Manufacture Systems Modeling and Performance Analysis on sewing firms. (A case of Gulele Garment Share Company Addis Ababa, Ethiopia)

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***Abstract** manufacturing system modeling and performance analysis is one of the tools that have been applied to model and analyze the performance of a manufacturing system. The modeling can be done either by analytical or simulation methods. This paper identified and mitigated the major problems of Gulele Garment Share Company production line. That related with low throughput, high cycle time, low resource utilization, etc. Therefore, the principal objectives of the paper are to model the production line of Gulele Garment Share Company, analyze its performance and finally proposed an improvement model based on the analysis made. The paper were done by taking two major product models and modeling the production line for each case. A simulation model which is established to understand and to analyze the structure of manufacturing reveals relationships among the processes and provides to determine the impact on the throughput of the production. Primary and secondary data have been collected from the case company, through direct observation of the production line and using stopwatch. Then, the data was analyzed and an appropriate mathematical model was selected from the available fit of probabilistic distribution.*

Under this study, Production and process analysis are significant for the manufacturing companies to improve their productivity and to optimize usage of the resources and time were the major area that recommended to mitigate the bottleneck and to avoid unexpected defects.

***Keywords:** simulation, line balancing, productivity improvement, cycle time, throughput.*

1. Introduction and Background

In the past half century, the apparel structure has changed from the custom fitting and assembly of individual hand-sewn garments to the design, mechanized, automated and sometimes robotized mass production and distribution of ready-to-wear products in the world market. Apparel manufacturing comprises a variety of product categories, materials and styling, and such complexities of manipulating flexible materials and dealing with constantly changing styles limits the degree of automation for the production system. Therefore, when it is compared to many other productions, apparel manufacturing remains labor intensive [1, 2]. When apparel manufacturing is analyzed, the central process in the production is the integration of different components, which is the most labor intensive part of this type of manufacturing, known as the sewing process [3]. Furthermore, when the cost structure is analyzed, apart from material costs, the cost structure of the sewing process is of critical importance because of the labor intensity [4]. Therefore, good balancing and small stocks of work in progress during sewing are the basic concepts to increase the efficiency of production [5]. An assembly line is described as a set of distinct tasks that is assigned to a set of workstations connected by a transport mechanism in detailed assembling sequences [6]. In garment sewing, the components are assembled through a subassembly process in order to form the finished product. In assembly line balancing, the allocation of jobs to machines is based on the objective of minimizing the work flow among the operators, reducing the throughput time as well as the work in progress and thus increases productivity. Up to now, researchers have developed different algorithms to estimate the performance of generally apparel manufacturers are focused on whether assembly work will be fished on time for delivery, finding ways to have more efficiency, how machines and employees are being utilized and how labor intensity can be minimized, whether any station in the assembly line is lagging behind the schedule and how the assembly line is doing overall [1, 10]. Therefore, in order to focus on this kind of labor-intensive structure, a sweatshirt sewing line was chosen for this study. The production line is analyzed by considering the innovative use of industrial engineering concepts, time study, assembly line balancing and simulation [11]. Firstly, real data taken from the factory floor using time studies and precedence constraints are taken into consideration to model the allocation of operations to the operators for simulation with the objective of minimizing the work flow among the operators. Afterwards with the help of the simulation model of the sewing line, the bottlenecks are determined. Finally, possible scenarios are tried in order to increase the efficiency of the line and to suggest investment strategies to manufacturers.

Therefore, a study was carried out in the garment industry named Gulele Garment Share Company located at Gulele (Asko), Addis Ababa, Ethiopia at sewing section to identify production and productivity, though for saving time, cost and improved product quality. Gulele Garment Share Company is one of the Garment Industry found in Ethiopia and established in 1983 at Addis Ababa Gulele Sub city. It produces different clothes such as Sweatshirt, T-Shirt, sport wear, Military Uniform for export and inside the country. The Industry has three main sections namely, cutting section, sewing section and finishing Section. This paper focuses on the sewing section of the garment to improve the productivity, production, minimizing time and increasing profit of company which highly affects the economy of the country.

The garment industry has unique market characteristics, such as short product life cycle, high volatility, low predictability, aesthetic value and a high level of impulse purchase, making quick response of paramount importance [2].

In today's world, garment industries make a significant contribution to many national economies especially in the developing world. Many countries are exploiting this industry for reasons of economic growth. According to [Ref.1] Garment producers in developing countries have labor-cost advantages compared to industrialized countries Because of its large labor pool (Central Statistics Agency estimated to be above 30 million persons in 2005), Ethiopia has a comparative advantage in producing garment. The increased salary levels in Asian countries, closing of factories particularly in China and dissatisfaction of EU and US importers provide an opportunity for new entrants such as Ethiopia into the global market [3].

Form early, Ethiopia has a long history for traditional and cultural garment manufacturing, which is endowed with profound national culture up to this today. Cottage industries have been the main style for traditional garment and have satisfied the demand of the people for centuries. The industrialization process of Ethiopia's garment manufacturing started in the 1950's..The public Akaki garment factory was founded in 1963, followed by the Gulele garment factory in 1983 and the Nazareth garment factory in 1992. These four state-owned garment factories have dominated Ethiopia's garment sub-sector for a long time [4]. At present, the garment sector consists of only 2.22 % of the country's manufacturing industries.

Currently, more than 50 garment factories are working in Ethiopia and most of the existing garment factories are located in the capital, Addis Ababa [6]. These industries produce different kinds of attires including uniforms, work wears, knit wear products like sportswear, under wears, polo shirts, clothing products and suits and soldiers uniform . The Ethiopian government has defined the textile and garment sector as a top priority sector in the industrial development package of the country. This is because textile and clothing market is always demanded next to food commodities. The sector also utilizes more labor which is available abundantly at low cost in the country. The garment sector has a large potential for creating employment opportunities. The sector has strong vertical linkages with the textile industry that have the potential to increase the development of agriculture. It has a vast potential to manufacture goods for export, thus earning highly demanded foreign exchange [5]. Recently the Ethiopian garment sector has opportunities in the global market such as African Growth Opportunity Act (AGOA) giving quota and duty free access to the USA market for sub-Saharan African countries [7]. Out of the total 1.4 billion USD dollars earned from the export of goods in the year 2007, textile and garment export is only 1% having a small impact on national revenue [6]. The Ethiopian garment industry is still at its infancy stage even when compared to that of other developing countries.

2. Statement of the problem

The majority of Ethiopian population, around 85 %, lives in rural area where agriculture is the only means of incurring an income for existence. In order to improve the living standard of our people, the development of different kinds of industries is essential. Among the different kinds of industries, garment industries result in poverty reduction since it is one of the most labor intensive industries providing ample employment opportunities.

An effective system of management of the resources of an industry is essential to produce quality products in a productive way and to be competent in the local as well as global market. The productivity of most garment factories is declining as result of poor human and material resources management.

Gulele Garment Share Company is one of the oldest garment producers and exporters of garment products in Ethiopia. Although it is aged for many years and passed through different changes, it is still producing below its capacity and its performance is low.

