve 100%-line efficiency, one station must never be blocked or starved, and the station must always operate at its theoretical capability. The higher outputs of the line can be considered as the efficient line because the line can produce higher outputs in the specific production time. (M Mohd et al., 2012)

Line balancing can be defined as the process of assigning tasks to workstations in such a way that the workstation has approximately equal time requirement. (Ubani, 2012). The tasks that assign to each workstation must fulfill the equal time requirement. In other words, the workloads at each workstation must be the same and the time consume during the assembly process is also equal at each workstation.

2.5 Types of Assembly Line

An assembly line can be classed into three categories based on numbers of models assembled on the line and according to the line step.

1. **Single-model assembly lines**

Single model assembly lines have been used in single type or model production only. There are large quantities of the products, which have the same physical design on the line. Here, operators who work at a workstation execute the same amount of work when a sequence of products goes past them at a constant speed. (Siti et al., 2013)

2. **Mixed-model assembly lines**

Mixed-Model Assembly lines are usually used to assemble two or more different models of the same product simultaneously. On the line, the produced items mixed model production lines are often used in manufacturing systems.

3. **Multi-model assembly lines**

In Multi-model assembly lines several (similar) products are manufactured on one or several assembly lines. Because of significant differences in the production processes, rearrangements of the line equipment are required when product change occur. Consequently, the products are assembled in separate batches in order to minimize set-up inefficiencies. While enlarging batch sizes reduces set-up costs, inventory costs are increased. (Mahmut, 2014)

In multi-model production, the homogeneity of assembled products and their production processes is not sufficient to allow for facultative production sequences. In order to avoid setup times and/or costs the assembly is organized in batches. This leads to a short-term lot sizing problem which groups models to batches and decides on their assembly sequence. Especially if lot sizes are large, the line balance can in principle be determined separately for each model, as the significance of setup times between batches is comparatively small. However, also in multi-model production a certain degree of similarity in production processes should be inherent. Typically, the different models are manufactured by use of the same resources, e.g. machines or operators. If line balances are determined separately, those resources which are shared by models might need to be moved to other stations whenever the production system is setup for a new batch or have to be installed multiple times. This increases setup times and/or costs. If this interdependency is regarded in the line balance, the setup times might be reduced considerably, which in turn allows for a formation of smaller lots with all associated advantages.

2.6 Terminology Used in Assembly Line Balancing

There are some terms which should be considered in a garment line balancing process. Such as lead time, task time, cycle time, downtime and minimum number of workstations which are explained below:

Lead Time

In apparel industry, lead time is the total amount of time required for completing a product beginning from the date of receiving the order to the shipment of the goods to customer. Time is a great issue in apparel trade as orders are based on weather, seasons and occasions. Lead time carries huge importance when delivering the products to the respective outlets is concerned.

The manufacturing lead time (MLT) of a product is the total time required to process the product through the manufacturing plant. The total lead time (TLT) of a product is the total time elapsed from the instant at which raw materials are ordered until the instant the finished product is delivered. (Nahom, 2011) Total lead-time is made up of time devoted to processing orders, procuring and manufacturing items, and transporting items between the various stages of the supply chain (Shahidul et al., 2012).

Takt Time

According to Pekin (2006), manufacturing a product on assembly lines requires dividing the total work into a set of elementary operations. A task is the smallest, indivisible work element of the total work content. Task time or processing time is the necessary time to perform a task by any specific equipment. It shows also how fast the need to manufacture product in order to fill the customer orders. Same or different equipment might be required to produce the tasks. Producing faster than task time results in over-production which is a type of waste whereas producing slower than task time results in bottlenecks where the customer orders may not be filled in time. (Swapnil, 2014)

The calculation of Takt time is based on the target production quantity per day and on the standard time per operation.

$$Takt\ Time = \frac{Time\ (min)}{Units}$$

Minimum Number of Workstations

A workstation is a physical area where a worker with tools, a worker with one or more machines, or an unattended machine performs particular sets of work together. Number of workstations working is the amount of work to be done at a work center expressed in number of workstations.

Minimum number of workstations is the least number of workstations that can provide the required production. Actual number of workstations is the total number of workstations required on the entire production line, calculated as the next integer value of the number of workstations working. (Swapnil, 2014)

Minimum number of workstations can be calculated by total task Duration time (the time it takes to make the product) divided by the cycle time. Fractions are rounded to the next higher whole number. (Naresh,2011)

$$Minimum\ Number\ of\ Workstations = \frac{\sum_{i=0}^{n} Time\ for\ Task\ i}{Cycle\ Time}$$

Where,

- n is the number of assembly tasks.

Work in process (WIP)

Work in process (WIP) is the amount of semi-finished product currently resident on the factory floor. A semi-finished product is either being processed or is waiting for the next processing operation. Inventories are also seen as the insurance buffer against various uncertainties induced by delayed supplies, machine breakdowns, absenteeism and uncertain customer orders. Inventory is the evidence of poor design, poor forecasting, poor coordination and poor operation of the manufacturing system.

Throughput time

For a manufacturing system, the throughput is generally expressed as an hourly or daily production rate i.e., the number of parts produced per hour or day. The reciprocal of the throughput or production rate is the production time per unit of the product. For transfer lines the throughput approximates the reciprocal of the cycle time (transfer time + longest operation time). The manufacturer should be able to handle quick delivery, thus ensures a short throughput-time at high productivity rates.

Machine Utilization

High machine utilization is assumed to be good because it amortizes the cost of the machinery faster. Idle time is supposed to be bad since high-priced equipment does not produce anything. Effective resource utilization is to run the machine to manufacture exactly the right quantity of exactly the right things at exactly the right time.

Capacity

The term capacity, or plant capacity, is used to define the maximum possible output of the transformation process the plant is able to produce over some specified duration.

Flexibility

Flexibility is the ability of the system to respond effectively to change. Flexibility is fundamental to achieve competitiveness. In general, high degree of flexibility requires higher levels of automation and more investments. However, such a system will be an adapting organism capable of surviving in uncertain and changing markets. Changing circumstances include both internal and external changes. Internal changes or disturbances include breakdown of equipment, variability in processing time, work absenteeism and quality problems. External changes are typically changes in design, demand and product mix. The ability to cope with internal changes requires a degree of redundancy in the system, whereas the ability to cope with external changes requires that the system should be versatile and capable of producing a wide variety of part types with minimum changeover times and costs to switch from one product to another.

Cost

This includes decreasing the total cost of production by reducing value adding cost, non-value adding cost, holding cost, waiting cost, material handling cost, and other costs.

Standard Minute Value (SMV)

SMV is the standard time allowed to an operator (worker) to complete a task. SMV or sometimes called SAM (Standard Allocated Minute) is the time value arrived at for a task based on the average rate of output which qualified workers will naturally achieve without over exertion provided that they know and adhere to the specified method and provided that they are motivated to apply themselves to their work.

In garment industry, specifically in production, SAM is used for measuring standard operation time. In the factory, work study department (also known as Industrial Engineering department) measure and calculate SAM for sewing operation using standard calculation method SAM is used many ways directly and indirectly. Some of those are

- Factory as well as individual operator performance is measured by means of SAM
- Labor cost and associated cost ratios are measured by SAM
- Operators payroll and incentive amount is calculated based on earned SAM
- Latest production scheduling systems like line balancing system and performance measuring systems use SAM as one of the primary parameters.

An organized garment manufacturing company cannot think about managing and controlling shop floor without using SAM of the garment and individual operations. Even apparel buyers do negotiation of garment manufacturing price based on garment SAM. (www.onlineclothing.com)

Cycle Time:

The area within a workplace equipped with special operators and/or machines for accomplishing tasks is called workstation. Cycle time is the time between the completion times of two consecutive units/workstations.

Cycle time also defined as how frequently a finished product comes out of production facility (Alireza *et al.,* 2011). Cycle time shows how often the production line can produce the product with current resources and staffing. It is an accurate indicator to represent of how the line is currently set up to run. Cycle time is the expected average total production time per unit produced. On an assembly line or in a work cell with multiple operators, each operator will have his own time associated with completing the work he is doing.

Task time and cycle time are definitely not the same. Task time represents the maximum time allowed to meet the customer demand whereas cycle time is the actual time necessary for an operator to perform an activity or complete one cycle of his process. Both task time and cycle time are determined by customer demand (Swapani, 2014).

To meet customer demand or monitor productivity the cycle time and takt time should be balanced in parallel. The higher cycle time than takt time may result the late delivery and customer dissatisfaction whereas shorter cycle time than takt time may cause the excess inventory or excess use of resource.

Cycle time also known as observed time is defined as the time duration from starting point of a job to the starting point of the next job. This time is established from the observation data of an operator while working at a certain pace.

Cycle time = Machine Time + Material handling time.

Basic Time:

Basic time of a job is determined by multiplying rating factor to the observed time (cycle time). Basic time is also expressed as Normal time. In Basic Time no allowances are included.

Basic time = (Cycle time X Performance Rating)/100 or

Basic Time = (Standard Time - Allowances)

Bundle allowance:

To determine Standard Time (SAM) using Time Study method various allowances are added to the basic time. Bundle allowance is one such allowance.

In Progressive Bundle Production System (PBS), number of garments is bundled together. These bundles are fed to the sewing line. Sewing operators need to open (untie) the bundle before he can start sewing garment pieces. After completing one bundle operators need to tie up the bundle before he stacks the bundle or slide it to the following operator. For this activity operator spends certain time. It may be fraction of minutes. The time required for bundle tying and untying is considered as bundle allowance. Bundle Allowance Time per piece will depend on the size of the bundle. A bundle may contain 5 pieces or 20 pieces of garments. For both bundles more or less same time will be required to untie and tie the bundle. When calculating standard time, it is done for single pieces. Bundle allowance will be less as bundle size increases.

Performance rating

Rating' is the process used by the industrial engineer to compare the actual performance of the operator with his/her mental concept of normal performance. In order to rate there must be a defined level of performance to compare with, an 'average' level. 'The rating' is the numerical value used to denote the rate of working. In order to rate there must be a defined level of performance to compare with, an 'average' level.

Rating is a subjective comparison of any condition or activity to a benchmark, based upon our experience. While the mechanics of time study record the time a task did take, applying a rating will determine the time a task should take.

The rating corresponding to the average rate at which an operator will naturally work at a job, provided they know and adhere to the specified method, and provided they are motivated to apply themselves to their work.

British standard provides the 0-100 scale for rating. Here 0 represent no work at all and 100 a normal rate. We rate the job on this scale after observing the operator. A slow rate may be rated around 50 and a fast one around 125. The concept of ‘Rating’ (known in the US as ‘grading’) is fundamental in time study. The ability to rate effectively distinguishes a qualified time study practitioner from a novice.

The concept of 100% performance is a critical element of time study and performance measures while normal performance is the rate of output which qualified workers will achieve without over-exertion over the working day shifts provided, they know and adhere to the specified method and provided they are motivated to apply themselves to the work.

A slower performance rate, which will produce fewer pieces per hour, is recorded as a percentage below 100%. A faster performance rate that produces more pieces per hour is recorded as greater than 100%.

To improve accuracy in rating an operator, the observer must:

- Have knowledge of the operation and the specified method or standard operating procedures for that task.
- Concentrate on the operator motions.
- Be alert to fumbles, hesitations, and other lost motions- these are seldom or absent in 100% performance.
- Eliminate or ignore interruption or events not in the operator’s control.
- Avoid a corrupting bias when observing fast and slow operators in succession.
- Know that increasing the number of cycles observed increases accuracy.

Standard Operator:

A ‘Standard Operator’ is fully trained and motivated to perform a defined task (having a defined method) and is, by definition average in terms of his or her work-pace. Standard Performance’ is achieved by a standard operator, as long as working conditions are correct. Operator performance is primarily a measure of the effectiveness of the individual operator. It is sometimes referred to as “Pay” performance as it is usually measured within an incentive scheme.

Allowance

A worker cannot and does not work continuously within required time scheduling. In an apparel industry a worker has to do lots of work. For executing all of the work, a worker needs some time for personal and physical refreshment. Therefore, a worker needs some extra time allowed for performing the job. Also, machines will delay from operating with different reasons such as changing bobbins and maintenance; this extra time added with basic time during SMV calculation.

To summarize, three types of allowances are counted or added with basic time during SMV calculation in Garment:

Relaxation Allowance:

Relaxation is the time allowed to a worker to feel up personal needs and to get back from fatigue. Relaxation allowance is divided in two ways which are:

A. Personal allowance

B. Fatigue allowance

A. Personal Allowance:

Personal allowance is one kind of relaxation allowance which is most common allowance in garments. This allowance is provided for the need to leave the work place such as going to wash room and fetching a drink. The common figure is about 5% to 7% of basic time.

B. Fatigue Allowance:

Fatigue allowance is not common allowance in garments. It is a mental and physical tiredness developed by an employee due to continuous work. This allowance is given depending on the energy expended in doing the job and to alleviate monitory. Normally it is counted as 4% on basic time.

Contingency Allowance:

Contingency allowance depends on the worker, physical strength for doing the job. It is a small amount of allowance which is given to meet the legitimate delay of work. It is counted less than 5% of basic time.

Machine Delay Allowance:

Sometimes, machines are off due to mechanical or technical problems. These are applied to the total basic time for those elements which are concerned with the operation of machinery.

Line efficiency/operator efficiency

In apparel manufacturing, skills and expertise of a sewing operator is being presented in "Efficiency" term. An operator with higher efficiency produces more garments than an operator with lower efficiency in the same time frame. When operators work with higher efficiency, manufacturing cost of the factory goes down. Secondly, factory capacity is estimated according to the operator efficiency or line efficiency. Hence, efficiency is one of the mostly used performance measuring tools. ***(27)***

$$Line\ Efficiency\ (in\ \%) = \frac{Total\ minuits\ procuced\ by\ the\ line}{Total\ minuits\ attended\ by\ all\ operators} * 100$$

Where:

- *Total minutes produced by the line:* To get total produced minutes multiply production pieces by SAM.
- *Total minutes attended by the all operators in the line:* Multiply number of operators by daily working hours and convert total hours into total minutes (multiplying by 60).

To calculate efficiency of a line for a day, the following data (information) are required from the line supervisor or records.

1. ***Number of operators*** – how many operators worked in the line in a day?
2. ***Working hours*** (Regular and overtime hours) – how many hours each of the operators worked or how many hours the line run in a day?
3. ***Production in pieces*** – How many pieces are produced or total line output at the end of the day?
4. ***Garment SAM*** – What is exact standard minute of the style (garment)?

On standard operator efficiency

Operator efficiency can be expressed in more specific ways, like 'On-Standard Efficiency' instead 'over-all efficiency'. An operator may be attending all hours in a shift but if he has not been given on-standard work to do in all hours, he will not be able to produce minutes as per his capability and skill level. In this case, to know operator's on-standard efficiency following formula is used.

Operator on-standard efficiency (%) = (Total minute produced /Total on-standard minute attended) *100%

Where,

- Total minutes produced = Total pieces made by an operator X SAM of the operation [minutes]
- Total on-standard minute attended = (Total hours worked – Lost time) x 60 [minutes]

Hourly production target

In apparel production you may often need to calculate hourly production target for a given style for setting up production target and production planning. Hourly production target is calculated for individual operators as well as for a line as needed.

Hourly production target calculation is a part of an operation bulletin preparation and daily production report. In an operational breakdown (OB) production target is calculated for each operation.

To calculate the hourly production target for a production line, the following formula can be used

Hourly Production Target of a line = ((60 * No. of operators working in a line * Line efficiency %) /Garment SAM)

To calculate daily production target of a line, just multiply the hourly line target by shift hours.

Labor/operator efficiency

In apparel manufacturing, skills and expertise of a sewing operator is being presented in "Efficiency" term. An operator with higher efficiency produces more garments than an operator with lower efficiency in the same time frame. When operators work with higher efficiency, manufacturing cost of the factory goes down. Secondly, factory capacity is estimated according to the operator efficiency or line efficiency. Hence, efficiency is one of the mostly used performance measuring tools. So, to calculate operator efficiency, the standard minutes (SAM) of the garment and operations are needed. The following formula can be used to calculate operator efficiency.

$$Efficiency\ (\%) = \frac{Total\ minuits\ procuced\ by\ an\ operator}{Total\ minuits\ attended\ by\ an\ operator} * 100$$

Where,

- Total minutes produced = Total pieces made by an operator X SAM of the operation [minutes]
- Total minutes attended = Total hours worked on the machine X 60 [minutes]

Time Study for Garment Manufacturing

Time study is a method of measuring work for recording the times of performing a certain specific task or its elements carried out under specified conditions. An operator does same operation (task) throughout the day. Time study help to define how much time is necessary for an operator to carry out the task at a defined rate of performance.to do time study stopwatch used and to recorded data properly a time study format needs to be prepared.