The productivity of workers is at a very low stage that large amount of man-hour and work forces are utilized to produce the same or decreased amount of output. The factory does not have an adequate human resources management system that enables continuous job analysis with the changing technology and the method of doing work. Most of the workers lack motivation, adequate skill and educational background, which had to be maintained through training and education to improve the products and production processes the company in a continuous manner.

Low productivity of materials is a result of high production cost of the small volume of production that is contributed by inefficient purchasing, inventory management and material handling of the large amount of input entering to the process. The raw material for garment industries is largely garment which is expensive and thread. By proper management of materials, the company can benefit a lot and be competent in the local as well as international markets. Gulele garment factory faces problems that are associated with inefficient human resource management & material resource management which leads to low productivity.

3. Objective

3.1 General Objective

The main objective of this paper is focused on Manufacturing and Performance analysis of Simulation modeling in the case of Gullele garment Share Company for product improvement by application of Simulation modeling and production line balancing.

3.2 Specific Objectives

- To arrange the individual processing and assembly tasks at the workstations so that the total time required at each workstation is approximately the same and to distribute the total workload on the assembly line as evenly as possible among the workers.\
- To improve human resource management through efficient man power planning technique, efficient employment procedure, need assessment of training and education for different sections, improve the worker's way of doing jobs and reduce wastage
- To improve the productivity of company by material management of raw materials, in-process goods and finished products
- To apply arena simulation model to identify bottlenecks and show possible solutions for the problems.

4. Significance of Study

This research has a varied area of contribution to Gulele Garment Share Company employees, management, and owners to know their current manufacturing and operating performance and constraints that affect their performance following privatization. It also provides the base information for potential investors to take corrective actions regarding the manufacturing in the industry. The study can serve as important insights for future researchers on evaluation of manufacturing and operating performance related studies in the Industry. Last but not least this study will help Ethiopian privatization agency to know the current position of the company.

5. METHODOLOGY

This chapter contains all methods that use to improve the quality of garment industry at Gullele Company depending upon the recorded data items.

The methods employed to achieve the objectives of the research by taking Gulele Garment factory as a case study include: Different related reading materials like books, journals and internet sources are referred to have a thorough understanding of productivity performance in relation to human and materials resources that can address the problems of materials and human resources management in Ethiopia garment factories. The standard methodology used for this paper is a generally accepted arena and simulation model. The total process station included in the sewing department selected for the simulation is totally 33 in numbers. So the observation data were collected based on these all stations five times by using stop watch on each station.

Activity identification in the production lines, process mapping to understand how the product(entities) are actually moving, processes time collection and analyzing using Built in Arena input analyzer, simulation model development and identification of replication numbers were the methodologies used.

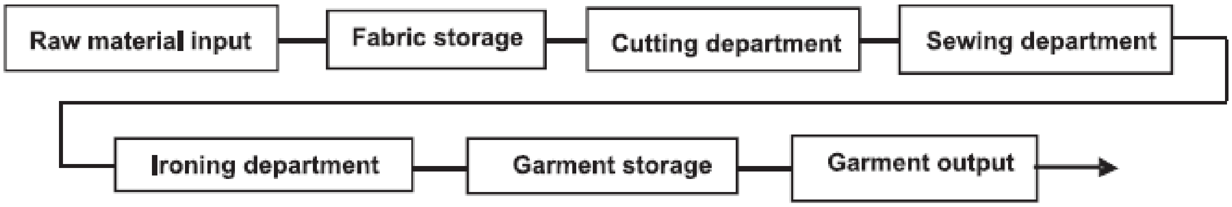

Figure 1. *Departments of garment industries.*

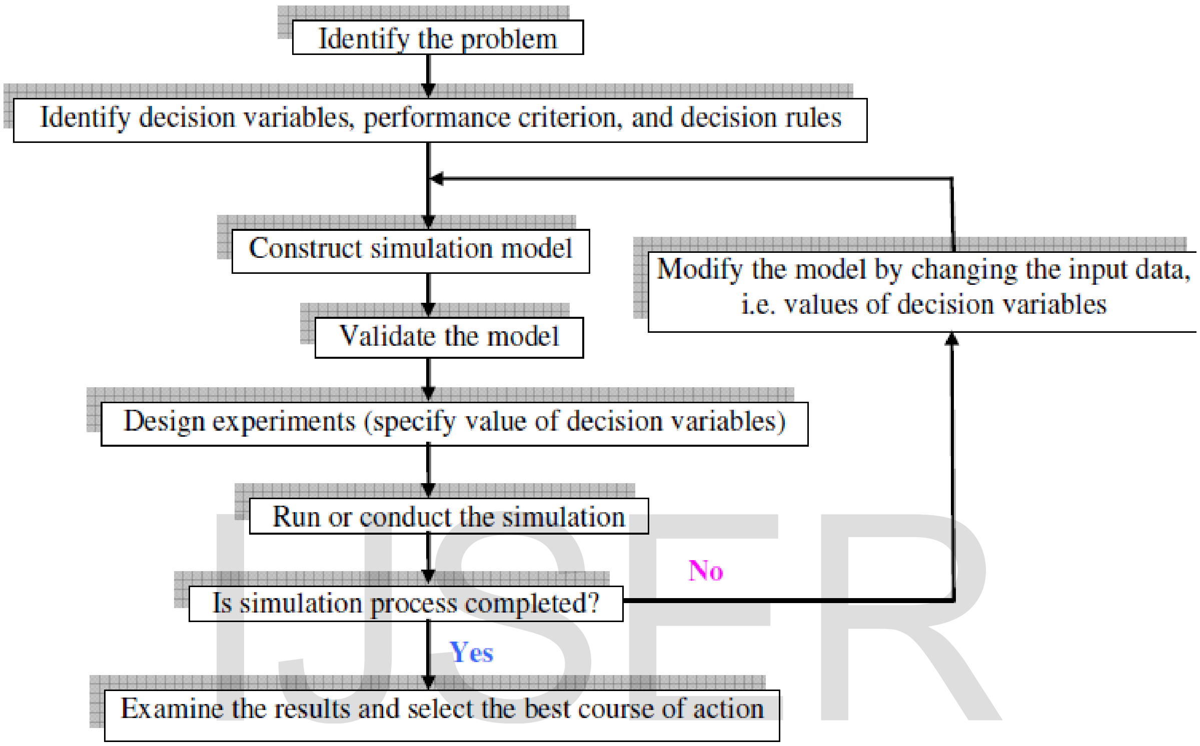

Figure 2. Steps of simulation process

6. DATA COLLECTION

The data is collected through: Discussion with section heads, supervisors, operators and concerned people; site visiting, conducting interviews, productivity records; and the process flow activity chart, resource utilization records, etc.

The primary data collection is carried out by several methods. This method includes garment factory visits, garment related organizational institutions visits, conducting interviews, distributing questionnaires and filling data sheet. The secondary data is collected from available electronic documents as well as different books, journals and magazines. The data collection is related to productivity performance improvement through human resource, material resource and work study method and focused in Gulele garment factory.

The data is analyzed using a proper technique of material and human resource management and method study procedures to develop a material and human resource management system that incorporate method study concept to improve the productivity of the organization significantly.

In order to carry out the simulation study successfully, the structured processes must be followed. These are: Problem

Formulation and Solution Methodology, System and Simulation, Specifications, Data Collection, Model Construction, Verification, Validation, Experimentation and analysis, Presenting the Results and Conclusions.

In a simulation analysis system, the ultimate use of input data is to drive the simulation modeling. For simulation model development of the (Gullele Garment Share Company) the following data were gathered:

- Total number of tasks
- Processing times of each task
- Priorities between processes

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Arrival frequencies of entities or time between arrivals of each assembly line
Manning level for each task
Conveyor length and speed
Working hours
Production output
Defect rate (rework)

These input data are obtained from historical records and collected in real time. The collection of input data is often the most difficult process involved in conducting a simulation modeling and analysis project. Initially, data collection begins from identifying and observing the different operations done on each assembly line.

Table 1 data of sewing company directly counted during production time.

Date	Total Pcs Checked	No of Pcs Accepted	date	Total Pcs Checked	No of Pcs Accepted
20-Oct-19	220	202	1-Nov-19	350	346
21-Oct-19	246	232	3-Nov-19	129	118
22-Oct-19	588	562	4-Nov-19	124	122
23-Oct-19	623	599	5-Nov-19	630	620
24-Oct-19	579	544	6-Nov-19	712	689
25-Oct-19	355	326	7-Nov-19	54	48
27-Oct-19	503	476	19-Nov-19	140	130
28-Oct-19	588	548	20-Nov-19	99	95
29-Oct-19	1012	983	22-Nov-19	77	76
30-Oct-19	750	741	24-Nov-19	121	112
31-Oct-19	1004	988	25-Nov-19	76	70
			29-Nov-19	110	106
			Total	9090	8733

Sewing Line Flow

The whole sweatshirt production cycle includes a sequence of different phases. The chronological sequence of assembly operations needed to transform raw materials into end product as shown in fig 3 below.

Time study: To balance the assembly line production and to suggest speculation strategies, a detailed work time study was done .Since the period of tasks is dependent on several factors, such as the task, operator fatigue, the properties of fabric and sub materials, working environment, level of quality, operator experience, capabilities of machine and etc.

Line balancing refers to assigning tasks to a workstation such that: the Cycle Time of the combined sequence of workstations satisfies the required Cycle Time, the tasks are assigned in the right order, and the task is as efficient as possible. First, the output of the sequence of workstations is sufficient to meet demand. For that to happen, the Cycle Time of the slowest workstation in the line must not go above the Cycle Time required. Second, the tasks of undertaking to workstations meet precedence requirements. Whenever a number of tasks are to be performed, there is a consistent sequence or ordering that must be followed. Third, the resultant number of operations in the line is the minimum possible given the Cycle Time required and similar with the precedence relationship

Total work content in line balancing

The work content achieved on an assembly line contains of many separate and distinct work components. Invariably, the sequence in which these elements can be performed is constrained, at least to some extent and the line must operate at a specified production rate, which reduce to a required cycle time.

Minimum rational work element:

It is a small amount of work taking a specific limited objective, such as adding an element to the base part or joining two components and also performing some other small portion of the total

$$T_{wc} = \sum_{k=0}^{n_e} T_{ek}$$

Where *Tek* = time to perform work element k (min), *ne* =

number of work elements into which the work content is divided; that is, $k = 1, 2\ldots$ In line balancing, it is assumed that element times are constant values, and *Tek* values are additive the time to perform two or more work elements in sequence is the sum of the individual element times. Various work elements require different times, and when the basics are grouped into logical tasks and assigned to workers, the station service times *Tsi* are not likely to be the same.

$$T_{wc} = \sum_{i=1}^{n} T_{si}$$

6.1 Data analysis

Simulation modeling

The simulation model is built using Simul-8 (14.5 student version) simulation software. The construction of the model is built on a production process flow in the firm. Sewing machines are organized according to the production process flow. During straight line production each operator uses only one machine. This study represents discrete-event modeling and the factory works for 7.5 hours/day. During production process were started at each station, the production line begins empty. This start-up condition must also be simulated. Data during this part of the simulation may negatively bias the final results since the line takes time to "warm up" and begin operating regularly in a steady state. When an entity arrives at a sewing machine, it waits in a first-in-first-out queue until the resource is presented. (Checked, 25% are plagiarized)

The following assumptions are used to define the problem of the production line.

- Set-up times are not taken into consideration, because in a real system the setup process is usually accomplished at the end of the working time, 450 minutes working time does not include breaks,
- There is no maintenance process performed during the working period,
- All process times for sewing operations include 'insignificant breakdowns' like threading of thread.
- The assembly line is never starved.
- Transportation of raw materials is performed by workers who aren't used for sewing operations. In this study, among other products the case under consideration is the production of a basic sweatshirt.
- The production of a sweatshirt consists of a total of 28 operators (3 on cutting operation, 28 on sewing operation and 2 quality inspectors).
- The line works for 450 minutes per shift.

SIMULATION MODEL INPUT

The data has been collected from Gulele garment share company sewing section on basic sweatshirt production line. In the plant, there are 33 work elements or tasks to complete the production of the basic sweatshirt and for each of them the workstation time is recorded using the stopwatch. For each work element, the time is recorded 5 times to determine the time variability distribution and operator performance consistency.

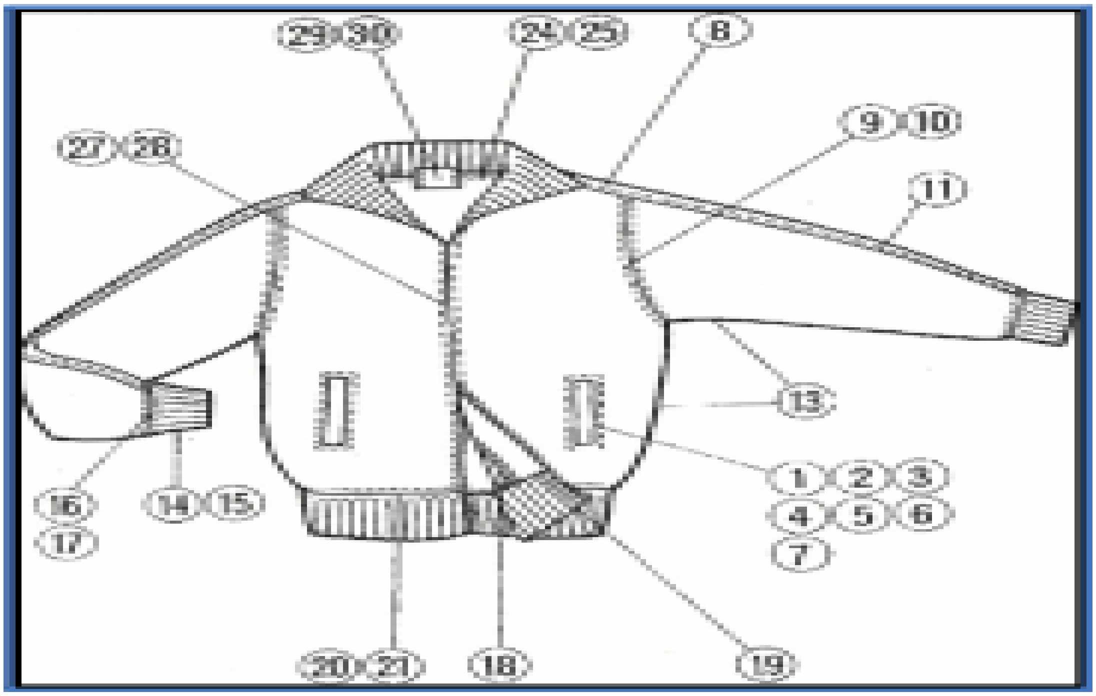

Figure 3. The end product of sweatshirt with different part indicators

. There are so many uncertain influencing factors (like sewing machine breakdown, low quality of sewing threads, absenteeism, etc.) that cause the process time variability in the basic sweatshirt production process. The process time variability of a basic sweatshirt production in Gulele garment wear section of 5 recordings is shown on Table below. The major activities are Cutting, sewing, inspection and finishing.