To do time study, the following tools are need:

- A stopwatch
- Time study format
- One pen or pencil
- Time Study board

Productivity per operator

As textile industry is mainly labor oriented and the degree of atomization compared with other industries considerably low, the influence of an improvement in worker/labor productivity is quite high.

Particularly, in countries like Europe where high labor costs affect the overall production costs highly, the productivity of each single operator is significant. Through good planning and application of high technology equipment productivity per operator can be improved easily. Productivity per operator is calculated by dividing total output in pieces by total manpower (operator).

2.7 Assembly Line balancing in Garment

Garment manufacturing in its nature is complicated; it involves a number of machines, hundreds of employees and thousands of bundles of sub-assemblies producing different styles simultaneously. In the apparel industry, assembly lines are widely adopted for mass production. Garment components are sub-assembled and eventually completed by final assembly. The design of the bundle assembly line is one important issue for efficient production. It consists of assigning and balancing tasks between workstations of an assembly line in order to minimize balance delay, labor force and ultimately minimizing the total production cost. Overall, the important criteria in garment production is whether assembly work will be finished on time for delivery, how machines and employees are being utilized, whether any station in the assembly line is lagging behind the schedule and how the assembly line is doing overall. Many researchers have made contributions to the assembly line balancing in apparel industries. (Naresh, 2011)

Different literatures have been reviewed to gain insight about line balancing in garment industries.

According to Benzer *et al.* (2007), the fundamental line balancing problem is how to assign a set of tasks to an ordered set of workstations, such that the precedence relations and some performance measures (minimizing the number of workstations, cycle time and idle time) are satisfied. Hence, Eryuruk *et al.* (2008) provides two main goals while balancing an assembly line which are minimization of the number of workstations for a given cycle time and minimization of the cycle time for a given number of workstations. (Mahmut, 2014)

S. H. Eryuruk *et al.* (2008) discussed two heuristic assembly line balancing techniques known as the "Ranked Positional Weight Technique", developed by Helgeson and Birnie, and the "Probabilistic Line Balancing Technique", developed by

El Sayed and Boucher as applied to solve the problem of multi-model assembly line balancing in a clothing company for two models. The aim of their work was the comparison of the efficiencies of two different procedures applied for the first time to solve line balancing in a clothing company. As a result of evaluation, they concluded that the Ranked Positional Weight Technique gives better results than the Probabilistic line balancing technique. Furthermore, The Ranked Positional Weight Technique is easier to apply and has higher line efficiencies.

Song *et al*. (2010) discussed specific example for sequential decision problem for real time optimal line balancing control in apparel industry. The change of operator efficiency during real time production is the main reason that causes production line imbalance and thus the adjustment of operator allocation is required.

In the study by Betts and Mahmoud (1989) the varying skill of operatives and stochastic task time were considered for assembly line balancing in the clothing industry. As a result, the actual time for the completion of each task varies between different operatives and such variations also exist at the same task repeatedly performed by the same operative.

In most apparel enterprises, the estimation of production time for each task is by reference to Standard Minute Value (SMV). The characteristic of SMV is deterministic in nature, derived from the method of work study. However, it cannot reflect the real production environment because a lot of factors such as the properties of fabric and sub-materials, performance of machinery, working environment and quality level of the product may cause variations on the task time. Such variations on task time cause the assembly line balancing problem in the clothing industry to become more complicated. Time variation between each task becomes important for the assembly line balancing. In the apparel industry, it is essential to form a new production line for each order, and also the number of workers is changed according to the complexity of the order, the number of operations, throughput etc.

Naresh (2011) reported that, since sewing department involves tedious manual labor, the process often resulted in a high cycle time and low yields, sewing department contribute a lot of problem in garment manufacturing company. There are lots of different operations done manually and sewing operations needs high skill as well as quality work, especially when handling the difficulty associated with repairing of products sewed with wrong specifications (Zuraida,2010).

Meanwhile, based on Chandra (2005), cycle time is one of the challenges in textile and apparel industry. Cycle time reduction is strongly correlated with high first pass yield, high throughput times, and low variability in process times, low WIP and consequently cost. Hence, cycle time is the key to competitiveness of a firm (Harrell et al., 2004). An improvement in calculation method to determine the number of workstations and cycle time in assembly line balancing considered by F Khosravi *et al.* (2012).

Different researches also noted that, line balancing problems in sewing department is most popular operational issue in apparel or garment industry (Guner *et al*., 2012). Line balancing in garment industry deals with allocating the resources such as workers and machinery to the assembly line so that the precedence relation is satisfied and the sum of task at any workstation does not exceed cycle time. Simulation has been a preferred tool to evaluate the performance of garment production line as it has the ability to model dynamic and stochastic nature of production systems. It enables the researcher to gain a critical insight into the performance of a manufacturing company.

In garment industries, to examine a real manufacturing system is very expensive and sometimes cumbersome. The rapid rate at which the whole process takes place, the interaction between workers, and the different transition times between workers make it increasingly more difficult for a human being to make correct decisions regarding how fast each operator should work in order to continue the process, while at the same time keeping productivity high and throughput at an acceptable level. Therefore, a simulation model is an easier way to build up models to represent real life scenarios, to identify bottlenecks, to enhance system performance in terms of productivity, queues, resources utilization, and the like.

According to Harrell *et al*. (2004), with recent advances in computing and software technology, simulation tools are now available to help meet the challenge of quickly designing and implementing complex manufacturing systems that are capable of meeting growing demands for quality, delivery, affordability and service.

Simulation and modeling allow management to study the dynamics of the business and to consider the effects of changes without risk. With simulation models, we can explore how an existing system might perform if altered, or how a new system might behave before the prototype is even completed, thus saving on costs. (Zuraida, 2010)

2.8 Modeling and Simulation in Line Balancing

Even though we have moved beyond the Industrial Age and into the Information Age, manufacturing remains an important part of the global economy. Modeling and simulation are emerging as key technologies to support manufacturing in the 21st century. There have been numerous efforts to use modeling and simulation tools and techniques to improve manufacturing efficiency over the last four decades (Chance *et al.*, 1996).

According to the Oxford English dictionary, simulation means: The technique of imitating the behavior of some situations or systems by means of analogous situation, model or apparatus, either to gain information more conveniently or to train personnel. In other words, simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and evaluating various strategies for the operating system.

A model is defined as an abstract and simplified representation of a system which includes the most important system components and the behavior or interaction between these components. Therefore, the model can be used to: (Sebastien *et al.*, 2004)

- Analyze current operations and identify problem area
- Test various scenarios for improvement and
- Design new manufacturing systems.

Process modeling and simulation are modeling techniques available to support companies in gaining a better understanding of their manufacturing system behaviors and processes and therefore helping them in decision making. Process modeling provides management with a static structural approach to business improvement, providing a holistic perspective on how the business operates, and provides a means of documenting the business processes. It also allows management to study the dynamics of the business and to consider the effects of changes without risk (Nahom.2011).

Simulation models allow to test potential changes in an existing system without disturbing it or to evaluate the design of a new system without building it. Simulation early in the design cycle is important, because the cost to repair mistakes increases dramatically the later in the product life cycle the error is detected. This methodology also allows comparing new concepts, equipment's or scenarios before purchasing. For some purpose, simulations are better than the analysis of real data. With real data, it is never possible to perfectly know the real-world process that caused a particular measured situation, because of the too complex interactions inherent in large systems (Sebastien *et al*., 2004).

In a simulation, the analyst controls all the factors making up the data and can manipulate them systematically to see directly how specific problems and assumptions affect the analysis. Because simulation software keeps track of statistics about model elements, performance can be evaluated by analyzing the model data. One important, but often difficult task for the "simulator" is to define a suitable level of representation with respect to the overall objectives of the simulation study. System modeling can be used to study an existing system under various scenarios without modifying it, or for planning the construction of a new system which does not exist yet. System models are developed in order to evaluate some functional or non-functional properties of the system. Functional properties include throughput, mean execution time, reliability and so on. Non-functional properties include deadlock-freedom, usability, responsiveness and others.

Simulation is one of several alternative methods of analyzing systems. Another technique is the use of mathematical analysis. Analytical modeling involves building a system description using some formal, mathematical notation. Unfortunately, mathematical analysis is limited to a relatively small number of simple systems and the opportunity to represent manufacturing systems in this way is felt to be limited (Chance *et al*., 1996). Based on state of the system simulation can be categorized as using either a continuous or discrete time representation. Systems may have discrete or continuous state. In some systems the state changes all the time, not just at the time of some discrete events. For example, the water level in a reservoir with given in and outflows may change all the time. In such cases "continuous simulation" is more appropriate. The status of components is continuously changing with respect to time. It uses differential equations to track properties. Other systems, however, only change at discrete points in time. For example, in an industrial plant, the system status changes when a new part arrives at a machine or when a machine breaks down. Between any two events, the status of the modeled system remains constant. To represent the changes in the system, it is only necessary to describe the actions or events which cause the status of the system to change. This is referred to as discrete event system modeling. Discrete event simulation has applications in a wide range of sectors including automotive, healthcare, defense, electronics, pharmaceuticals, food and beverages, packaging, construction, footwear manufacturing and logistics (Nahom, 2011).

Manufacturing, industrial and service sectors have been the most common fields of simulation applications. Simulation in general is to pretend that one deals with a real thing while really working with an imitation. The imitation is a computer model of the simulated reality. It is very costly, dangerous and often impossible to make experiments with real systems. So that models are very important to describe reality, experimenting with them can save money, suffering and even time. This is done by developing a simulation model of the system. The model is based on a set of assumptions on the real system behavior, and on the workload driving the system. A correct and validated simulation model in fact can substitute the real system as long as the underlying assumptions are met.

In general, simulation is a practical methodology for understanding the high-level dynamics of a complex manufacturing system. Simulation has several strengths including: (Alula, 2013)

- ***Time compression*** – the potential to simulate years of real system operation in a much shorter time,
- ***Component integration*** – the ability to integrate complex system components to study their interactions,
- ***Risk avoidance*** – hypothetical or potentially dangerous systems can be studied without the financial or physical risks that may be involved in building and studying a real system,

- ***Physical scaling*** – the ability to study much larger or smaller versions of a system,
- ***Repeatability*** – the ability to study different systems in identical environments or the same system in different environments, and
- ***Control*** – everything in a simulated environment can be precisely monitored and exactly controlled.

Modern manufacturing is characterized by high levels of automation and integration, complex interactions among system elements, and high capital costs. While modeling and analysis are important to help ensure good system performance, the integration and complexity of systems often makes purely analytic tools difficult to use. Hence, simulation remains one of the most widely used tools to fill this need.

A number of commercially available software packages are in use both in industry and academia, including Arena, Auto Mod., Quest, Simu8, And Witness. Such packages and simulation in general, have experienced great improvements with recent advances in computational technologies. Specific improvements include graphical user interfaces to facilitate model-building, integration with spreadsheets and databases for better data management, and powerful capabilities to visualize and animate model execution. In general, increased computational power has enabled development of detailed "high fidelity" models of systems to aid in design and operation. The ability to create high fidelity models has important potential benefits in prototyping system performance.

Computer simulation modeling has been applied to manufacturing industry since the late 1960’s when IBM introduced its General-Purpose Systems Simulator (GPSS) package. Simulation was found to be a very useful means of analyzing the dynamics of materials flow through a manufacturing plant, for example, to:

- Identify current or potential bottlenecks and their impact on profitability.
- Examine effects of changing resource capacity (e.g. adding or subtracting operators or units of equipment, working additional shifts and purchasing extra machine)
- Analyze effects of different batch sizing policies on inventory levels, throughput and lead times.

- Examine effects of random equipment breakdowns and the potential impact of different maintenance strategies.
- Analyze the relative impact on material flow velocity of reducing process variability in alternative targeted areas.
- Check on the overall ability of the plant to respond to different assumed rates of demand increase, and identification of what resources will be the first to come under pressure. (Alula,2013)

2.9 Arena Simulation Software

The Arena modeling system from Systems Modeling Corporation is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system. First released in 1993, Arena employs an object-oriented design for entirely graphical model development. Simulation analysts place graphical objects - called modules on a layout in order to define system components such as machines, operators, and material handling devices. Arena is built on the SIMAN simulation language. After creating a simulation model graphically, Arena automatically generates the underlying SIMAN model used to perform simulation runs. Arena allows the interactions with other computer tools such as Visual Basic and Excel wile integrating very well with Windows environment (Desalegn, 2009).

2.10 Literature gaps

Different related literatures reviewed to get insights and analyze the gaps on their productivity improvement approaches; mainly specific to line balancing in garment manufacturing. The recent literatures reviewed from different sources among these journals, articles and thesis works are the main ones. Summary of literatures are briefly shown in ***Table 2.2***.

Table 2.2: - Summary of literatures

Author	Title	Product analyzed	Approach	Finding /Solution
Rupali Biswas (2013)	Productivity improvement in garment industry through cellular manufacturing	Long sleeve T-shirt	Cellular Manufacturing approach	Reduction of overproduction and waste, Improved quality and productivity, improved teamwork and communication
Mahmut Kayar *et al.*	A research on the effect of	Blouse	Method study and	The effect of method study

(2014)	method study on production volume and assembly Line efficiency		assembly line balancing using Ranked Positional Weight	on production volume and assembly line efficiency analyzed. Author concludes that there isn't another method that are used within gaining higher productivity, reduction of costs by using present resources.
Lina Katharina Rambausek (2008)	Analysis of Assembly Line Balancing in Garment Production by Simulation	Trouser	Line balancing Simulation	Identifying bottlenecks, and model proposed by arena to balance line and increase efficiency. productivity improvement and cost analysis not considered in this research.
Mazharul *et al.* (2015)	Line Balancing for Improving Apparel Production by Operator Skill Matrix	Jacket	Operator Skill Matrix	Maximum utilization of manpower in labor intensive assembly lines, by delegating workers to various operations based on their skill. The study not focusing giving training and enhancing operator skills.
F. Sarwar (2013)	Investigation of a Hybrid Production System for Mass Customization Apparel Manufacturing,	Woven shirt	Time study, progressive bundling system (PBS) and a hybrid production system	Study proved that Bundle Modular Production System were more advantageous than Progressive bundling system for mass customization
Eryuruk *et al*. (2008)	Assembly line balancing in a clothing company	command pocket and welt pocket pants	Ranked Positional Weight Technique and Probabilistic Line Balancing Technique"	Comparison of the efficiencies of two different procedures applied for the first time to solve line balancing in a clothing company.
Herbert Mapfaira (2016)	productivity improvement using simulation modeling and lean Tools: a case study	Manufactures of security garage doors.	Lean manufacturing	Suggested to transform the existing manufacturing system to lean system to reduce wastes.
Balaji Rathod *et al.* (2016)	Optimization of Cycle Time by Lean Manufacturing Techniques-Line Balancing Approach	Axle Manufacturing	Lean manufacturing Line balancing	To improve productivity and cost by optimization of Cycle Time and reduction of non-value-added activity.
Hussain and Ghulam (2012)	The Role of Productivity Improvement Tools and Techniques in the Textile Sector during Manufacturing	Garment	Time and motion study	Evaluation of the overall progress of employees and performance of man machine system.
Rezaul *et al*. (2012)	Productivity improvement through balancing process using multi-skilled manpower in apparel industries	T shirt	Line balancing	Improving the production line balance by optimal operator allocation with the consideration of operator efficiency. Proposed layout based on the logic of modular systems considered SMV and seriously skilled workers for improvement. lead-time

				and quality assumptions not taken
Rebecca and Aile (2015)	Application of Lean Manufacturing Tools in a Garment Industry as a Strategy for Productivity Improvement	Baby dresses	Lean tools	Improving manufacturing systems that lead to Reduction of wastes and standardization of cycle time.
F Khosravi *et al.* (2013)	An improvement in calculation method for apparel assembly line	Jeans trouser	Calculation method	Determining number of workstations and cycle time, productivity not considered.
Naresh (2011)	Implementation of Lean Manufacturing Tools in Garment Manufacturing Process Focusing Sewing Section of Men's Shirt	Men Shirt	Lean manufacturing tools Time study	Improving workers multi skill level and effective communication and flexibility of the styles with proposed model of cellular manufacturing approach. Research limited to sewing section and skill gap not considered.
Swapnil *et al.* (2014)	Productivity improvement of automotive assembly line through line balancing	engines	Time study	Improving overall line efficiency by eliminating non-value added activities.

Reviewed literature gaps summarized as below:

- Most of the reviewed literatures not considered productivity improvement by simultaneously improving the lead-time through line balancing.
- Most of the researches used arena simulation software focused on basic simple products like T shirts instead of complicated products. Complicated process, takes longer processing time, uses more number of resource and operations.
- On their improvement proposal the researches mainly focused on giving training as priority solution which may lead to additional cost to implement instead of finding possible alternatives first with the existing resource and skills.
- Impacts of quality rejection rates (i.e. Low production output and less productivity) on productivity improvement through line balancing are not considered.

CHAPTER THREE

METHODOLOGY

It is important to identify and understand the research approaches to be undertaken because it influences the research instruments to be employed and the ultimate goal of the thesis. In addition, the selection should be based on the problem of interest, resources available, skills & training of the researcher, and the audience for the research. Integration of the following methods are used to achieve the objectives of this research.

3.1 Literature Survey

Literature survey will be done to analyze and deeply understand what is previously done on productivity improvement through line balancing and also to find out important techniques for problem formulation and modeling through browsing internet books, thesis, articles and journals.

3.2 Data Collection and Analysis

Data collection is depending on the nature of data as it could be categorized as quantitative or qualitative. For this research primary and secondary data collected from the production lines of the case factory to examine the production level mainly containing the production output, inputs involved, production process and processing time for each operation.

3.2.1 Primary Data

To analyze the actual case factory manufacturing system primary data will be collected by

- Observations of the assembly flow and production process.
- Time study
    - Time study was done with a stopwatch to collect the time taken of each process within the workstations to assess processing times.
- Discussions with factory responsible bodies (i.e. general manager, production and quality manager, line supervisors and operators) focusing on bottlenecks.

3.2.2 Secondary Data

Secondary data were collected from the factory's previous records of daily production reports, general stich data (GSD), line layout, operation breakdowns and production plans.

3.3 Sampling Strategy

For this research available sampling technique was used to determine the number of observations (cycle time) required and to collect data (Daniel and Ajit, 2014). To determine the number of observations (cycle time) required for data collection, five preliminary samples were considered for operation Side Pocket facing Over Lock.

Table 3.1: - preliminary sample for Side Pocket facing Over Lock

Observations	Stopwatch time in second)
1	14
2	12
3	12
4	15
5	11
Mean	**12.8**
Standard deviations	**1.64**

Standard deviation and number of observations were calculated by ***Eqn. 3.1*** and ***Eqn. 3.2*** respectively.

$$s = \sqrt{\frac{(x-\bar{x})^2}{n-1}} \quad \text{......................................} \textit{ Eqn. 3.1}$$

$$N = \left(\frac{zs}{h\bar{x}}\right)^2 \quad \text{...} \textit{Eqn. 3.2}$$

Where,

- N = the number of observation (cycle time) required,
- n = preliminary sample,
- x = recorded stopwatch times,
- x = mean of initial preliminary sample,
- s = standard deviation
- h = half the precision interval in percent,
- z = number of normal standard deviations needed for desired confidence level.

The value of normal standard deviations (z) and half the precision interval (h) were fixed for the reason that most of industries use the confidence level of for 95.5% and correspondence values for z and h are 2 and 0.1 respectively. The number of observations for operation front over lock calculated as 7 observations. Even if the number of observations calculated is seven, the garment manufacturing operations are different in nature and as the number observation increases the confidence level also increases. Thus, in this study 15 cycles (observations) were taken in order to get accurate data for the complete garment production processes of the model as used by the research works by Daniel *et al.* (2010) and Lina (2008) 15 observation data used for each operation.

3.4 Tools Selection

Based on the research needs and objectives, arena simulation software selected as suitable tool to deal with the research problems and meet the objective of this study. Due to many operations in garment manufacturing, cost of implementation trials is very high, Arena simulation software helpful to model and examine the real production system.

3.5 System Modeling and Simulation

It is appropriate to use simulation in order to simplify real life situations. Based on the data analysis of the existing system, simulation will be performed, and then different proposed models will be developed and measured for their performance by selecting and using suitable simulation tool. Finally, by considering different scenarios and alternative solutions will then be proposed.

However, a model cannot represent the real system exactly rather it can approximate the system how it behaves and interact. This is mainly due to the assumptions made while developing the model. Therefore; there is some variation between the constructed model and the real system. This variation directly affects the performance measures of the system. The performance measures extracted from a model will only represent the real system if the model is a good representation of the system. Therefore; our criteria for judging the goodness of models will be based on how performance measures extracted from the model correspond to the measures which would be obtained from the real system. (Nahom, 2011)

3.5.1 Model Verification

Verification is the process to ensure that the simulation model is correctly implemented with respect to the conceptual model with sufficient accuracy. Verification is practically seen as debugging the simulation model, which can be done with several tools such as animation by running the model, to further verify the simulation model trial runs were made under a variety of settings of the input parameters, and will check the model output results for appropriateness. From a verification perspective, animation provides the information about the internal behavior of the model.

A model which includes all the components specified under the system definition phase and capable of running without any errors or warnings is considered to be verified successfully. To verify the model simulation trial runs made under different setting of the inputs by altering the arrival times. The animation of the processes observed to verify that each process path was correct.

3.5.2 Model Validation

After verification of the model is done validation will continue. Validation is necessary to show that the proposed model has an acceptable level of confidence in the performances processing assumed. Validation is the task of demonstrating that the model is a reasonable representation of the actual system. Model verification techniques are general while the approach taken to model validation is likely to be much more specific to the model, and system, in question.

There are two major types of validation of simulation model. The first is face validity which is to mean that the model at least on the surface represents reality. The second is statistical validity. Statistical validity involves a quantitative comparison between the output performances of the actual system and the model (Alula, 2013)

Model validation for this Research is made by statistical validity comparing the output of the real system and the model output of the existing system. If there is no statistically significant difference between the data sets, then the model is considered valid. Conversely, if there is a statistically significant difference, then the model is not valid and needs additional work before further analysis may be conducted.

3.5.3 Number of Replications

Number of replications is number of simulations runs that should be executed to analyze statistically the differences between the simulation model and the real system to increase the output reliability. The output result become more accurate by doing more replication thereby we can estimate the error we introduce in modeling the real system. It has an integer value greater or equal to one. (Lina, 2008; Nahom 2011).

The input distributions of simulation models are usually probabilistic in nature. This input variability naturally results in some variation in the output measures of performance. Because the output measures have some variation, it is necessary to run several simulation replications and then make the recommendations based on all the available data. (Alula 2013)

The replication analysis process begins with selecting an initial number of replications. Summary statistics from this initial set of replications are then used to calculate whether additional replications are required at a particular level of confidence. If more replications are required, then there is a need to run additional replications and recalculate the summary statistics and replication formulas for the process. A common number of initial replications is ten. This provides a sufficient number of replications to have reasonable statistical confidence given that additional replications can always be subsequently added (Alula 2013; Nahom, 2011).

3.6 Result and Discussion

After experimentation and analysis is done on the model, an improved model is developed. Finally, conclusions will be drawn from the analysis made and then recommendations will be given based on those concluded points.

3.7 Research Framework

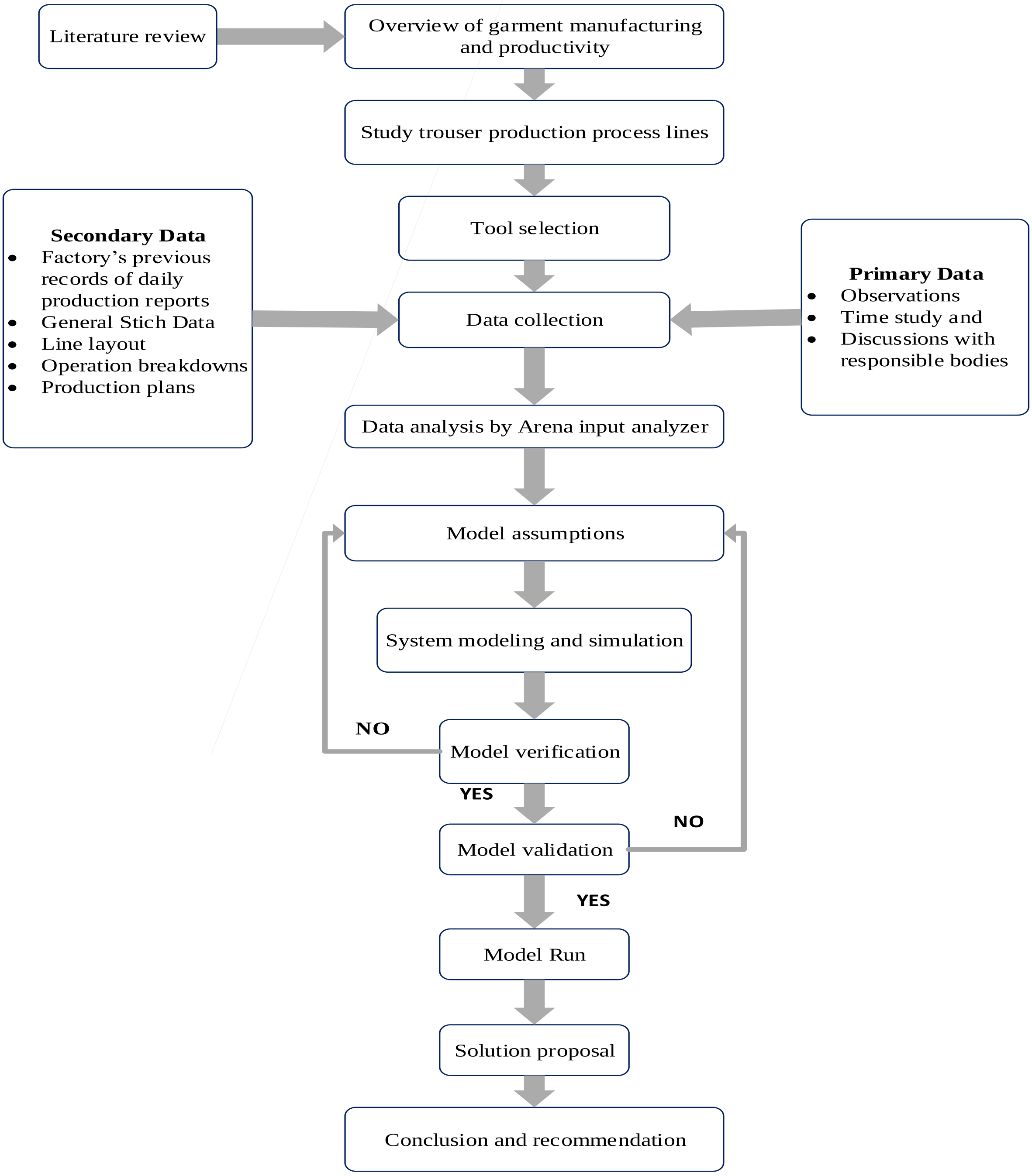

Fig. 3.1: - Research framework

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

4.1 Overview of Case Company

Nazareth Garment Share Company (NGSC) was established by the Government of Ethiopia in 1991 to produce light fabric garments mainly geared to shirts. Started to export to the US market. In 2006 the factory was privatized. Started to export to the German market.

On April 2014 Bagir Group Ltd., a company which listed on the London AIM Stock Exchange, has purchased 50% of NGSC shares (now Bagir purchased the remaining share. Through this partnership, Bagir is contributing its expertise, global presence and technical know-how in the field of tailored garment while NGSC is providing its facility, current skilled workforce and management and sustainable relationships with the local authorities to ensure a successful outcome in this challenging assignment

Company is placed in Nazareth (Adama) area, which is approximately 100 Km South East from Addis Ababa, area which has a great potential as workforce and infrastructure, the city having direct highway to Djibouti port.

Factory oriented more to the export markets, producing an average of 130,000 pcs per month – shirts, trousers, T-Shirts and Polo in two separate cutting – sewing sections.

Operations of company are carried out during a daily shift of 8 hours, with 5.5 working days per week extra time being performed only in emergency cases and not on regular basis; approach of management regarding the workforce is considered proper company taking decision to subsidies the food provided in the canteen in order to motivate the workers and improve the attendance rate.

Cost structure indicated by company highlights 50-60% in fabrics; 10% accessories; 10% workforce; 9-10% administrative cost and 10-20% profit margin.

Nazareth company uses for the products the following woven structures: plain and twill and from the knit structures the most used are: S Jersey, rib. It covers for all kind of functional work wear like: mechanics/maintenance, household, hospital uniforms and surgery room garments, formal uniforms for banks airlines and police and also Men/Women pants, jackets, shirts, overcoats, overall, skirts, guans, and raincoats.

Fig. 4.1: - Organizational structure of Nazareth Garment SC.

4.2 Production Process of the Company

The production division of the factory consists different sections; Cutting, sewing(assembly), finishing and packing. In cutting section different parts of the product prepared and placed as bundle. Then the cut parts moved to assembly production floor. The assembly section divided in to two sections. Preparatory section, for subassembly of different parts and final assembly section for each line to make the final garments. Once the garments stitched and ready, they moved to finishing and packing sections.

The product assembly line of the factory constitutes straight lines. The parts or sub assembled components transferred to subsequent stations manually by using table. After processing of the part in respected operation, the operator places the component on the table where subsequent operation is to take place. If operation is to be undertaken on station not adjacent to the previous, additional helpers are used to transfer components.

4.3 Existing Process Flow of Trouser Assembly Lines

During data collection time factory producing men dressed trouser, main size 52 for export purpose to one of the buyers, the analysis based on this dressed trouser. Trousers production facility composed of after cutting sections, Small parts preparation, Front parts and back Parts' Preparation, Assembly section and Finally finishing section for final inspection and packing. The trousers can be slightly hard to create because they require many accurate measurements and some dedicated time to properly craft them.

The design of the trousers may be an important part of a successful manufacturing process. Popular trends in men's clothing help set the style for trousers. Fabrics, new colors, flare of the trousers and innovation may be among the new styling features the designers manipulate to produce new products. Pattern makers provide the tools that will enable the manufacturer to produce these new trousers. The process for this is fairly straight-forward; the pattern parts are sketched on paper and once there is consensus that these parts will create the targeted design, the pieces are digitized into a Computer-Aided Design (CAD) system. Each fabric type utilized affects other aspects of production including how the fabric is cut, the lining and tapes that must be used to reinforce the fabric type, the kind of needle that most cleanly pierces the fabric, the type of thread that will ensure the fabric will not be pulled, etc. Once these specifications for production are established, production is ready to proceed.