Simulation model formulation

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 is easy to observe the route the entity follows during the model building stage. For simplicity and limitation with the student version arena software, we made the following assumption and simplifications in developing the simulation mode

LINE BALANCING CONCEPT

Balancing refers to the process of adjusting the **operation times** at work station to conform as much as possible to the required cycle time. The Line balancing is "design a smooth production flow by allotting processes to workers so as to allow each worker to complete the assigned workload within a set time. Line balancing is the problem of handover various tasks to workplaces, while optimizing one or more objectives without violating any restrictions enforced on the line. (Checked)

Required cycle time is the production objective of an operation that is determined by the demand for the element being manufactured. A balanced process is one where the definite cycle times at every stage are equivalent. Actual cycle time represents the actual manufacture capability of a procedure or operation. In a work cell, the actual cycle time is determined by physical conditions such as the time to implement manual or automatic operations, to walk around the cell, and etc. the cycle time of the production process were determined by the operating time per amount of demanded per given time.

$$CT_{Required} = \frac{\text{Operating Time}}{\text{Demand}} \quad \text{………... (1)}$$

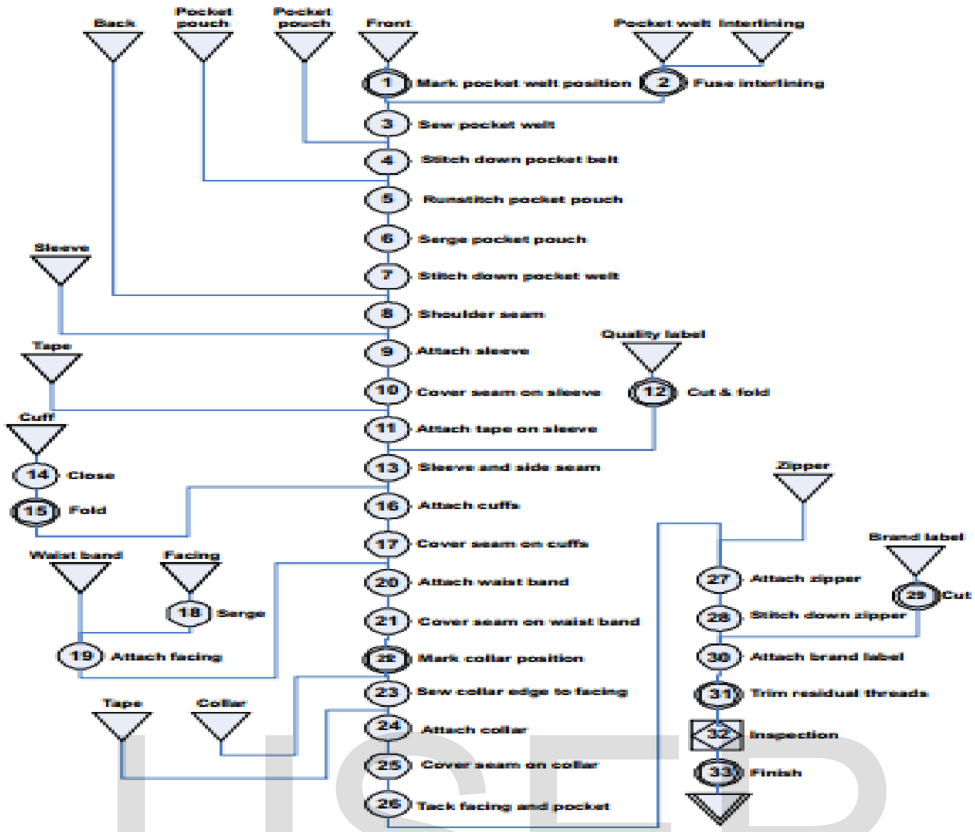

Figure 4. The working process of sweatshirt passing different stage

Two and more similar individual work elements which are done by a single worker are merged together and considered as one individual work element.

In addition to the main task the worker entitled; he/she is responsible for quality inspection on his/her work and previous work done in the upstream station. However, considering this task independently in modeling of the sweatshirt manufacturing makes the simulation so difficult since the student version Arena software is incapable of handling more than 150 entities. Therefore, it needs to add up 5sec of processing time for quality inspection on the basic processing time.

The other most important thing is the transportation time between stations: work in process are transported by a constantly moving conveyor from station to station. However, taking each transportation time in between stations as one entity makes the simulation and modeling of sweatshirt manufacturing process so complex and difficult in which the student version Arena software is incapable of running if number of entities is greater than 150. Therefore, divide the transportation time in between the adjacent stations and add up to the basic processing time of each station.

The lasting assembly line is categorized as mixed model assembly line in which different models can be loaded at the same time. However; in model development of the assembly process on this line it is treated as multi model assembly line. The main reason for this is the company follows a batch production system. Therefore; even if the line is capable of handling different models at the same time; usually it is loaded a single model based on batch production system.

Considering some unexpected circumstances for example the machine may stack or fail for some time, the worker may take more time in repositioning the work piece, the worker may strolling around his /her station, the worker may be busy in deed some private task other than the intended one. Therefore considering all this unsuspected circumstances add up15% of the basic processing time as allowance to each basic processing time. By considering those all processing tasks, their predecessors, average processing time and operating level for each task are listed in the in following tables for each assembly line.