Fig. 4.2: - Pictures of dressed trouser

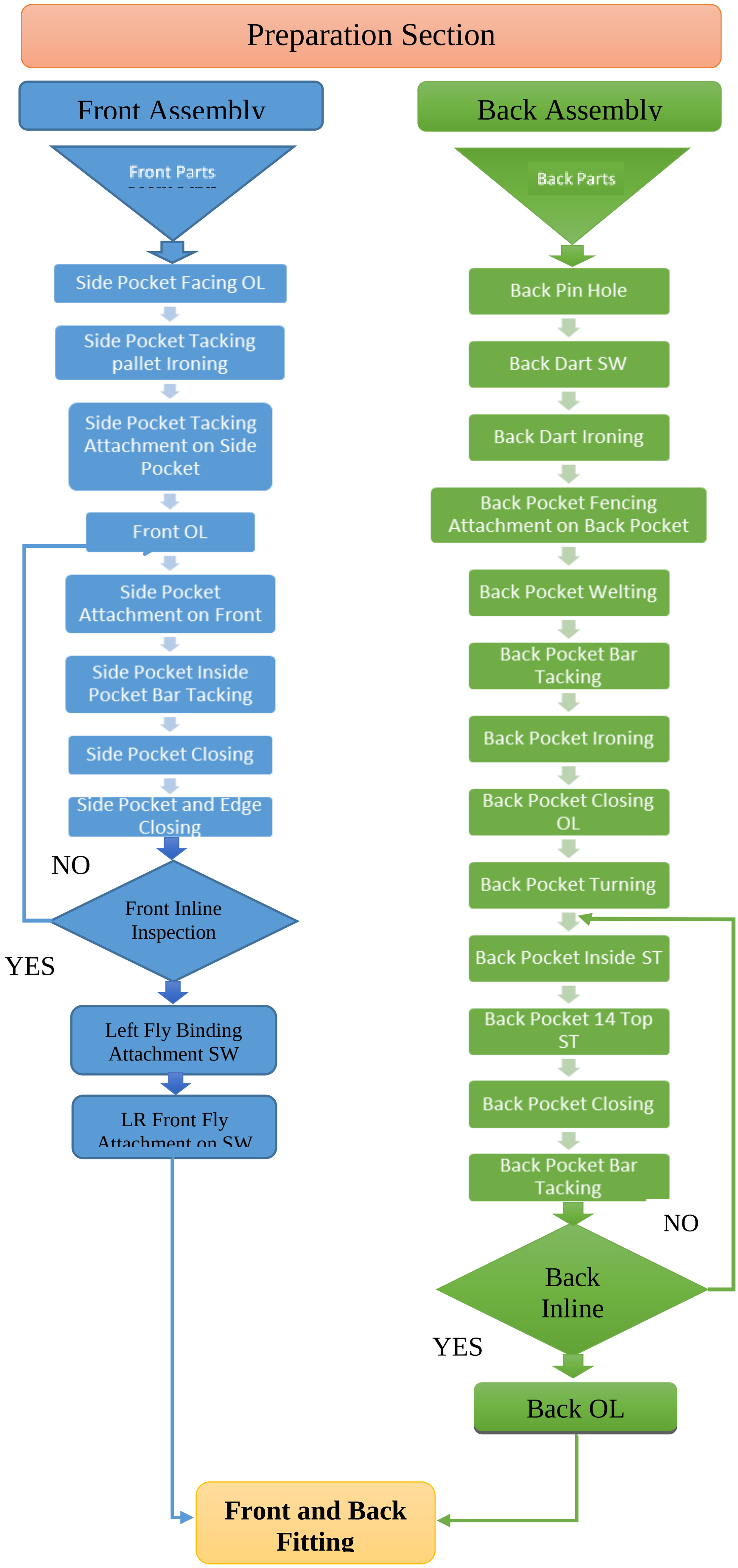

Fig. 4.3.: - Production process of preparatory section

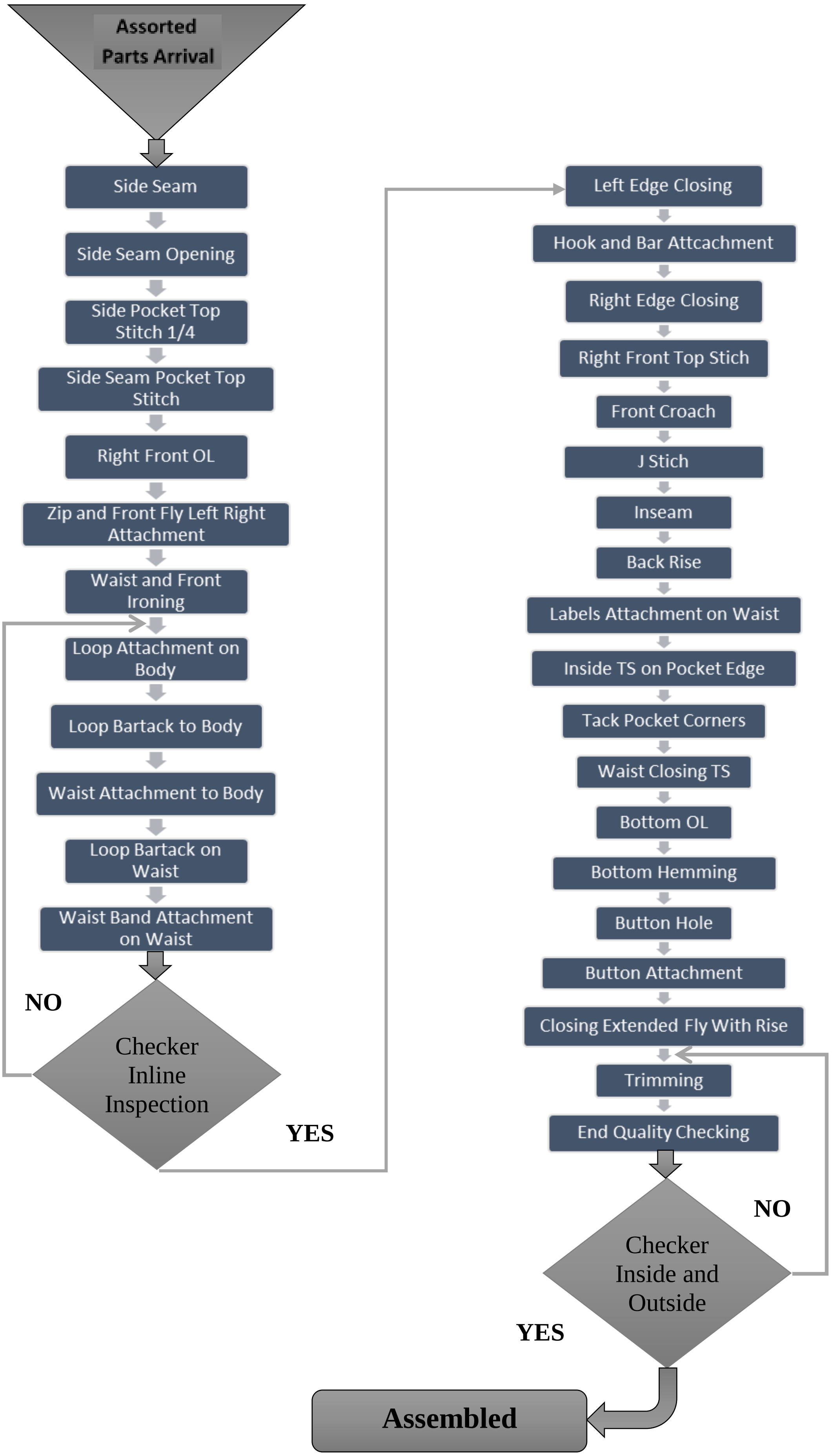

Fig. 4.3 Production process of assembly section

4.4 Data Collection Process

Data collection and analysis for developing simulation model is important as all output depends on the accuracy of the data in order to balance the sewing line. Initially, data collection begins from identifying and observing the different operations done on preparatory and assembly line. After observing all operations or tasks which are done on the lines; then defining individual work elements to each workstations follows. Individual work element is a minimum rational work element having a specific limited objective. Based on this, the number of tasks on each assembly lines are determined and the processing time for each operation was measured in second and 15 measurements for each task recorded using stopwatch. In addition to make more accurate/validate the collected data, production reports, GSD, line layout and operation breakdowns and production plans considered.

The time required to complete a task depends on a lot of factors such as the task, operator, properties of fabric and sub materials, working environment, quality level of product, hour of the day and psychology of the operator (Fozzard *et al*, 1996). It's not expected that operator will work all day without some interruptions. Allowances like personal, fatigue and delay allowances will consider calculating the standard time value for each operation. For this research standard times were not taken into account, but the distributions of the collected time for each operation considered. Because process time of operations is variable and so a distribution is the best way to represent real system; sticking to predetermined standard times would decrease the model's authenticity for realistic applications due to their rigidity.

In general, the data collected were:

- Production output
- Total no of tasks(operations)
- Processing time for each operation
- Working hours
- Process flow layout

All processing times were found to be probabilistic rather than deterministic. The variation in processing times and the random arrivals from day to day according to market demand caused randomness in the observations.

Sometimes workers are going to other workstations or other part of transportation table to pick up the WIP if helpers are not around. This makes difficult and complex the data collection process. So, the focus of the data collection to follow the activity rather than the worker. The second strategy was to get the data over several one-day activities that had influenced the quality of the data because of the change in the station conditions and the change of the labor force size.

Table 4.4: - Collected processing time for each operation in trouser preparatory section

No	Operation /Process name	Observed time (sec)															Average time
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
Preparation section																	
1	**Small Loop Preparation**	51	52	52	53	53	48	51	51	55	53	53	51	48	46	48	51
2	**Waist band Fusing**	18	17	15	18	17	18	18	17	17	17	15	18	17	18	18	17
3	**Waist Preparation**	61	61	63	64	67	60	62	63	66	69	63	64	67	60	63	64
4	**Side Pocket facing Over Lock**	14	12	12	15	11	14	14	14	15	12	12	12	15	14	14	13
5	**Side Pocket facing Patlate Ironing**	63	65	60	74	69	60	69	66	64	67	71	74	64	67	69	67
6	**Side Pocket facing attachment on side pocket**	63	56	58	60	55	56	57	58	59	61	55	58	63	60	55	58
7	**Front Over Lock**	53	50	63	60	65	65	65	60	63	63	53	55	60	60	63	60
8	**Side Pocket attchment on Front**	94	104	104	100	92	97	99	100	101	101	97	99	100	101	103	99
9	**Side Pocket Inside pkt Bar Tacking**	47	48	48	50	50	55	49	44	48	46	48	50	50	55	49	49
10	**Side Pocket Clothing**	59	61	62	62	64	58	59	61	64	65	62	62	64	62	65	62
11	**Side Pocket and Edge Clothing**	93	87	95	105	91	91	95	91	103	99	97	101	91	93	97	95
12	**Left Fly Binding Attachment S/W**	49	54	46	48	51	54	46	48	48	51	54	46	51	51	51	50
13	**L&R Front Fly Attachment on S/W**	66	60	64	57	70	59	66	72	60	70	59	66	72	57	70	65
14	**Back Pin Hole**	54	56	57	60	62	68	59	54	59	65	62	57	62	59	57	59
15	**Back Dart S/W**	77	68	70	73	79	71	71	73	75	76	79	75	73	79	73	74
16	**Back Dart Ironing**	65	65	67	67	68	67	67	62	65	67	64	64	68	67	67	66
17	**Back Pocket fencing attachment on back pocket**	51	48	58	54	48	55	53	55	48	48	58	54	53	50	55	53
18	**Back Pocket Welting**	55	64	57	60	62	57	58	60	62	62	57	60	62	57	58	59

19	**Back Pocket Bar tacking**	77	76	84	80	81	84	78	80	76	84	80	81	84	80	82	80
20	**Back Pocket Ironing**	57	58	58	59	61	57	57	58	58	59	61	57	58	59	61	59
21	**Back Pocket Clothing OL**	40	44	48	40	53	46	50	48	53	40	48	40	53	46	44	46
22	**Back Pocket Turning /Mouthing**	44	45	45	47	49	43	44	46	47	48	45	47	49	43	44	46
23	**Back Pocket inside ST**	60	56	63	62	67	60	62	63	64	65	63	62	67	60	65	63
24	**Back Pocket 1/4 Top S/T**	59	60	61	61	63	60	60	62	62	63	58	59	60	60	62	61
25	**Back Pocket Clothing**	58	60	61	63	65	61	61	63	59	61	63	65	63	59	61	62
26	**Back Pocket Bar Tacking**	50	55	63	57	59	55	63	57	57	59	55	63	57	57	59	58
27	**Back Overlock**	52	52	53	56	57	50	51	52	52	52	53	56	57	50	53	53
28	**Front and back Fitting**	46	45	45	45	46	45	45	45	45	45	45	45	46	45	45	45

Table 4.4: - Collected processing time for each operation in trouser assembly line

No	Operation /Process name	Observed time (sec)															Average time
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Assembly section																	
1	**Side Seam**	116	118	119	120	119	114	115	117	118	118	118	118	120	120	118	118
2	**Side Seam Opening**	115	119	127	122	122	118	120	121	123	124	117	119	120	121	121	121
3	**Side Pocket Top Stitch 1/4**	98	99	99	101	103	83	85	88	80	83	83	101	103	83	85	92
4	**Side Seam Pocket top stitch 1/16**	90	92	94	95	96	94	95	97	90	92	94	95	96	94	94	94
5	**Right Front Over Lock**	28	31	31	34	37	28	28	29	29	30	31	31	34	37	28	31
6	**Zipp and Front Fly L&R attachment**	67	69	69	70	70	68	69	71	71	73	68	71	73	74	75	71
7	**Waist and Front Ironing**	43	44	44	45	46	44	45	46	47	48	44	44	44	45	46	45
8	**Loop attachment on body**	114	115	116	116	117	111	112	113	114	115	116	117	111	112	113	114
9	**Waist attachment on body**	113	114	116	117	117	113	114	114	116	116	113	114	114	116	116	115
10	**Loop Bartack to body**	49	50	51	53	55	50	52	52	53	53	50	51	53	55	50	52
11	**Loop Bartack on waist**	90	90	91	93	94	90	92	93	94	95	90	91	93	94	94	92
12	**Waist band attachment on waist**	102	103	103	105	107	102	103	104	105	106	104	105	106	106	108	105
13	**Left edge closing**	49	49	50	52	53	49	49	51	52	53	56	53	49	49	51	51
14	**Hook and Bar attachment**	53	54	56	57	58	55	56	59	56	51	51	51	53	55	57	55
15	**Right edge clothing**	101	97	98	99	100	101	101	102	103	104	101	97	98	99	104	100
16	**Right front Top stitch**	99	101	101	102	101	97	98	99	100	101	101	101	102	102	100	100
17	**Front Crotch**	53	53	55	56	58	51	56	51	51	53	55	56	59	56	59	55
18	**J stitch**	53	54	56	57	59	53	54	55	56	57	53	54	55	57	58	55
19	**Inseam**	83	84	85	86	88	83	83	88	84	80	88	83	83	88	83	85
20	**Back Rise**	115	115	117	118	119	113	114	110	117	125	117	118	119	113	114	116
21	**Labels Attachment on Waist**	76	76	77	78	78	75	75	76	76	78	77	78	78	75	75	77
22	**Inside TS on pocket edge**	83	85	87	87	88	82	84	84	85	85	87	87	88	82	84	85
23	**Tack pocket corners**	66	67	68	69	70	70	66	68	67	68	69	70	67	68	69	68

24	**Waist Closing TS**	56	59	59	60	62	61	63	65	67	60	62	61	63	65	67	62
25	**Bottom Over Lock**	57	59	60	62	63	57	58	60	60	61	60	62	63	57	58	60
26	**Bottom Hemming**	68	69	70	70	71	69	70	71	71	73	97	88	88	84	90	77
27	**Button Hole**	40	42	43	44	45	46	48	48	44	45	44	45	46	48	49	45
28	**Button Attachment**	49	49	46	52	55	53	54	56	57	59	53	54	55	57	55	54
29	**closing extended fly with rise**	56	51	51	53	55	53	53	55	56	58	51	59	56	56	59	55
30	**Trimming**	59	61	62	64	65	59	60	60	61	61	54	57	59	56	59	60
31	**End Quality Checking**	68	68	69	70	70	68	67	71	75	73	66	67	67	69	67	69

4.5 Arena Input Analyzer

The analysis involves the identification of the theoretical distribution that represents the input data. The use of the input data in the model involves specifying the theoretical distributions in the simulation program code. The input analyzer tools built in Arena was used to convert the collected data into probability distributions to be used in the simulation model.

The process of determining the underlying theoretical distribution for a set of data usually involves what is known as a goodness of fit test. These tests are based on some sort of comparison between the observed data distribution and a corresponding theoretical distribution. If the difference between the observed data distribution and the corresponding theoretical distribution is small, then it may be stated with some level of certainty that the input data could have come from a set of data with the same parameters as the theoretical distribution. There are four different methods for conducting this comparison: Graphic approach, Chi-square test, Kolmogorov–Smirnov test and Square error.

The Input Analyzer has the capability to calculate chi-square, Kolmogorov–Smirnov (KS), and square error tests. In addition to these it is capable of determining the quality of fitness of probability distribution functions to input data and generate high quality data plots.

Therefore, the collected data was processed in the Input Analyzer tool built in Arena, and the results are used to set the type of probability distribution function and its value to be used in simulation model.

It was critical phase to determine the best distribution because it affects the performance of the assembly line. In deciding which distribution to present, it tried to choose those that are simple to describe, implement and are reasonably efficient as well (Law et al., 1991). The distributions that are occurring in continuous simulation are Uniform, Exponential, Erlang, Gamma, Weibull, Normal, Lognormal, Beta, Pearson Type V, Pearson Type VI, Log-Logistic and Triangular. The data's input to arena as per the existing straight-line balancing.

Sample Input analyzer data distribution function for bottom hemming processes of trouser assembly lines is shown in ***figure 4.5*** below.