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Table 2. The real data recorded from company during operation time

No of operators	Work element (Operation)					
	working process	Operator1	Operator 2	Operator 3	Operator 4	Operator 5
1	*Mark pocket welt position*	6.58	7.83	6.66	7.93	9.27
2	*Fuse interlining*	27.76	22.26	21.28	20.89	22.3
1	*Sew pocket belt*	11.4	15.91	10.24	16.78	14.6
1	*Stitch down pocket belt*	13.33	12.49	13.61	12.1	12.3
2	*Run stitch pocket pouch*	27.82	35.7	36.98	28.2	34.6
1	*Serge pocket pouch*	20.43	24.31	20.35	18.63	17.8
1	*Stitch down pocket welt*	47.54	53.73	51	61.6	52.2
2	*Shoulder seam*	49.5	39.15	45	52.33	45
2	*Attach sleeve*	10	11.12	8.9	8.91	9.34
2	*Cover seam on sleeve*	34.6	37.14	33.66	31.72	23.7
1	*Attach tape on sleeve*	11.3	12.6	9.78	8.77	9.21
1	*Cut & fold quality label*	29.78	30.99	25.33	25.29	24.2
2	*Sleeve and side seam*	15.5	17.01	15.45	17.65	20
3	*Close sleeve cuff*	45.32	41.98	53.74	43.33	43.3
1	*Fold sleeve cuff*	17.2	18.73	19.14	17.55	18.6
2	*Attach cuffs*	16.5	17.61	16.88	15.93	15.9
2	*Cover seam on cuffs*	18.7	19.68	21.89	19.54	18.5
1	*Serge facing*	5.45	7.89	6.9	8.07	7.01
1	*Attach facing*	6.58	7.83	6.66	7.93	9.27
1	*Attach waist band*	27.76	22.26	21.28	20.89	22.3
1	*Cover seam on waist band*	11.4	15.91	10.24	16.78	14.6
1	*Mark collar position*	13.33	12.49	13.61	12.1	12.3
2	*Sew collar edge to facing*	27.82	35.7	36.98	28.2	34.6
2	*Attach collar*	20.43	24.31	20.35	18.63	17.8
1	*Cover seam on collar*	47.54	53.73	51	61.6	52.2
2	*Tack facing and pocket*	49.5	39.15	45	52.33	45
1	*Attach zipper*	10	11.12	8.9	8.91	9.34
1	*Stitch down zipper*	34.6	37.14	33.66	31.72	23.7
1	*Cut & fold*	11.3	12.6	9.78	8.77	9.21
1	*Attach brand label*	29.78	30.99	25.33	25.29	24.2
1	*Trim residual threads*	15.5	17.01	15.45	17.65	20
2	*Inspection*	45.32	41.98	53.74	43.33	43.3
	Finish	17.2	18.73	19.14	17.55	18.6

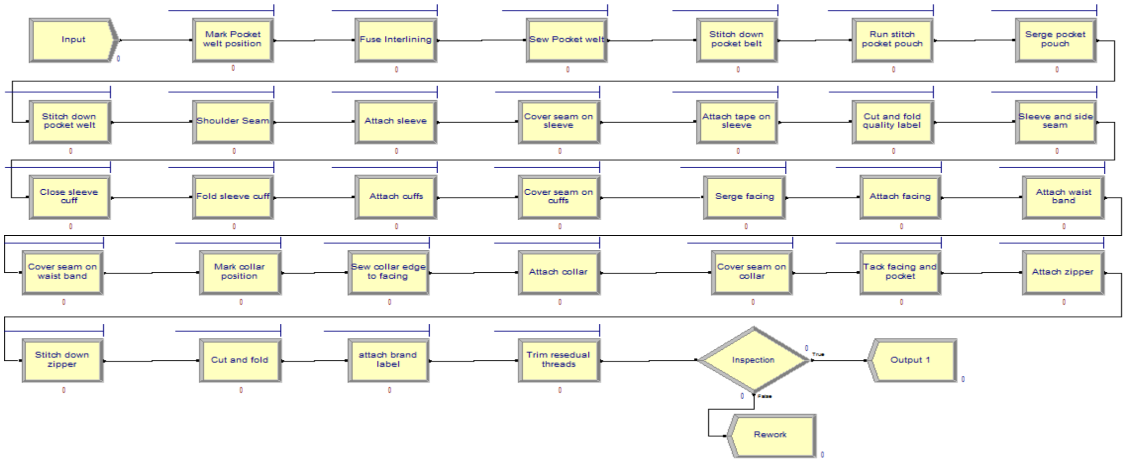

Figure 5. Gulele Garment Share Company simulation model for existing manufacturing system

Model Verification and Validation

One of the most important steps of simulation modeling 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. The simulation software arena 12 is user friendly for testing the model in visual way and every step it helps the user to control the steps.

Verification

Verification is the process of ensuring that the arena model behaves in a way it was intended according to the modelling assumptions made. Generally, it assesses the correctness of the model. Different methods have been applied to verify the model. One easy verification method is to allow only a single entity to enter the system and follow that entity to be sure that the model logic and data are correct. In this simulation model, allowing only a single entity to go through the hall system did not make any difference at all.

Checking how the model behaves under extreme conditions. The researchers have increased and decreased parts inter arrival time respectively. The author has tried different inter arrival times like 2, 4, 7,15,30,60 minutes to identifies any problems. No problems have shown up in these stressed out situation. Making long runs for different data's and observing the summary results for potential problems is another verification method applied.

Code verification: when arena simulation run, it examines each option selected in the modules and the data that is supplied and then creates SIMAN MOD and EXP files. These are the files that are used to run the simulation. Therefore, the SIMAN code for this model can be viewed using Run/SIMAN/View menu option. The author has seen this code to check if they are performing as intended.

The author has also tried to use different process times, failure rate etc to see any difference. The model was allowed to run for extended periods and results from these runs were carefully reviewed looking for huge Queues, resources not utilized etc. From these it was seen that there is no any resource that was not utilized.

The other method by which the simulation model is verified is by checking the conformance of its output with some factory laws. The first law is little's law in which work in process inventory is directly proportional with cycle time and throughput (WIP=CT*TH). The model can be verified by checking if it works by this relationship. The checkup was done by taking only the results of the first two replication of each department's model.

Validation

Validation is the task of ensuring that the model behaves the same as the real system. The author has tried to validate the simulation model by comparing the results of the model with the results of the real or actual system. The other validation technique that was used is inviting the existing system working staff to revise the model. Supervisors, industrial engineers, etc. have participated in this process.

Experimentation and Analysis

After verification and validation of simulation model is done, the next thing to do is statistical analysis of its outputs. However, some factors affect the kind of analysis done on the model.

The first one is the time frame of simulations. As we know most (not all) simulations can be classified as either terminating or steady state. In this thesis, the simulation model is decided to be terminating. The reason for avoiding steady state simulation is that, it is a lot harder to carry out anything approaching a valid statistical analysis than in terminating case if anything beyond arenas standard 95 % confidence intervals on mean performance measure is wanted (kelton). In addition, the run length for steady state simulation needs to be long. However, as we know, the number of entities allowed in the student version of arena per one replication is not more than one hundred fifty, which of course is less than the number of entities or pairs of shoes produced in peacock per day. Therefore, one day is divided in to two with the run length of 4 hours to meet the requirement of the student version software. This constraint is another reason to reject steady state simulations because it needs a longer run length.

Number of Replication Estimation

In terminating simulation, it is simple to collect the appropriate data for statistical analysis. It is just to make some number n of independent replication. However, the main question is what number of replication to make. Therefore, some analysis has to be made to decide on the number of replication. First, the model must run some initial set of replication so that sample average, standard deviation and confidence interval are computed.

It is obvious that the way to reduce the half width of the confidence interval on expected number out or anything for that matter is to increase the sample size n. Since it is wanted to achieve a specific half width, which is smaller than the one from the initial replication, the author tried to set h equal to the half width formula.

ARENA INPUT ANALYZER

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 data was processed in the Input Analyzer tool built in Arena, and the results are used to set the type of 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. 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.