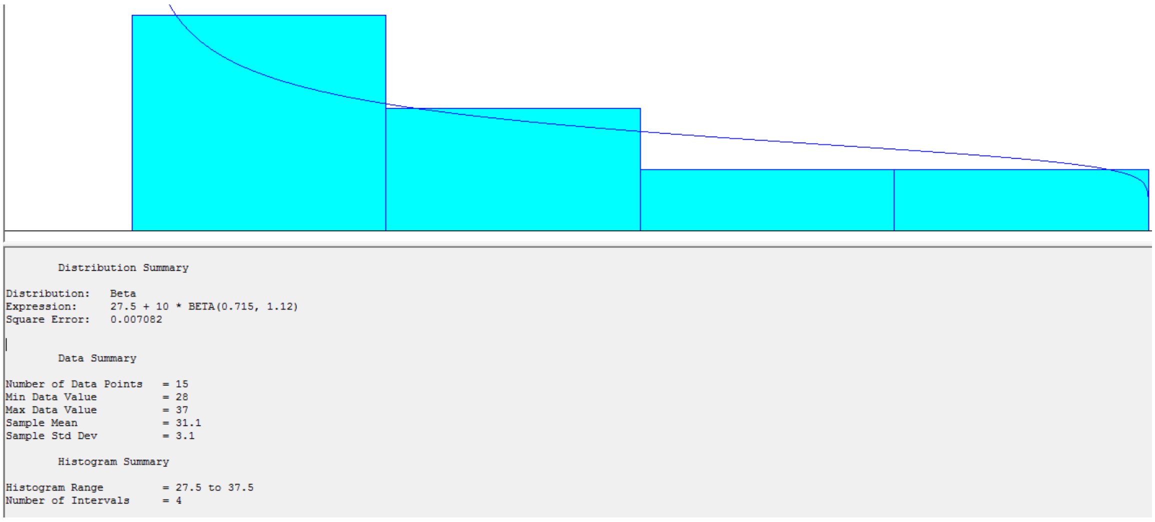

Fig. 4.5 Input analayzer distribution function for bottom hemming operation

Preparatory line operations data distribution function summarized as below on ***table 4.3.***

Table 4.3: - Input analyzer data distribution function of each operation preparatory section

No	Operation /Process name	Distribution
	Preparatory Section	
1	**Small Loop Preparation**	TRIA (45.5, 52, 55.5)
2	**Waist band Fusing**	14.5 + 4 * BETA (1.63, 0.784)
3	**Waist Preparation**	59.5 + ERLA (2.02, 2)
4	**Side Pocket facing Over Lock**	UNIF (10.5, 15.5)
5	**Side Pocket facing Patlate Ironing**	NORM (66.8, 4.18)
6	**Side Pocket facing attachment on side pocket**	54.5 + 9 * BETA (0.883, 1.15)
7	**Front Over Lock**	TRIA (49.5, 64.6, 65.5)
8	**Side Pocket attachment on Front**	TRIA (91.5, 101, 105)
9	**Side Pocket Inside pkt Bar Tacking**	TRIA (43.5, 48.5, 55.5)
10	**Side Pocket Clothing**	57.5 + 8 * BETA (1.51, 1.2)

11	**Side Pocket and Edge Clothing**	TRIA (86.5, 91, 106)
12	**Left Fly Binding Attachment S/W**	NORM (49.9, 2.75)
13	**L&R Front Fly Attachment on S/W**	UNIF (56.5, 72.5)
14	**Back Pin Hole**	53.5 + ERLA (2.95, 2)
15	**Back Dart S/W**	67.5 + GAMM (2.57, 2.58)
16	**Back Dart Ironing**	NORM (66, 1.67)
17	**Back Pocket fencing attachment on back pocket**	47.5 + 11 * BETA (0.771, 0.93)
18	**Back Pocket Welting**	TRIA (54.5, 57.5, 64.5)
19	**Back Pocket Bar tacking**	NORM (80.5, 2.73)
20	**Back Pocket Ironing**	56.5 + WEIB (2.26, 1.49)
21	**Back Pocket Clothing OL**	POIS (46.2)
22	**Back Pocket Turning /Mouthing**	42.5 + 7 * BETA (1.16, 1.3)
23	**Back Pocket inside ST**	TRIA (55.5, 64.8, 67.5)
24	**Back Pocket 1/4 Top S/T**	57.5 + WEIB (3.57, 2.33)
25	**Back Pocket Clothing**	57.5 + ERLA (1.34, 3)
26	**Back Pocket Bar Tacking**	NORM (57.7, 3.4)
27	**Back Overlock**	49.5 + 8 * BETA (0.837, 1.04)
28	**Front and back Fitting**	44.5 + WEIB (0.797, 1.92)

Assembly line operations data distribution function summarized as below on ***table 4.4***.

Table 4.4: - Input analyzer data distribution function of each operation of assembly line

No	Operation /Process name	Distribution
Assembly Section		
1	**Side Seam**	TRIA (113, 120, 121)
2	**Side Seam Opening**	NORM (121, 2.82)
3	**Side Pocket Top Stitch 1/4**	79.5 + 24 * BETA (0.712, 0.662)
4	**Side Seam Pocket top stitch 1/16**	TRIA (89.5, 94.6, 97.5)
5	**Right Front Over Lock**	27.5 + 10 * BETA (0.715, 1.12)
6	**Zipp and Front Fly L&R attachment**	66.5 + 9 * BETA (1.37, 1.61)
7	**Waist and Front Ironing**	42.5 + LOGN (2.55, 1.62)
8	**Loop attachment on body**	UNIF (111, 118)
9	**Waist attachment on body**	113 + LOGN (2.49, 2.26)
10	**Loop Bartack to body**	UNIF (48.5, 55.5)
11	**Loop Bartack on waist**	89.5 + 6 * BETA (0.824, 0.963)
12	**Waist band attachment on waist**	102 + 7 * BETA (1.37, 1.71)
13	**Left edge closing**	POIS (51)
14	**Hook and Bar attachment**	NORM (54.8, 2.48)
15	**Right edge clothing**	96.5 + 8 * BETA (0.943, 1.03)
16	**Right front Top stitch**	TRIA (96.5, 102, 103)

17	**Front Crotch**	NORM (54.8, 2.64)
18	**J stitch**	52.5 + 7 * BETA (0.922, 1.3)
19	**Inseam**	79.5 + LOGN (5.46, 4.2)
20	**Back Rise**	NORM (92.2, 2.56)
21	**Labels Attachment on Waist**	74.5 + 4 * BETA (0.801, 0.775)
22	**Inside TS on pocket edge**	UNIF (81.5, 88.5)
23	**Tack pocket corners**	65.5 + 5 * BETA (1.26, 1.13)
24	**Waist Closing TS**	NORM (62, 2.99)
25	**Bottom Over Lock**	56.5 + 7 * BETA (0.82, 0.919)
26	**Bottom Hemming**	74.5 + 32 * BETA (0.506, 0.971)
27	**Button Hole**	39.5 + 10 * BETA (1.7, 1.32)
28	**Button Attachment**	TRIA (45.5, 55.8, 59.5)
29	**closing extended fly with rise**	NORM (54.8, 2.64)
30	**Trimming**	NORM (59.8, 2.74)
31	**End Quality Checking**	65 + GAMM (1.65, 2.38)

4.6 Simulation Model Formulation

The simulation model was built using Arena® version 14.0 simulation software. The construction period of the model is based on the existing trouser line process flow production diagram which highlighted during observation. Sewing machines are organized according to the production process flow, but the number of machines which are used for each operation are determined by the line balancing algorithm. During straight line production each operator uses only one machine. The objective of model formulation or development is to determine which components of the system should be included in the model and how the model should flow to imitate the real system.

The model development was started with the declaration of the entity, the location of the workstations, generating path network and resources, declaration of the arrival and processing programming.

Logic flow describes the way by which the entity acts during its journey in the simulation model. It was easy to observe the route the entity follows during the model building stage. The animation part of the Arena was very helpful in ensuring that everything works as desired.

The following assumptions are used to develop the simulation model.

- The assembly line is never starved; continuous supply of material, there is no fabric loss since all cut panel bundles will ready in advance before production started.
- Set-up times/warming period are not taken into consideration. Because in a real system the setup process in garment manufacturing usually accomplished at the beginning in trial production (up to 50 pieces) in advance before production started date.
- 480-minute working time does not include lunch breaks. (lunch break for 30 minutes)
- No maintenance process is performed during the working period, Machines and energy (i.e. electric power) are available at all times.
- All process times for sewing operations includes 'insignificant breakdowns' like the detachment of sewing thread.
- Considering some unanticipated circumstances for example the machine may stack or fail for a while, the worker may take more time in repositioning the work piece,
- The operator works without interruption; the operator's performance stays constant throughout the entire process time. Breaks due to fatigue or personal issues are omitted.
- Transportation of raw materials is performed by workers who aren't used for sewing operations.
- No change in the product model and style: The product stays exactly the same during the whole production process. Also, material and trimmings as well as accessories do not change.
- Trouser main assembly line and the component production lines (preparatory section) considered separately.
- Small components preparation process of small loop preparation, waist band fusing and preparation not considered, its observed there is no problem occurred due to this operation.
- The existing factory quality rejection rate of 15 % considered in model development.

4.6.1 Trouser Assembly Line Model

This layout, the individual parts are made and sub assembled in preparatory sections and these parts are then moved to the assembly section. In the assembly section, parts are assembled to shape a final garment. There is quality check in lines and in end of each section to avoid defective parts and improve the quality of the product. WIP movement of sub assembled parts in each section made with the help of the long table along with machines and helpers.
Due to Arena training or evaluation version limitation on entity, it's difficult to develop model for both preparatory and assembly section at a time. Therefore, for this thesis simulation modeling of trouser assembly line developed for preparatory section and assembly section separately. Cutting section, preparation of non-value-added parts like waist band preparation and fusing, final finishing and packing are not considered on this model.

Preparatory section line simulation model for existing manufacturing system

Preparatory and assembly line simulation model for existing system shown below in ***Fig 4.6*** and ***Fig 4.7.***

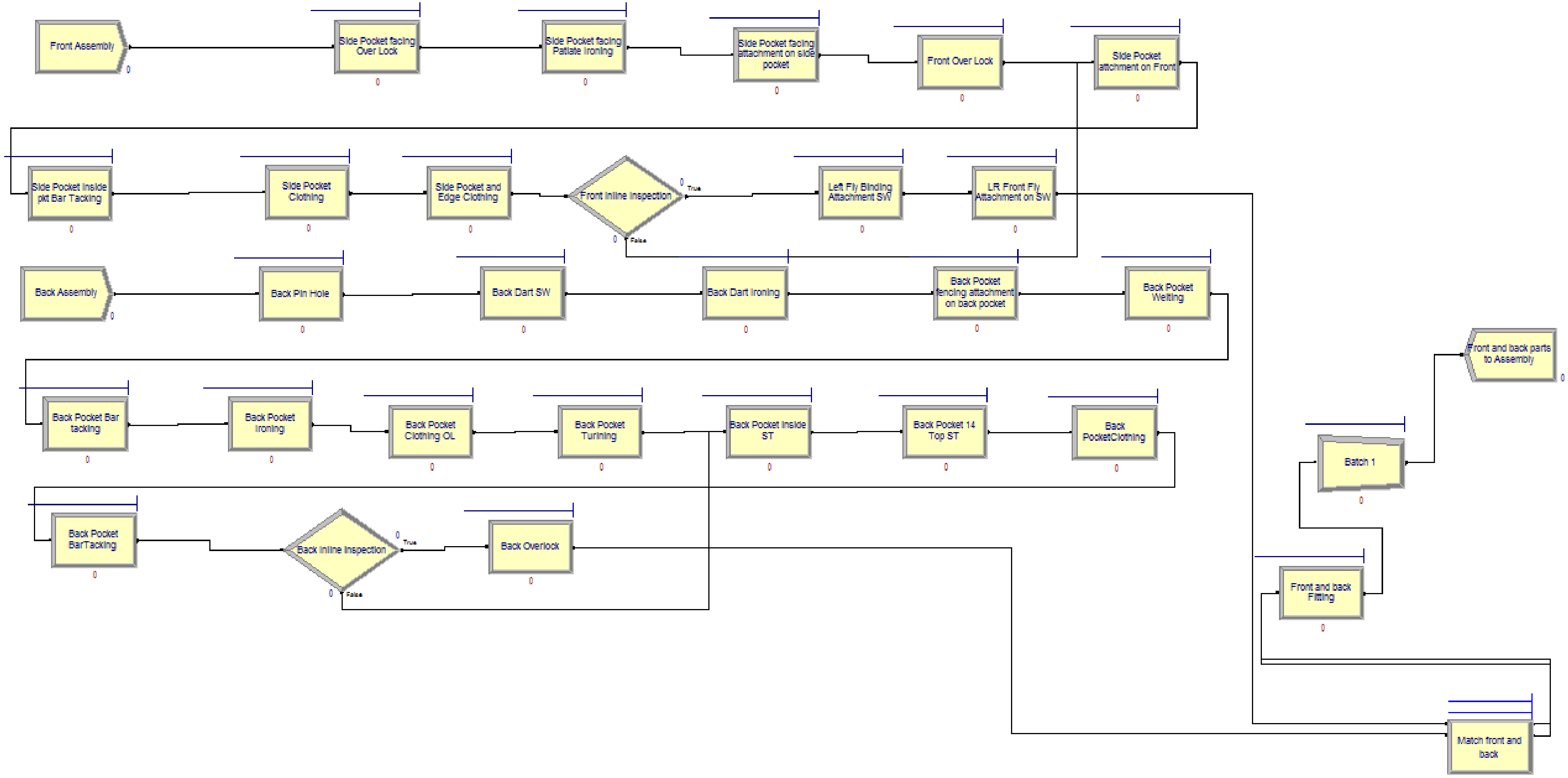

Fig. 4.6: - Preparatory section line simulation model for existing manufacturing system

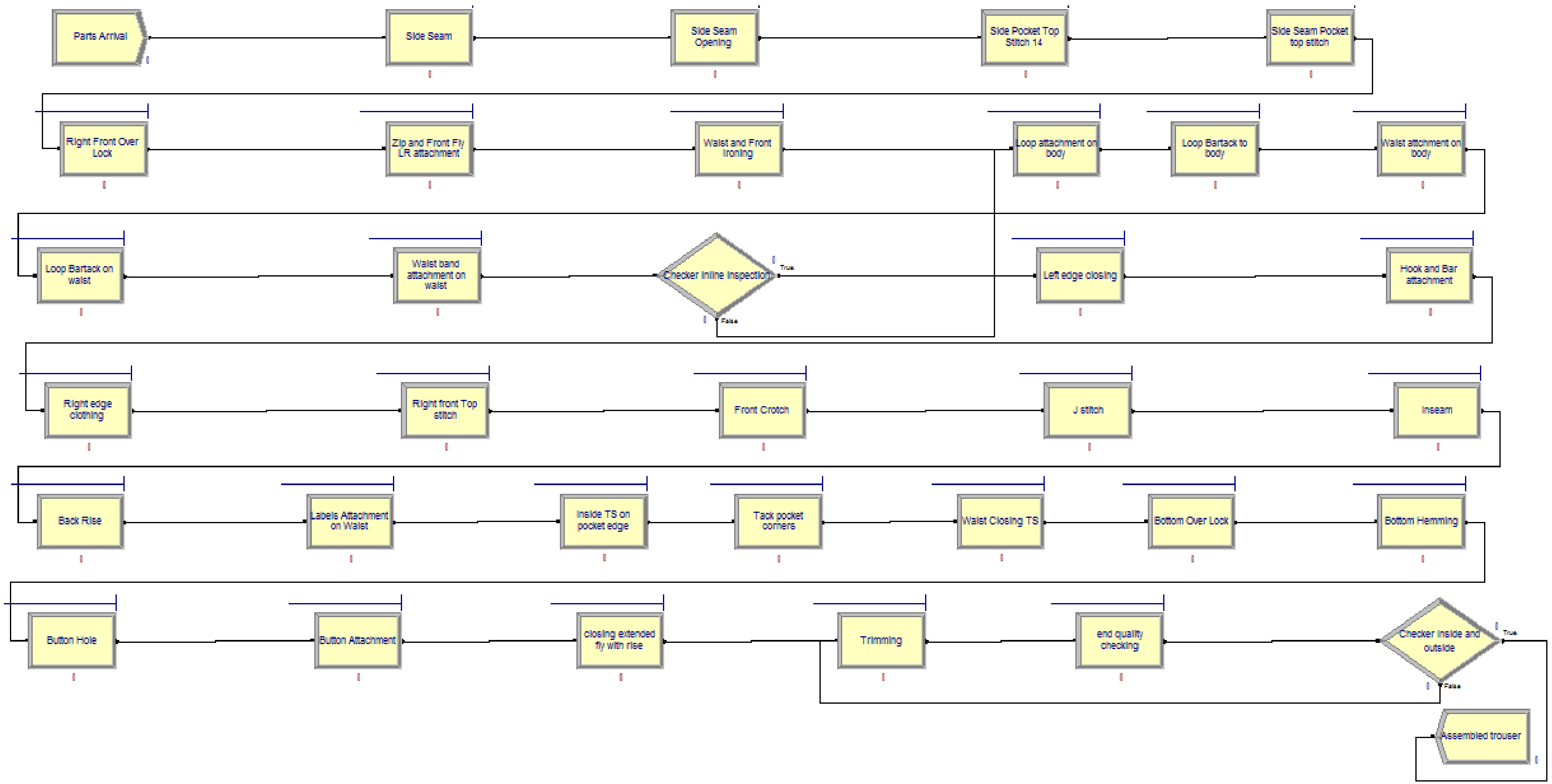

Fig. 4.6 Assembly section line simulation model for existing manufacturing system

4.7 Model Verification and Validation

One of the most important steps of simulation modelling is validation and verification. If the model does not reflect the real system, outputs of the model has a bad effect on the reliability and quality of the decision that will be made. Therefore, in order for this model to correctly reflect the production line behavior, it is verified and validated.

4.7.1 Model Verification

During test run model working smoothly without any errors or warnings under different settings of the inputs by altering the arrival times. The animation of the processes observed; the path was correct. It can be said this model verified and represent the real system.