For example, sample input analyzer data distribution of a task Mark pocket and

A. ***Stitch down pocket belt*** *welt position assembly line is shown in the figure 6 and 7 below respectively. Whereas; input analyzer data distribution function for all processes of both assembly lines is shown.*

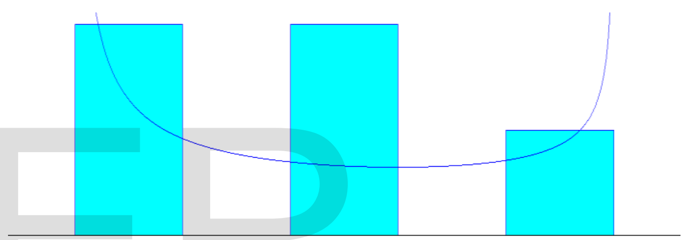

Figure 6: distribution graph for Mark pocket welt position

Distribution Summary

Distribution: Beta

Expression: 6.31 + 3.23 * BETA (0.452, 0.634)

Square Error: 0.125079

Kolmogorov-Smirnov Test

Test Statistic = 0.349

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 6.58

Max Data Value = 9.27

Sample Mean = 7.65

Sample Std. Dev = 1.1

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Histogram Summary

Histogram Range = 6.31 to 9.54

Number of Intervals = 5

A. Stitch down pocket belt

Distribution Summary

Distribution: Beta

Expression: 12 + 1.77 * BETA (0.781, 0.974)

Square Error: 0.047574

Kolmogorov-Smirnov Test

Test Statistic = 0.232

Corresponding p-value > 0.15

Data Summary

6.1.1 Fitting Input Distribution through the Arena Input analyzer

After the data are collected, it has to be tested for their independence. Scatter plot method is employed for the data collected on each machine. In this thesis process time is measured using stopwatch. The observation is taken for 5 times on each operation. Before input distribution is fitted into the data, an ordinary ASCII text file containing the data's in free format is prepared using notepad. The individual data values are separated by tabs. Then based on this data files, distribution is fitted to it. When input analyzer fits a distribution to the data, it estimates the distribution's parameter (including any shifts or offset that's required to formulate a valid expressions) and calculates a number of measures of how good the distributions fit the data.

There are theoretical and empirical distributions and each type of distribution is further broken down into continuous and discrete types. To select which type of distribution to

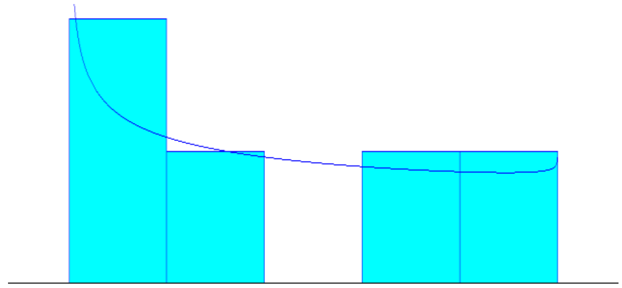

*Figure 7: distribution graph for **Stitch down pocket belt***

Number of Data Points = 5

Min Data Value = 12.1

Max Data Value = 13.6

Sample Mean = 12.8

Sample Std. Dev = 0.665

Histogram Summary

Histogram Range = 12 to 13.8

Number of Intervals= 5

use, the author has compared the square error of each distribution. The larger the square error value, the further away the fitted distribution is from the actual data (and thus the poorer the fit).

Therefore, the following fit all summary orders the distribution from smallest to largest square error. From the table it can be seen that beta is the one with smallest square error and thus it is selected.

6.1.2 Fit All Summary

Table 3. Data File:C:\Users\shimexpc\Desktop\ale\model \Arena model \Input Analyzer\Decoration stitching.dst.txt

Function	Sq. error
Beta	0.125
Weibull	0.167

Triangular	0.183
Normal	0.185
Erlang.	0.15
Gamma	0.17

Uniform	0.16
Lognormal	0.181
Exponential	0.15

Table 4: Distribution types for each operation (unit: second)

S.N	Work Element	Distribution Type	Expression	Square Error
1	*Mark pocket welt position*	Beta	6.31 + 3.23 * BETA(0.452, 0.634)	0.125079
2	*Fuse interlining*	Lognormal	20.2 + LOGN(2.63, 2.52)	0.056824
3	*Sew pocket belt*	Beta	10 + 7 * BETA(0.661, 0.599)	0.073492
4	*Stitch down pocket belt*	Beta	12 + 1.77 * BETA(0.781, 0.974)	0.047574
5	*Run stitch pocket pouch*	Beta	27 + 10 * BETA(0.574, 0.394)	0.08744
6	*Serge pocket pouch*	Beta	17.1 + 7.83 * BETA(0.545, 0.804)	0.116555
7	*Stitch down pocket welt*	Triangular	TRIA(47, 50.6, 62)	0.053746
8	*Shoulder seam*	Normal	NORM(46.2, 4.5)	0.077583
9	*Attach sleeve*	Exponential	8.67 + EXPO(0.984)	0.03571
10	*Cover seam on sleeve*	Triangular	TRIA(23, 35.5, 38)	0.050531
11	*Attach tape on sleeve*	Beta	8.38 + 4.61 * BETA(0.448, 0.61)	0.035191
12	*Cut & fold quality label*	Beta	24 + 7 * BETA(0.432, 0.385)	0.098101
13	*Sleeve and side seam*	Exponential	15 + EXPO(2.12)	0.148706
14	*Close sleeve cuff*	Exponential	41 + EXPO(4.53)	0.078516
15	*Fold sleeve cuff*	Beta	17 + 2.34 * BETA(1.05, 0.972)	0.078288
16	*Attach cuffs*	Exponential	15.7 + EXPO(0.844)	0.033628
17	*Cover seam on cuffs*	Lognormal	18.2 + LOGN(1.53, 1.55)	0.064192
18	*Serge facing*	Beta	5.18 + 3.16 * BETA(0.728, 0.493)	0.119949
19	*Attach facing*	Beta	6.31 + 3.23 * BETA(0.452, 0.634)	0.125079
20	*Attach waist band*	Lognormal	20.2 + LOGN(2.63, 2.52)	0.056824
21	*Cover seam on waist band*	Beta	10 + 7 * BETA(0.661, 0.599)	0.073492
22	*Mark collar position*	Beta	12 + 1.77 * BETA(0.781, 0.974)	0.047574
23	*Sew collar edge to facing*	Beta	27 + 10 * BETA(0.574, 0.394)	0.08744
24	*Attach collar*	Beta	17.1 + 7.83 * BETA(0.545, 0.804)	0.116555
25	*Cover seam on collar*	Triangular	TRIA(47, 50.6, 62)	0.053746
26	*Tack facing and pocket*	Normal	NORM(46.2, 4.5)	0.077583
27	*Attach zipper*	Exponential	8.67 + EXPO(0.984)	0.03571
28	*Stitch down zipper*	Triangular	TRIA(23, 35.5, 38)	0.050531

29	*Cut & fold*	Beta	8.38 + 4.61 * BETA(0.448, 0.61)	0.035191
30	*Attach brand label*	Beta	24 + 7 * BETA(0.432, 0.385)	0.098101
31	*Trim residual threads*	Exponential	15 + EXPO(2.12)	0.148706
32	*Inspection*	Exponential	41 + EXPO(4.53)	0.078516
33	*Finish*	Beta	17 + 2.34 * BETA(1.05, 0.972)	0.078288

Simulation Model Run Results Interpretation

The objective of this paper is to model the production line of Gullele Garment S.C, analyze its performance, and finally proposed an improved

Model. The problems identified are low throughput, high WIP, high waiting time and low productivity, which are due to low capacity utilization, unorganized flow of processes etc. This is why almost all operations are done manually. Therefore, the performance measures selected to be analyzed are entity, process, queue and resource for each department's model.