4.7.2 Model Validation

To validate the model reliability by comparing the output of the real system and the model output of the existing system, a test run with 10 replications was done and the output value checked. The output of the real system varies from 220 -260 pcs/shift. The average output is 250 pcs for assembly section and 235 for preparatory section. The model test run with 10 replications showed an output value of 234 pcs for preparatory section and 247 pcs for assembly section. Thus, the output value according to the model is realistic value. The test run was operating without problems; hence, the production line in the model run smoothly without interruptions. The assumption was made that the model is a realistic approach to the data basis of each operations. It can be said this model represents the real system and is said to be verified and validated. The decision made to use the model as basis of further analysis and propose productivity improvement model.

4.7.3. Calculation of replication number

In order to determine the number of replications, first the mean and standard deviation of the first ten replication calculated for preparation and assembly lines then standard error of the data calculated using ***Eqn 4.1***. (Nahom,2011)

$$Standard\ Error = t_1 - \frac{\alpha}{2}, \frac{(n-1)*s}{\sqrt{n}} \quad \text{……………………………}Eqn.\ 4.1$$

Where,

- t = t probability distribution value for 1- α/2 from table
- n-1 degrees of freedom
- s = standard deviation of the replication means
- n = number of observations in the sample

The standard error is essentially the amount of dispersion around the mean value that data may exhibit. The first term t comes from the t probability distribution table, the t value depends on two parameters, the α level and the number of degrees of freedom. The α level has to do with the level of confidence, for 95% confidence level the α level is 1 minus the confidence level, or 0.05.

$$s = \sqrt{\frac{\sum_1^n x_i - x}{n-1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eqn. 4.2$$

Where,

- s = standard deviation of sample
- xi bar = the replication average
- x bar = average of the replication averages
- n = number of replications

Considering the first 10 replications, the standard deviation and half width value shown below on ***table 4.5***.

Table 4.5: - Mean standard deviation and half width for initial 10 replication

Number of replications	**Preparatory**	**Assembly**
1	233	240
2	235	240
3	237	248
4	238	245
5	237	251
6	235	249
7	233	252
8	232	252
9	232	251
10	233	249

Mean	**234.5**	**247.7**
Half width	**1.58**	**3.27**
Standard Deviation	**2.22**	**4.57**

Standard deviation measures the amount of variability or dispersion of the replication results from the mean. The half width statistic is used to help in determining the reliability of the results from the replication. In other word half width is a sampling error introduced in taking sample. Therefore, the value of half width can be simply determined by using the standard error. Considering a 95% confidence level the value of t can be read from t probability distribution table, hence t (at 95%,9) = 2.262. Half width of preparatory section=2.262*2.22/√10=1.58 and similarly for assembly section calculated and half width is 3.27.

To achieve specific half width h, presumably smaller than the one in the initial set of 10 replications, h equal to the half-width formula above and solved for n.

$$n = t^2_{1-\alpha/2,\, n-1} * s^2/h^2 \,.$$

The difficulty is that it may not solved for n since the right-hand side still depends on n. However, to get at least a rough approximation to the sample size required, the t probability distribution value replaced in the formula above with the standard normal probability distribution value. This led to the following as an approximate required sample size to achieve a confidence interval with a half width equal to a pre-specified desired value h:

$$n \cong z^2_{1-\alpha/2} \frac{s^2}{h^2} \,.$$

Where s is sample standard deviation from initial set of n replications. The above equation can further be approximated as:

$$n \cong n_0 \frac{h_0^{\,2}}{h^2} \,.$$

Where,

- n_o is the number of initial replications we had and ho is the half width. If error level from the initial sample of 10 replications is not quite satisfying, the initial half width can be reduced thus greater precision level can be achieved.

Assume half width for preparatory section to be 0.79 and for assembly line to be 1.635, and taking the value of Z at 95% confidence level to be 1.96 form z table then the number of replications for each line became:

1.962*2.222/0.792 = approximately 31 replications (preparatory section first approximation) and

102*1.582/0.792 = 40 preparatory section second approximation.

Similarly, for assembly line section calculated with same result of 30 and 40 replications. Therefore 40 replications are taken for both lines which would give low acceptable error level.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1 Simulation Model Results and Analysis

5.1.1 Introduction

Output analysis is the examination of data generated by a simulation model. Its purpose is to predict the performance of a system or to compare the performance of two or more alternative system designs. Output analysis also predicts the initial model performance and look after the weaknesses therefore are able to overcome the problems occurred in initial model. The output results gathered from the simulation model generated report, the confidence interval defined for the values is set to 95%.

The objective of this thesis is to improve the productivity of the garment production lines through line balancing, the output of the simulation model for the existing preparatory and assembly lines analyzed to propose different scenarios for productivity improvement through line balancing.

Based on the simulation model results /report with 40 replications the output, WIP values, Capacity utilization, productivity per operator, Number of operator/resources, lead time, waiting time in queue, takt time and make span discussed as below.

Table 5.1: - Existing Manufacturing system simulation model results

Section		Input	Average production Output	WIP	Total time in minute	Total no of resource	Productivity /operator
Preparatory section	**Assorted Front and Back**	238.43	238	0	35.2004	37	6.43
	Back Parts	254.55	238	13.3616			
	Front parts	254.33	238	13.8459			
Body assembly section	**Assembled trousers**	282.55	253	26.9981	48.0194	59	4.29

Output: Preparatory section consists two entities back part and front part, the output value seemed similar for both back and front parts, but the trouser assembly section shows 253 pcs which is 15 pcs more than the preparatory section. The assembly section getting the inputs from preparatory section; preparatory section average output less by 15 pcs. Comparing the output values of each section it was observed that the output of assembly section might be limited due to 15 pcs less production in preparation section. As a result of this WIP of the lines moved to the subsequent day production which may affect the overall production plan of the coming days. In other word, the output of the two assembly line sections not balanced.

Average makespan: for preparatory section 35 minute and for assembly line 48 minute. The total average makes span of both sections 48+35=83 min (1.38 hour)

Takt time: The calculation of Takt time is based on the production quantity per day and on the standard working time of operation.

Takt time (min) = Working min/daily production. Factory planned production is 300 pcs/day. Takt time for both assembly section planned to be 480 min/300 =1.6 min. That means every 1.6 min one unit needs to be produced. The Takt time needs to be adapted to the output targets per time. On the real system by considering the average output of both sections an average takt time is 1.96 min which is far from the factory plan. To fulfill the planned output quantity, the operational time at each operation for the production of one unit shall be equal to takt time. If the cycle times of the operations are equal to Takt time, the production runs smoothly, if not the line needs to be balanced.

Productivity per operator: Another scenario to show that productivity is low and line is not balanced, in above table 5.1 it's shown that productivity per operator for preparatory section 6.43 and assembly section 4.29 min which is lower compared to planned productivity 7.18 for both sections. For entire production system (both sections) factory planned productivity per operator is 7.18pcs. On the real system overall productivity per operator is 2.55 pcs which is very less.

Lead time: Buyer gives a minimum order qty of 15000 pcs per line trousers within 8 weeks production time, buyer expecting an average of 1875 pcs per line to be produced in a week. But on the existing system production average output per week is 1391 pcs. (5.5 days per week considered as per factory working days). therefore, with current scenario factory delivering the goods with an average of 10.8 weeks per minimum order qty.

Resource Capacity utilization: In the existing manufacturing system, the capacity utilization of preparatory section summarized on ***table 5.2***.

Table 5.2: - Instantaneous capacity utilization of existing preparatory section line

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bar Tack for side pocket inside pkt	0.5065	0.0	0.4556	0.5823	0.00	1.0000
Bartack for back pkt tacking 2	0.5779	0.0	0.4977	0.6684	0.00	1.0000
Bartack for back pocket 1	0.6997	0.0	0.6003	0.7885	0.00	1.0000
Dart machine	0.3262	0.0	0.2788	0.3689	0.00	1.0000
Iron for back dart	0.5784	0.0	0.4954	0.6502	0.00	1.0000
Iron for back pocket	0.5074	0.0	0.4341	0.5711	0.00	1.0000
Iron Table Side Pocket Facing	0.2945	0.0	0.2642	0.3329	0.00	1.0000
OL for back Overlock	0.2267	0.0	0.1937	0.2560	0.00	1.0000
OL for back pkt closing	0.4001	0.0	0.3437	0.4529	0.00	1.0000
OL for Front Over Lock	0.5258	0.0	0.4768	0.5889	0.00	1.0000
OL for pocket and edge closing	0.4845	0.0	0.4352	0.5601	0.00	1.0000
OL for side pocket closing	0.3188	0.0	0.2867	0.3680	0.00	1.0000
OL for side pocket facing	0.1148	0.0	0.1042	0.1300	0.00	1.0000
Pressing for back pocket turning	0.1978	0.0	0.1684	0.2232	0.00	1.0000
SNL back pocket insideST	0.6309	0.0	0.5405	0.7267	0.00	1.0000
SNL for back pkt attach on back pkt	0.4594	0.0	0.3939	0.5183	0.00	1.0000
SNL for back pocket closing	0.6176	0.0	0.5322	0.7134	0.00	1.0000
SNL for back pocket top ST14	0.3050	0.0	0.2621	0.3519	0.00	1.0000
SNL for Left fly Binding	0.4314	0.0	0.3878	0.4850	0.00	1.0000
SNL for LR front fly attachment	0.2782	0.0	0.2513	0.3122	0.00	1.0000
SNL for side pocket facing	0.2570	0.0	0.2327	0.2896	0.00	1.0000
SNL for Side Pocket attachment on Front	0.3414	0.0	0.3086	0.3943	0.00	1.0000
Table for backpin	0.5240	0.0	0.4451	0.5920	0.00	1.0000
Welt for back pocket	0.2567	0.0	0.2186	0.2893	0.00	1.0000
Work table for Fit	0.7498	0.0	0.6577	0.8478	0.00	1.0000

In the existing manufacturing system, the capacity utilization of assembly section summarized on ***table 5.3***.

Table 5.3: - Instantaneous capacity utilization of existing assembly section line

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bartack for Loop to body	0.2871	0.0	0.2582	0.3201	0.00	1.0000
Bartack for loop to waist	0.5056	0.0	0.4567	0.5631	0.00	1.0000
Blind stich machine	0.3807	0.0	0.3445	0.4270	0.00	1.0000
Eyelet button hole	0.4010	0.0	0.3663	0.4486	0.00	1.0000
Hook and Bar attcher	0.5053	0.0	0.4591	0.5589	0.00	1.0000
Iron for waist and front	0.4259	0.0	0.3900	0.4722	0.00	1.0000
Machine for button attach	0.4748	0.0	0.4324	0.5285	0.00	1.0000
OL Bottom overlock	0.2667	0.0	0.2420	0.2977	0.00	1.0000
OL for Right front	0.1492	0.0	0.1368	0.1655	0.00	0.5000
Open Seam machine	0.3929	0.0	0.3594	0.4417	0.00	1.0000
QC table for Inspection	0.3568	0.0	0.3114	0.4157	0.00	1.0000
SN chain stich back rise	0.4172	0.0	0.3786	0.4635	0.00	1.0000
SN chain stich for Inseam	0.3858	0.0	0.3473	0.4272	0.00	1.0000
SN Chain stich for Side Seam	0.3850	0.0	0.3526	0.4344	0.00	1.0000
SNL for closing extended fly	0.4839	0.0	0.4408	0.5375	0.00	1.0000
SNL for front crotch	0.2498	0.0	0.2265	0.2782	0.00	1.0000
SNL for Inside TS	0.3822	0.0	0.3467	0.4249	0.00	1.0000
SNL for J stitch	0.2524	0.0	0.2294	0.2819	0.00	1.0000
SNL for Labels	0.3452	0.0	0.3124	0.3839	0.00	1.0000
SNL for left edge closing	0.2358	0.0	0.2129	0.2602	0.00	1.0000
SNL for loop to body	0.4228	0.0	0.3791	0.4707	0.00	1.0000
SNL for right edge closing	0.4611	0.0	0.4190	0.5110	0.00	1.0000
SNL for right front TS	0.4598	0.0	0.4174	0.5093	0.00	1.0000
SNL for side pkt TS 14	0.4464	0.0	0.4071	0.5002	0.00	1.0000
SNL for side seam pkt TS	0.8932	0.0	0.8217	0.9889	0.00	1.0000
SNL for tack pocket corners	0.6107	0.0	0.5541	0.6791	0.00	1.0000
SNL for waist band to waist att	0.3825	0.0	0.3459	0.4259	0.00	0.6667
SNL for waist close TS	0.5545	0.0	0.5045	0.6173	0.00	1.0000
SNL for waist to body	0.6354	0.0	0.5715	0.7088	0.00	1.0000
SNL for Zip	0.2228	0.0	0.2035	0.2461	0.00	0.3333
Table for Trimming	0.3104	0.0	0.2710	0.3605	0.00	1.0000

From ***table 5.2 and 5.3*** it can be seen that for preparatory section the OL for side pocket facing has 11.5% utilization (lowest) whereas Work table for Fit has 74.98 % utilization (highest). And for assembly section OL for right front has 14.92% utilization (low) and SNL for side seam pkt TS 89.32% utilization (highest).

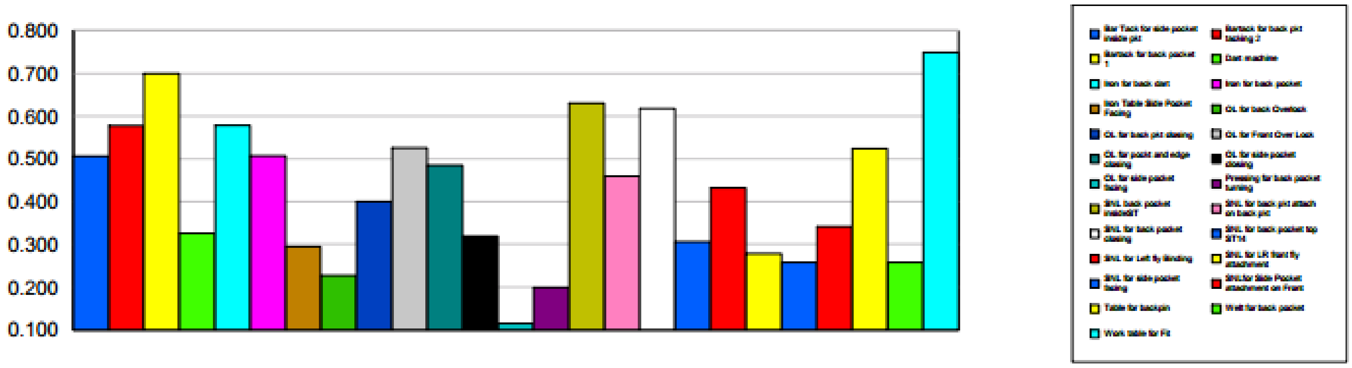

Fig. 5.1: - Instantaneous capacity utilization of existing Preparatory section

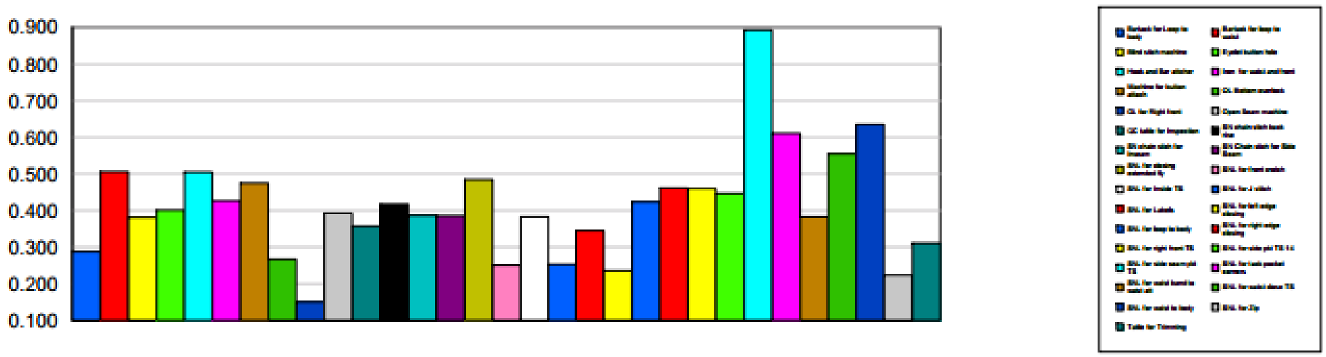

Fig. 5.1 Instantaneous capacity utilization of existing assembly section

From ***fig 5.2*** for both assembly lines we can see clearly how the capacity utilization of different resources of lines is varied. This shows that the work content of both lines is not distributed uniformly among stations. In other word the lines are not balanced.

Number of waiting time

In the existing system some operations show higher number of waiting time as shown in ***table 5.4***.