7. Sewing model result analysis and interpretation

Based on the simulation modeling result the following concepts were analyzed and interpreted.

1. Entity performance

The percentage out for the selected model is more than nine percent. The number of work in process record were still higher and therefore the necessary mitigation had given result and discussion.

2. Process performance

In the production line, the wait time is larger than the value adding time cover seam sleeve, packing, cut & fold quality label, Cover seam on collar, Stitch down zipper, Cut & fold attach brand label operations. Therefore, first the stations identified as a bottleneck in each model are considered separately and then they will be combined in the proposed model.

3. Queue performance

The waiting time and the number waiting of production line simulation model are higher in processes like attach tape on sleeve, cut and fold, stitch down pocket, shoulder seam, tack facing and pocket and cover seam on collar. Therefore, improvements can be made on the production line taking the above-mentioned processes as a core points that need change.

4. Resource performance

For the production line model, Cover seam on collar and Fuse interlining were not utilized the resource well *i.e* have instantaneous scheduled while the rest of the resources are utilized less than half and whereas the other lines utilization more than half Therefore, if the resource utilization is improved, the performance of the production line can be increased.

7.2 Bottleneck Analysis

After modeling of production line, performance analysis is done. Performance analysis of the existing system includes bottleneck analysis, throughput analysis, etc. The bottleneck in a production line occurs when workloads arrive at a given point more quickly than that point can handle them. Different bottleneck identification methods are discussed in the literature review. Some of the bottleneck identifications that are based on queue analysis, machine utilization is used in this paper.

7.1 Proposed Model Result Analysis

The proposed model results are analyzed based on the objectives set first. The objectives were related to the following parameters:

- ✓ Work in Process reduction
- ✓ Increasing throughput
- ✓ Increasing capacity or resource utilization
- ✓ Waiting time/number waiting reduction(bottleneck)
- Productivity increasing
- Flexibility of resources or flows
- Cycle time

Total time or the cycle time is the summation of waiting, value adding, and non-value adding time. In order to increase the throughput of any system, the total time or the cycle time must be reduced. This can be done by reducing the waiting and non-value adding time. Therefore, in the proposed model, the cycle time is smaller compared to the existing model due to the reduction of waiting time.

Throughput

The following figure xxx shows the number out from each model. As it can be seen the number out is increased for the proposed model:

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Table 5. The value accessed from arena input data analyzer

3:31:23AM **Category Overview** November 3, 20

Values Across All Replications

Sweatshirt Production line

Replications: 100 Time Units: Minutes

Process

Time per Entity

VA Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
attach brand label	0.5374	0.02	0.2570	0.7271	0.00014768	1.0000
Attach collar	0.4292	0.02	0.2035	0.6415	0.00000657	0.9999
Attach cuffs	0.8690	0.05	0.4287	1.8653	0.00218436	5.9217
Attach facing	0.4262	0.02	0.2430	0.7365	0.00000467	1.0000
Attach sleeve	0.9794	0.07	0.3195	1.8824	0.00066372	8.2283
Attach tape on sleeve	0.4277	0.02	0.2355	0.6567	0.00006416	0.9999
Attach waist band	2.6347	0.15	1.2977	4.8685	0.08513519	17.7945
Attach zipper	0.9519	0.07	0.3683	2.1155	0.00026292	6.7818
Close sleeve cuff	4.3238	0.26	1.8101	8.6218	0.00612792	35.5339
Cover seam on collar	53.1970	0.19	50.6917	55.2531	47.0847	61.6881
Cover seam on cuffs	1.5056	0.10	0.6302	3.0084	0.07913165	13.3076
Cover seam on sleeve	32.2543	0.22	29.0205	34.3467	23.2808	37.7617
Cover seam on waist band	0.5282	0.02	0.3193	0.7574	0.00029362	0.9999
Cut and fold	0.4494	0.02	0.2433	0.6726	0.00000824	1.0000
Cut and fold	0.4494	0.02	0.2433	0.6726	0.00000824	1.0000
Cut and fold quality label	0.5283	0.02	0.2437	0.7740	0.00014389	1.0000
Fold sleeve cuff	0.5065	0.02	0.2490	0.6663	0.00135972	0.9986
Fuse lining	2.7860	0.21	1.5128	8.7738	0.1064	43.0382
Mark collar position	0.4589	0.02	0.2493	0.6858	0.00041157	0.9999
Mark Pocket welt position	1.0071	0.01	0.8410	1.2084	0.5204	1.4820
Run stitch pocket pouch	0.5813	0.02	0.3171	0.8128	0.00012535	1.0000
Serge facing	0.5876	0.02	0.3389	0.7778	0.00043009	0.9999
Serge pocket pouch	0.4019	0.02	0.1922	0.5678	0.00012891	0.9977
Sew collar edge to facing	0.5886	0.02	0.3515	0.7903	0.00004866	1.0000
Sew Pocket welt	0.5224	0.02	0.1519	0.7664	0.00050925	1.0000
Shoulder Seam	46.4058	0.28	43.2204	49.5408	33.0590	61.7603
Sleeve and side seam	2.0893	0.14	0.7263	4.1475	0.00118506	17.1842
Stitch down pocket belt	0.4444	0.02	0.2291	0.6016	0.00176871	0.9981
Stitch down pocket welt	53.2245	0.22	50.5714	55.8908	47.3308	61.8180
Stitch down zipper	32.0929	0.22	28.7450	34.6233	23.0705	37.7981
Tack facing and pocket	46.2515	0.26	43.1388	49.3692	28.6584	63.6955
Trim resedual threads	2.0372	0.12	1.1457	3.7492	0.00243834	11.9642

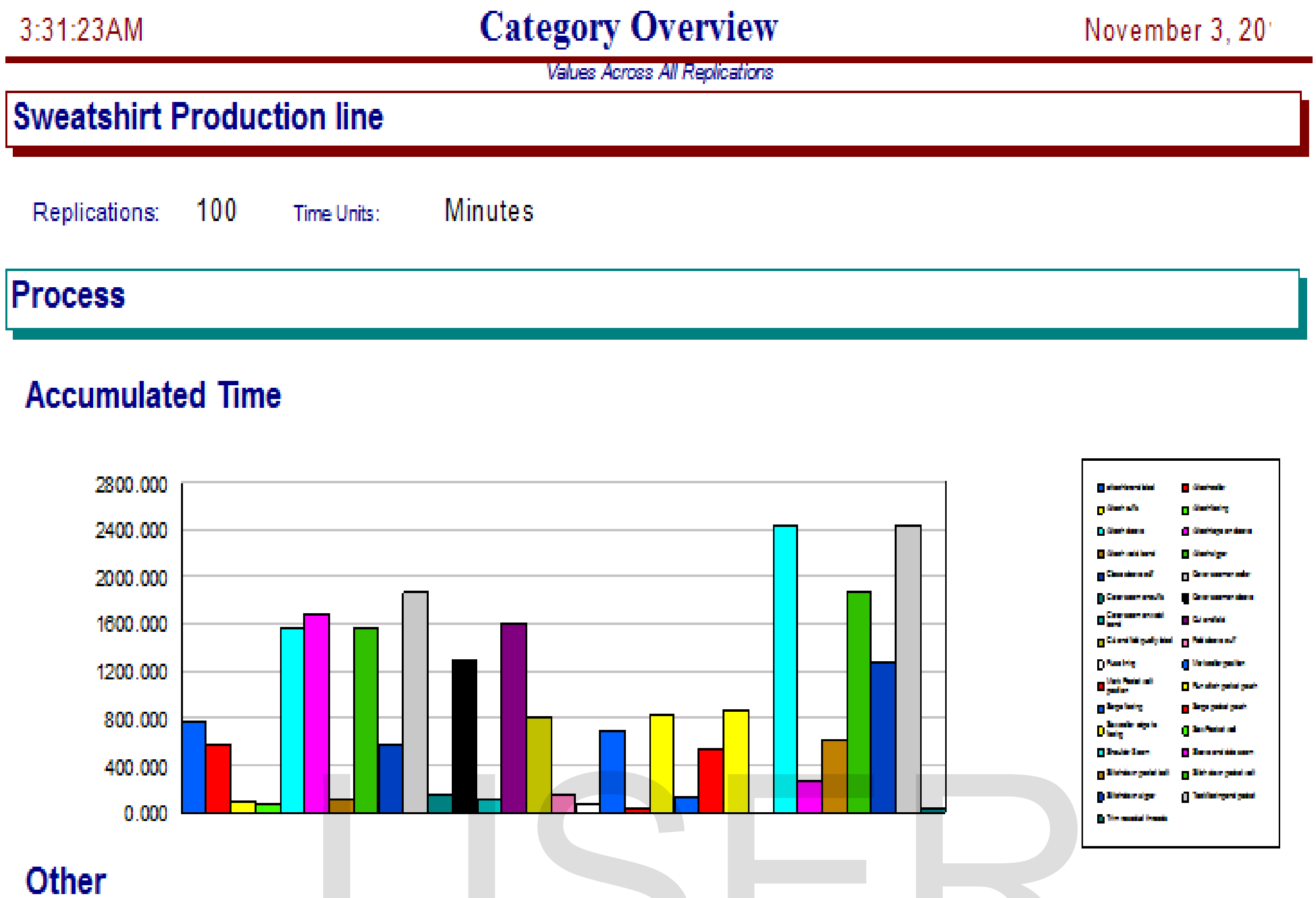

Fig 8 the value accessed for all replication which gained from arena input analyzer

Option 1

In the existing system**, 400** sweatshirts have been produced per **8 shift hours**. And the productivity of each operator is about **10 sweatshirts in 8 shift hours**. Mark pocket well position, run stitch down pocket, shoulder seam, sleeve and side and attaching face operations are the major bottleneck operations in the existing condition. Due to this, a large amount of work in process is accumulated on the line. Under the existing situation 762 items in collar attach operation, 585 items of mark pocket well positioned and 569 items of sleeve and side seam has been work in process

.Table 6: Bottleneck operations in the existing production system

S.N	Operation	WIP (items)
1	mark pocket well positioned	585
2	Run stitch down pocket	446
3	Shoulder seam	372
4	Sleeve and side seam	569
5	Attaching collar	762

After verification and validation process, one more effective working center is
added for collar attaching process to reduce the huge amount of work in process. After simulating the process, the work in process reduces dramatically from 762 pieces to 160 pieces but the production of the finished sweatshirt remains the same. On the other hand more queues are formed at collar closing operation. Therefore, to further investigate the process, one more effective working center is added at collar closing operation and the resulting queue

is reduced with increased productivity from 400 finished sweatshirts to 420 (20 difference) pieces. Further by adding one extra effective work center to cover closing operations the productivity of the line have significantly increased to 692 pieces of sweatshirt per shift. Therefore, by adding three effective work centers the productivity of the line is increased from 349 to 692 pieces of finished polo-shirts. This means productivity is increased by two folds i.e. the productivity per operator is increased from 12 pieces to 19 pieces per operator per shift. The snapshot of the modified simulation model considering the three effective resource additions was stated.(it needs some correction)

7.3 Proposed Solutions

In developing alternative solutions researchers have proposed and experimented with different Scenarios and come up with the following two main optimal solutions:

Scenario 1: Avoiding unnecessary duplication of resource from station with low capacity utilization. Some stations have compound resources but their capacity utilization is under 50%. In these stations unnecessary duplication of resources exists. Therefore, these unnecessary duplication resources should be deducted from the line. From the capacity utilization graphs presented above these stations and their respective capacity and average number of busy resources are presented.

Scenario 2: Merging similar operations with low resource utilization together and assign to one worker. For instance, Consecutive similar operations that can be merged together are these scenarios are modeled and simulated as.

8. Conclusion

In this study manufacturing system modeling and performance analysis using simulation has been used. It is a powerful and an interactive technique in which we can imitate the real manufacturing system to understand how it behaves if something is altered and evaluates the performance of various strategies and scenarios of manufacturing system. The simulation is done by using Arena 14.5 student version software. The performance measure used is throughput and it is directly related to waiting time; work in process inventory, resource or capacity utilization, and with flexibility of resources or flow lines.

This research is concerned with the modeling and performance analysis of garment industry which is mainly concerned with the modeling and simulation of the sweatshirt production lines which has 33 main series sewing process lines. Collecting and analyzing all the necessary input data using input analyzer of Arena, the simulation model was developed for the existing manufacturing system of this model sweatshirt.

Simulation models were built for the sewing department and finally an aggregate model is prepared for the purpose of conducting the computer based simulation. Based on the results of the simulation runs, the following conclusions are drawn:

- The throughput from the existing system is low due to presence of bottlenecks, absence of flexible flow lines and etc.
- The station with the largest queue and high resource utilization are identified as a bottleneck,
- The bottlenecks identified in the two product models is more or less similar,
- The bottlenecks identified are eliminated using reassigning the existing resources (labour and machineries), and there is the need of rehabilitating the machines rather than buying an additional machines,
- The necessity of line balancing system to distribute workloads and equally allocation of work time for the production line was also identified.
- In addition to bottleneck elimination, existing system simulation model built using the two product types are used to build a more flexible production line for the proposed model.

Finally, a new model was proposed and similar simulation runs had been conducted. This cycle time reduction resulted in more than 10 % increase in the throughput of the production line. It had been observed that there are additional possibilities for improving the performance of the company.

The performance measures of the proposed model are improved compared to the existing system. This improvement resulted in more than 10 percent profit increase. Therefore, it can be concluded that the proposed model is beneficial to the factory.

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