Table 5.4: - Number of waiting time for existing manufacturing system

Section	Station queue	waiting time	Number waiting
Preparatory section	Front and back Fitting	1.7541	1.7701
	Match front and back. Queue1	11.8173	6.1431
	Match front and back. Queue2	6.0796	3.2476
Assembly Section	Side Seam Pocket Top Stitch	6.4611	3.8597

5.1.2 Alternative Model Development

The proposed productivity improvement model built based on the existing system model problems that have been identified in the simulation model analysis of the existing line which already discussed on data analysis section. To build the proposed model different analysis and decision-making are used on the existing system. In order to balance the production lines for both assembly section below three alternative models were proposed.

1. Avoiding unnecessary duplication resource from processes with low capacity utilization
2. Changing level of resource at stations with higher number waiting
3. Merge operations by enhancing the operator skill and decreasing the processing time operation

Scenario 1. Avoiding unnecessary duplication resource from processes with low capacity utilization

For both preparatory and assembly lines it is shown that most of the resource's utilization is below 50%, even Some stations/process have multiple resources but their utilization is still below 50% which shows unnecessary duplication of resources exist which do not add value to the final product. Therefore, these unnecessary duplication resources should be deducted from the line. The operations and their respective capacity utilization and resources presented in ***table 5.5*** and ***table 5.6***

Preparatory section with duplicated resources

Total number of 9 resource capacity deducted from preparatory section, number of operators and machines reduced from 37 to 28.

Table 5.5: - Preparatory section duplicated resources

Resource	Exiting Model		Proposed 1&2 Model		
	Instantaneous utilization	Scheduled Capacity	Instantaneous utilization	no of deducted capacity	Resource usage
Dart machine	0.3262	2	0.6512	1	1
Iron Table Side Pocket Facing	0.2945	2	0.5796	1	1
OL for back Over lock	0.2267	2	0.453	1	1
OL for side pocket closing	0.3188	2	0.6268	1	1

Pressing for back pocket turning	0.1978	2	0.3969	1	1
SNL for back pocket top ST14	0.305	2	0.615	1	1
SNL for LR front fly attachment	0.2782	2	0.5484	1	1
SNL for Side Pocket attachment on Front	0.3414	3	0.5038	2	1
Welt for back pocket	0.2567	2	0.5139	1	1
Total		19		10	9

Assembly section with duplicated resources

Total number of 17 resource capacity deducted from assembly section, no of operators and machines reduced from 59 to 42.

Table 5.6: - Assembly section duplicated resources

Resource	Exiting Model		Proposed 1&2 Model		
	Instantaneous utilization	Scheduled Capacity	Instantaneous utilization	Resource usage	no of deducted capacity
Bartack for Loop to body	0.2871	2	0.5975	1	1
Blind stich machine	0.3807	2	0.7906	1	1
OL Bottom overlock	0.2667	2	0.5539	1	1
OL for Right front	0.1492	2	0.3121	1	1
Open Seam machine	0.3929	3	0.6049	2	1
QC table for Inspection	0.3568	2	0.7348	1	1
SN Chain stich for Side Seam	0.385	3	0.5925	2	1
SNL for front crotch	0.2498	2	0.5222	1	1
SNL for Inside TS	0.3822	2	0.7923	1	1
SNL for J stitch	0.2524	2	0.5267	1	1
SNL for Labels	0.3452	2	0.7190	1	1
SNL for left edge closing	0.2358	2	0.4923	1	1
SNL for loop to body	0.4228	3	0.6597	2	1
SNL for waist band to waist att	0.3825	3	0.5975	2	1
SNL for Zip	0.2228	3	0.6972	1	2
Table for Trimming	0.3104	2	0.6394	1	1
		37		20	17

Scenario 2 Changing level of Resource at stations with higher number waiting

Assembly section has one operation with high number of waiting, Side seam pocket top stich the number of resource capacity allocated for this operation is one in the existing line, by doing resource trial and errors in the simulation, one capacity is added for this operation to propose the model scenario.

Table 5.7: - Assembly section added resource for scenario two

Resource Usage	Exiting Model		Proposed 1&2 Model		
	Instantaneous utilization	Scheduled Capacity	Instantaneous utilization	Resource usage	no of added capacity
SNL for side seam pkt TS	0.8932	1	0.4668	2	1

By adding the deducted resources from scenario 1 and added resource of scenario 2, a total of 16 resources deducted. Total number of resources for preparatory section reduced to 28 and for assembly section to 43.

There are some operations with small waiting number in preparatory section, as per the trial and err adding there is no any significant input to add resources for this operation. Number waiting is not considered for preparatory section, since less entities was waiting.

By combining both alternative scenarios (1&2) simulation model for preparatory and assembly section developed with 40 replications after validating the model. The results analyzed in following ***table 5.8*** for both sections.

Table 5.8: - Scenario 1 and 2 proposed manufacturing system simulation model results

Section		Input	Output	WIP	Total time in minute	No of Resource/operators	Productivity /operator
Preparatory section	**Assorted Front and Back**	235.85	236	0	35.4406	28	8.43
	Back Parts	254.1	238	14.3455			
	Front parts	254.33	238	13.0663			
Body assembly section	**Assembled trousers**	289.88	261	26.7961	46.4329	43	6.07

Output: Preparatory section output decreased to 236 from existing 238pcs and for assembly section increased to 261 from 253 pcs of the existing system.

Average makespan: For preparatory section 35.4406 minute which is a bit higher from the existing 35.2004 minute and for assembly line 46.4329 minute which is less from the existing 48.0194 minute. The total makespan for both lines reduced to 81.88 minutes from 83 minutes of the existing system.

Takt time: reduced to 1.93 minute from 1.96 minute of the existing manufacturing system, compared to the factory plan 1.6 minute still its higher.

Work in process: WIP for back part is 14.3455 which is higher from 13.3616 of the existing system and for front part 13.0663 which is almost similar to existing system 13.3616. for assembly line almost same as the existing system.

Productivity per operator: for preparation section improved to 8.43 from 6.43 of the existing system and for assembly section Productivity per operator improved to 6.07 from 4.23 of the existing system. Even if the output a bit less for preparatory section productivity is improved. In other word, the distribution of work content among operations is improved.

Leadtime: due to the improvement in productivity per operator and out put the lead time reduced to 10.44 weeks from existing 10.8 weeks.

In general, with Scenario 1 and 2 proposed model a total of 26 operators and machines reduced from the existing system, with increase of the assembly line output and with 2 output reduction of the preparatory section. By considering cost efficiency this reduction of operators and machines, will help to setup other lines for different product or for same product by adding the remaining resource to fulfill as one line.

Number waiting

As seen in the ***table 5.9*** waiting time reduced for both sections.

Table 5.9: -Scenario 1 and 2 proposed model number waiting

		Existing Model		Scenario 1 and 2	
Section	**Station queue**	**waiting time**	**Number waiting**	**waiting time**	**Number waiting**
Preparatory section	**Front and back Fitting**	1.7541	1.7701	1.5277	1.5251
	Match front and back. Queue1	11.8173	6.1431	10.0401	5.3094
	Match front and back. Queue2	6.0796	3.2476	8.0897	4.3663
Assembly Section	**Side Seam Pocket Top Stich**	6.4611	3.8597	0.00001724	0.00001013

However, during running the model with scenario1 and 2, another operation for assembly section exposed to more waiting time and number ***table 5.10***.

Table 5.10: -Scenario 1 and 2 assembly section operation with more number waiting

		Existing Model		Scenario 1 and 2	
Section	**Station queue**	**waiting time**	**Number waiting**	**waiting time**	**Number waiting**
Assembly Section	**Inside TS on pocket Edge**	0.00	0.00	1.49	0.8636

Number waiting of inside TS on pocket edge operation and further improvement on queue of the operation in preparatory section will improve on scenario 3 by enhancing the skill of the operator.

Resource Capacity utilization:

For both preparatory and assembly lines due to the proposed model most of the resources capacity utilization increased on average (Annex E, F).

As shown on table ***5.11 and 5.12*** some operations capacity utilization seen below 50% after proposed model of scenario 1 and 2 which needs further improvement.

Table 5.11: - Scenario 1 and 2 preparatory section resources with below 50% instantaneous capacity utilization

Resource	Exiting		Proposed 1&2	
	Instantaneous utilization	**Number of capacity**	**Instantaneous utilization**	**Number of capacity**
Bar Tack for side pocket inside pkt	0.5065	1	0.4984	1
OL for back Overlock	0.2267	2	0.453	1
OL for back pkt closing	0.4001	1	0.4019	1
OL for pocket and edge closing	0.4845	2	0.4764	2
OL for side pocket facing	0.1148	1	0.1132	1
Pressing for back pocket turning	0.1978	2	0.3969	1
SNL for back pkt attach on back pkt	0.4594	1	0.4595	1
SNL for Left fly Binding	0.4314	1	0.4256	1
SNL for side pocket facing	0.257	2	0.2535	2
		13		**11**

Table 5.12: - Scenario 1 and 2 assembly section resources with below 50% instantaneous capacity utilization

Resource	Exiting		Proposed 1&2	
	Instantaneous utilization	**Number of capacities**	**Instantaneous utilization**	**Number of capacities**
Eyelet button hole	0.4010	1	0.4157	1
Iron for waist and front	0.4259	1	0.4441	1
Machine for button attach	0.4748	1	0.4920	1
OL for Right front	0.1492	2	0.3121	1
SN chain stich back rise	0.4172	2	0.4353	2
SN chain stich for Inseam	0.3858	2	0.4025	2
SNL for left edge closing	0.2358	2	0.4923	1
SNL for right edge closing	0.4611	2	0.4812	2
SNL for right front TS	0.4598	2	0.4800	2
SNL for side pkt TS 14	0.4464	2	0.4586	2
SNL for side seam pkt TS	0.8932	1	0.4668	2
		18		**17**

Scenario 3 Merge operations by enhancing the operator skill and decreasing the processing time operation

The approach of scenario 3 based on the data analysis of scenario 1and 2 to improve further the results. For both preparation and assembly process some consecutive operations have low capacity utilizations. Resource level merged and varied by trial and error to see whether the utilization improved or not. For some few specific operations to handle two or more operations by one operator training needs to be consider to improve the productivity of the operator. Assuming that training is given and operator capable to work in two or more operations. For both preparation and assembly section consecutive operation with same type of resource (machines) merge made and listed in ***Table 5.13***.

Table 5.13: -Operations with same resource type that can be merged

<table>
<tr><th>Section</th><th>Operation</th><th>Resource</th><th>Scheduled Capacity</th><th>Average instantaneous utilization</th><th>Deducted capacity</th><th>Proposed capacity</th></tr>
<tr><td rowspan="2">Preparatory section</td><td>Left Fly Binding Attachment SW</td><td>SNL for Left fly Binding</td><td>1</td><td>0.4256</td><td rowspan="2">1</td><td rowspan="2">1</td></tr>
<tr><td>LR Front Fly Attachment on SW</td><td>SNL for LR front fly attachment</td><td>1</td><td>0.5484</td></tr>
<tr><td rowspan="4">Assembly Section</td><td>Side pocket top stitch 14</td><td>SNL for side pkt TS 14</td><td>2</td><td>0.4586</td><td rowspan="2">2</td><td rowspan="2">2</td></tr>
<tr><td>Side seam pocket top stitch</td><td>SNL for side seam pkt TS</td><td>2</td><td>0.4668</td></tr>
<tr><td>Right edge clothing</td><td>SNL for right edge closing</td><td>2</td><td>0.4812</td><td rowspan="2">2</td><td rowspan="2">2</td></tr>
<tr><td>Right front Top stitch</td><td>SNL for right front TS</td><td>2</td><td>0.48</td></tr>
</table>

After merging the operations to maximize the capacity utilization of Side Pocket facing attachment in preparatory section one resource capacity deducted, similarly for assembly section by assuming after training the processing time for back rise operation minimized to 1.33 minute, one resource capacity deducted and shown in ***Table 5.14***.

Table 5.14: - Preparatory and assembly section duplicated resources for scenario 3

Section	Operation	Resource	Scheduled Capacity	Average instantaneous utilization	Deducted capacity	Proposed capacity
Preparatory section	Side Pocket facing attachment on side pocket	SNL for side pocket facing	2	0.2535	1	1
Assembly Section	Back rise	SN chain stich back rise	2	0.4353	1	1

To reduce the no of waiting in preparatory section shown listed in scenario 1 and 2 proposed model by further investigating one capacity resource added to front and back fitting operation shown in ***Table 5.15***.

Table 5.15: - Preparatory section added resources for scenario 3

Section	Operation	Resource	Scheduled Capacity	Average instantaneous utilization	Added Capacity	Proposed capacity
Preparatory section	Front and back fitting	Work table for fit	1	0.7417	1	2

In scenario 3 the total number of resources for preparatory deducted to 27 and for assembly section to 38.

Table 5.16: -Operations with low capacity utilization for scenario 3

Section	Operation	Resource	Exiting		Proposed 1 and 2	
			Instantaneous utilization	Number of capacity	Instantaneous utilization	Number of capacity
Preparation	Side Pocket facing Over Lock	OL for side pocket facing	0.1148	1	0.1132	1
	Side Pocket facing Patlate Ironing	Iron Table Side Pocket Facing	0.2945	2	0.5796	1
	Back Pin Hole	Table for back pin	0.524	1	0.5229	1
	Back Dart SW	Dart machine	0.3262	2	0.6512	1
Assembly	Side Seam	SN Chain stich for Side Seam	0.385	3	0.5925	2
	Side Seam Opening	Open Seam machine	0.3929	3	0.6049	2

Comparatively in the existing model the first operations in both sections shows less utilization due to low capacity loading of the entities ***table 5.16***. The inter arrival time of each entity changed after proved by repetition that using less time for the inter arrivals not affect the production process and the simulation model. In the existing production system, the time between arrival for both preparatory section 1.9 minute and assembly section 1.7 minute. In scenario 3 the inter arrival time reduced to 1.6 minute for both preparatory and assembly section.

By considering all above points we have the following simulation model and results for scenario 3.

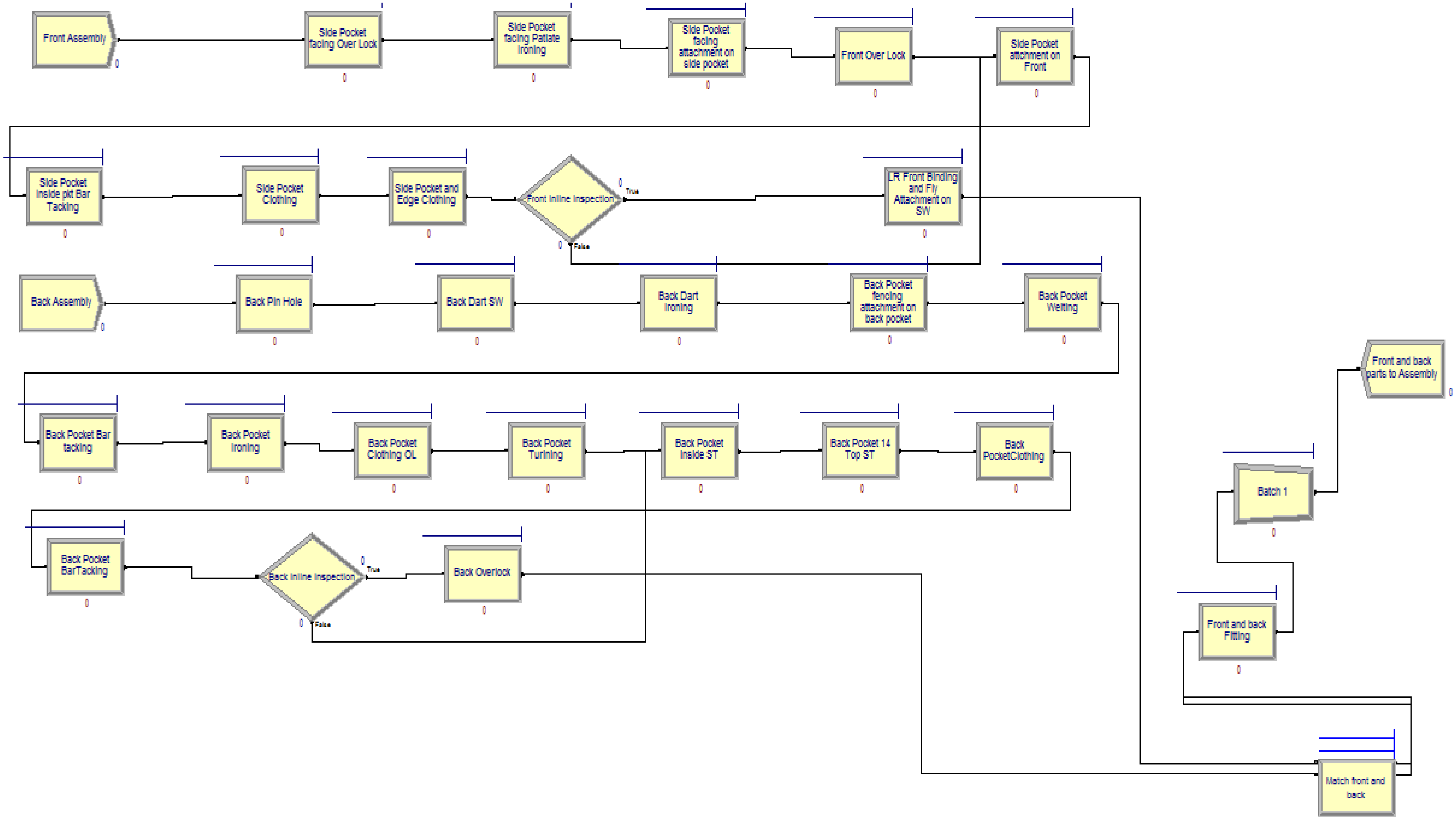

Fig. 5.3: - Proposed preparatory section simulation model for scenario 3

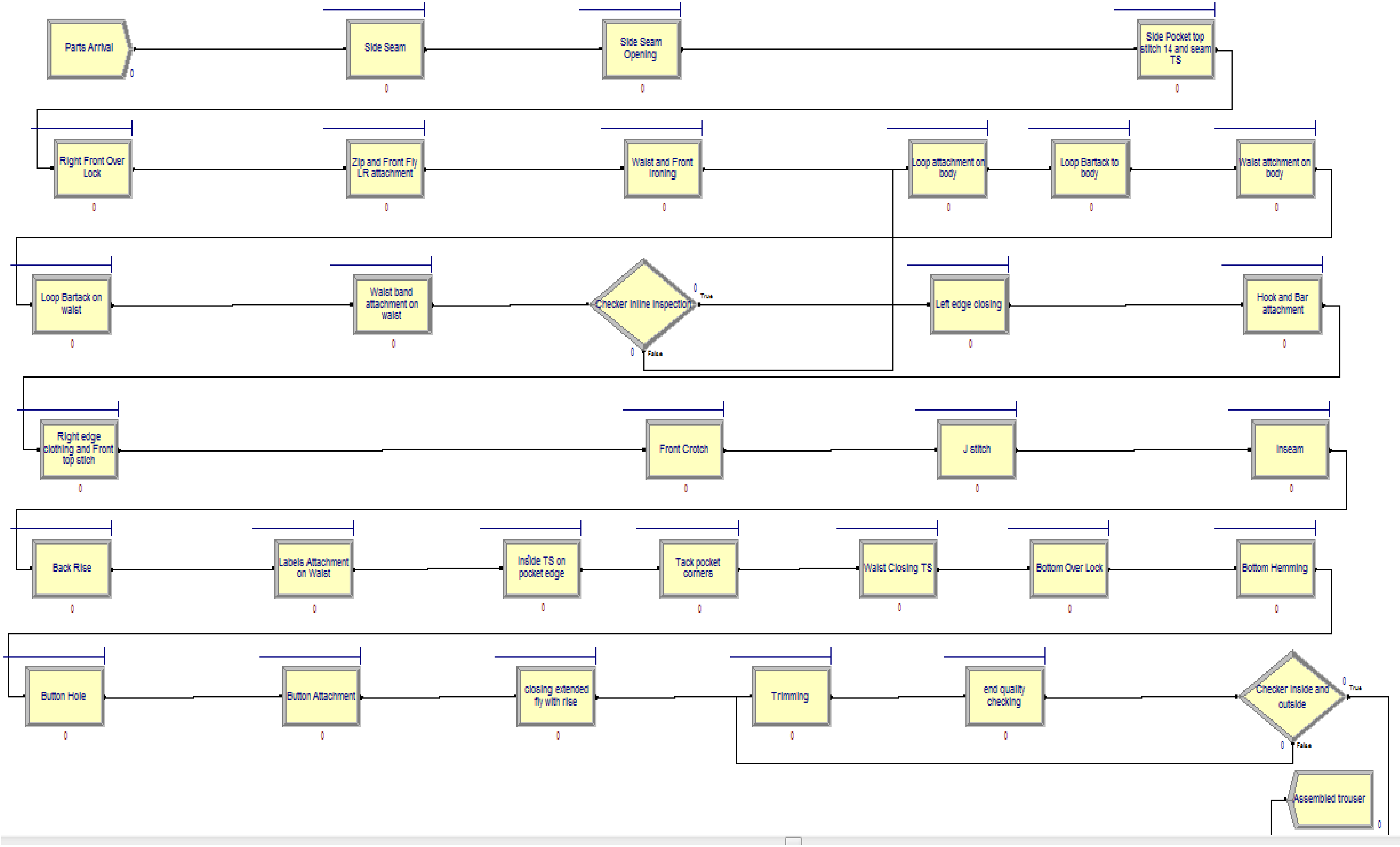

Fig. 5.4: - Proposed assembly section simulation model for scenario 3

Table 5.17: - Scenario 3 proposed manufacturing system simulation model results

Section		**Input**	**Output**	**WIP**	**Total time in minute**	**Number of Resource/operators**	**Productivity /operator**
Preparatory section	Assorted Front and Back	280.48	280	0	35.6513	27	10.37
	Back Parts	298.40	280	15.1681			
	Front parts	299.05	280	16.9305			
Body assembly section	Assembled trousers	302.98	275	26.7745	44.3720	38	7.24

Output: preparatory section output increased to 280pcs from existing 238 pcs and for assembly section increased to 275 from 253 pcs of the existing system.

The output difference between both sections reduced to 5 from 15 difference in the existing system.

Average makespan: for preparatory section 35.6513 minute which is slightly higher from the existing 35.2004. and for assembly line 44.3720 minute which is less from the existing 48.0194 minute. The total makes spun for both lines reduced to 80.802 minutes from 83 minutes of the existing system.

Takt time: reduced to 1.73 minute from 1.96 minute of the existing manufacturing system.

Work in process: WIP for back part 15.1681 which is higher from 13.3616 of the existing system and for front part 16.9305which is almost similar to existing system 13.3616.for assembly section there is no any change almost same as the existing system. As the no of output increased some increment in work process expected.

Productivity per operator: for preparation section improved to 10.37 from 6.43 of the existing system and for assembly section Productivity per operator improved to 7.24 from 4.23 of the existing system.

Even if the WIP and time span slightly higher for preparation section of productivity is improved. In other word, the distribution of work content among stations is improved. By considering the average output of both sections productivity per operator increased to 4.27 pcs from 2.55 pcs of the existing system.

Leadtime: due to the improvement in productivity per operator and out put the lead time reduced to 9 weeks from the existing system 10.8 weeks.

Number Waiting

On the simulation result of scenario 3. Waiting time for operations front and back fitting and side seam pocket top stich reduced to 0.00. On the other hand, more queues formed for some operations in preparatory section. Number waiting for this operation shown in ***Table 5.18***.

Table 5.18: - Number of waiting time for scenario 3 proposed manufacturing system

		Existing Model		**Scenario 1 and 2**		**Scenario 3**	
Section	**Station queue**	**waiting time**	**Number waiting**	**waiting time**	**Number waiting**	**waiting time**	**Number waiting**
Preparatory section	Back Dart SW.	0.00	0.00	0.5728	0.3051	1.2745	0.8025
	Back Pocket Bar tacking.	0.8568	0.4541	0.4626	0.2454	1.3075	0.8233
	Side Pocket facing Patlate ironing	0.04764189	0.02536817	0.7213	0.3803	1.2057	0.7610
Assembly Section	Back Rise.	0.00018555	0.00010119	0.00009592	0.00005571	1.7310	1.0504

Resource Capacity utilization: In scenario 3 the resource utilization increased for both assembly and preparatory sections as can be seen in ***annex G*** and ***H.***

Comparison of scenarios

The improvements of each scenario summarized in tables ***5.19 to table 5.23.***

Table 5.19: - Preparatory section scenarios comparison

Scenarios	Input			Output	WIP		Total time in minute	Number of Resource/ operators	Productivity /operator
	Front Part	Back part	Assorted Front and back		Front part	Back Part			
Existing System	254.33	254.55	238.43	238	13.8459	13.3616	35.2004	37	6.43
Scenario 1 and 2	254.33	254.1	235.85	236	13.0663	14.3455	35.4406	28	8.43
Scenario 3	299.05	298.4	280.48	280	16.9305	15.1681	35.6513	27	10.37

Table 5.20: -Assembly section scenarios comparison

Scenarios	Input	Output	WIP	Total time in minute	Number of Resource/operators	Productivity /operator
Existing System	282.55	253	26.9981	48.0194	59	4.29
Scenario 1 and 2	289.88	261	26.7961	46.4329	43	6.07
Scenario 3	302.98	275	26.7745	44.372	38	7.24

Table 5.21: -Number waiting scenarios comparison

Section	Station queue	Existing Model		Scenario 1 and 2		Scenario 3	
		waiting time	Number waiting	waiting time	Number waiting	waiting time	Number waiting
Preparatory section	**Front and back Fitting**	1.7541	1.7701	1.5277	1.5251	0	0
	Match front and back. Queue1	11.8173	6.1431	10.0401	5.3094	14.1652	8.7446
	Match front and back. Queue2	6.0796	3.2476	8.0897	4.3663	5.1403	3.2877
	Back Dart SW	0	0	0.5728	0.3051	1.2745	0.8025

	Back Pocket Bar tacking.	0.8568	0.4541	0.4626	0.2454	1.3075	0.8233
	Side Pocket facing Patlate ironing	0.04764189	0.02536817	0.7213	0.3803	1.2057	0.761
Assembly Section	**Side Seam Pocket top Stich**	6.4611	3.8597	0.00001724	0.00001013	0	0
	Back Rise.	0.00018555	0.00010119	0.00009592	0.00005571	1.731	1.0504
	Inside TS on pocket edge	0	0	1.49	0.8636	1.3427	0.8128

Table 5.22: - Preparatory section instantaneous utilization scenarios comparison

Resources	**Average Instantaneous utilization**		
	Existing System	**Scenario 1 and 2**	**Scenario 3**
Bar Tack for side pocket inside pkt	0.5065	0.4984	0.5904
Bartack for back pkt tacking 2	0.5779	0.5819	0.6835
Bartack for back pocket 1	0.6997	0.7013	0.8211
Dart machine	0.3262	0.6512	0.7642
Iron for back dart	0.5784	0.5788	0.679
Iron for back pocket	0.5074	0.5085	0.5955
Iron Table Side Pocket Facing	0.2945	0.5796	0.6907
OL for back Overlock	0.2267	0.453	0.5317
OL for back pkt closing	0.4001	0.4019	0.4691
OL for Front Over Lock	0.5258	0.5183	0.6156
OL for pocket and edge closing	0.4845	0.4764	0.5646
OL for side pocket closing	0.3188	0.6268	0.7428
OL for side pocket facing	0.1148	0.1132	0.135
Pressing for back pocket turning	0.1978	0.3969	0.4646
SNL back pocket inside ST	0.6309	0.6362	0.7464
SNL for back pkt attach on back pkt	0.4594	0.4595	0.539
SNL for back pocket closing	0.6176	0.622	0.7296
SNL for back pocket top ST14	0.305	0.615	0.7214
SNL for Left fly Binding	0.4314	0.4256	0.654
SNL for LR front fly attachment	0.2782	0.5484	0.6028
SNL for side pocket facing	0.257	0.2535	0.5969
SNL for Side Pocket attachment on Front	0.3414	0.5038	0.6144
Table for backpin	0.524	0.5229	0.6023
Welt for back pocket	0.2567	0.5139	0.4407
Work table for Fit	0.7498	0.7417	0.6577

Table 5.23: - Assembly section instantaneous utilization scenarios comparison

Resources	Average Instantaneous utilization		
	Existing System	Scenario 1 and 2	Scenario 3
Bartack for Loop to body	0.2871	0.5975	0.6251
Bartack for loop to waist	0.5056	0.5265	0.5509
Blind stich machine	0.3807	0.7906	0.8279
Eyelet button hole	0.4010	0.4157	0.4357
Hook and Bar attcher	0.5053	0.5270	0.5516
Iron for waist and front	0.4259	0.4441	0.4646
Machine for button	0.4748	0.4920	0.5159
OL Bottom overlock	0.2667	0.5539	0.5805
OL for Right front	0.1492	0.3121	0.3261
Open Seam machine	0.3929	0.6049	0.6311
QC table for Inspection	0.3568	0.7348	0.7715
SN chain stich back rise	0.4172	0.4353	0.7939
SN chain stich for Inseam	0.3858	0.4025	0.4231
SN Chain stich for Side	0.3850	0.5925	0.6183
SNL for closing extended	0.4839	0.5018	0.5264
SNL for front crotch	0.2498	0.5222	0.5480
SNL for Inside TS	0.3822	0.7923	0.8314
SNL for J stitch	0.2524	0.5267	0.5534
SNL for Labels	0.3452	0.7190	0.7528
SNL for left edge closing	0.2358	0.4923	0.5141
SNL for loop to body	0.4228	0.6597	0.6906
SNL for right edge	0.4611	0.4812	0.5031
SNL for right front TS	0.4598	0.4800	
SNL for side pkt TS 14	0.4464	0.4586	
SNL for side seam pkt TS	0.8932	0.4668	0.4882
SNL for tack pocket	0.6107	0.6331	0.6642
SNL for waist band to	0.3825	0.5975	0.6249
SNL for waist close TS	0.5545	0.5751	0.6029
SNL for waist to body	0.6354	0.6615	0.6921
SNL for Zip	0.2228	0.6972	0.7297
Table for Trimming	0.3104	0.6394	0.6716

From the above comparison tables of both sections, we can see how the different productivity improved for the proposed scenarios with respect to the existing manufacturing system. Scenario 3 gives the best productivity improvement results Hence; it is recommended that the company to take into consideration this developed scenario.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Productivity improvement is an important issue in textile and garment industry in order to stay alive in competitive fashion market. The profit earning of textile and garment products industry largely depends on productivity improvement.

This research concerned with the productivity improvement of garment manufacturing through line balancing where the case study taken for Nazareth garment SC. In order to process and meet customers demand orders on time it is crucial to know the current situation of a system. Arena simulation software used to imitate the real manufacturing system to describe a behavior of the system and to generate alternative systems for productivity improvement.

The research focused on production process of export dressed trouser line which consists two sections preparatory and assembly sections. All the necessary data collected for both sections and analyzed with the help of arena input analyzer to develop simulation model for the existing system. After verifying and validating, system runs with 40 replications to generate the simulation results report.

Based on the generated report problem areas of the existing system identified and analyzed in terms of output, work in process, capacity utilization, productivity per operator, Number of operator/resources, waiting time in queue, takt time and make span. The results predict there is a gap in balancing the production line and consecutively low productivity on the line. Output differences shown between preparatory and assembly sections, as a result of this relatively higher WIP observed in the lines. Low capacity utilization and duplicated results seen with some waiting time. The makespan, takt time and productivity per operator is low as compared to the factory plan.

In order to improve identified gaps, there are many possibilities to manipulate the existing model. This research addressed three major decision options(scenarios) to propose improved model. The first scenario is avoiding unnecessary duplication resource from processes with low capacity utilization to increase the system output and capacity utilization. The second one is changing level of resource at stations with higher number waiting. Lastly, by basing the result of scenario one and two third scenario focused on merge operations by enhancing the operator skill and decreasing the processing time operation developed.

The proposed model showed the makespan of the simulation lines for preparatory line becomes 35.6513 minute which was initially 35.2004 minute. In fact, the assembly line makespan also become 44.372 minute from 48.0194 minute. In addition, the total output of the preparatory line increased from 238 to 280 pcs per day and that of the assembly line is increased from 253 to 275 pcs per day. The output gap between the preparatory and assembly section reduced to 5 pcs which shows line is quite close to balanced. The number of resources reduced to 65 from existing 96 and capacity utilization of each section improved. Productivity per operator for preparatory and assembly section improved to 10.37 and 7.24 pcs respectively. Overall Productivity per operator improved to 4.2 pcs from existing 2.55 pcs per operator, still lower as the productivity per operator plan of the factory is 7.18 pcs.

Thus, the proposed models improve the results of identified gaps and enable to predict increase in productivity and balanced line. Still there is room for further productivity improvement which is not addressed due to time limitation for this research work.

6.2 Recommendations

Based on the results of this study the following points are recommended.

- The factory loses opportunities in capacity and resource utilizations, improving the resource allocation helps to minimize the overall cost.
- Simulation is a powerful tool to easily analyze the real manufacturing system of garment lines. Adapting this tool will help industrial engineers to follow the line problems closely and to strengthen efficient planning of the production process.
- To be able to produce garments in efficient and competitive way factory need to adapt best practices which help to improve productivity.
- In order to improve productivity of the lines, company will be beneficiary by review and implement the proposed productivity improvement scenarios.
- Arranging regular training programs on productivity improvement will help company to improve the productivity of workers.

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Annex

Annex A: -

Annex B: -