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Industrial Engineering

Simulation based inventory management analysis: the case of GMM Garment

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A thesis submitted to the school of Mechanical and industrial Engineering of Addis Ababa University in partial fulfillment of the requirement for the Masters Degree of Science in Industrial Engineering.

November 2021

ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES

POSTGRADUATE PROGRAM IN INDUSTRIAL ENGINEERING

SIMULATION BASED INVENTORY MANAGEMENT ANALYSIS: THE CASE OF GMM GARMENT

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitled **"Simulation based inventory management analysis: the case of GMM Garment"** 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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Samson Tesfaye Date

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

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ACKNOWLEDGEMENT

First and foremost, I would like to thank **Almighty GOD** for he has made this research a success.

Secondly, I would like to pass my gratitude to my advisor Dr.Ermias Tesfaye, assistant professor of Industrial Engineering. His immense knowledge, invaluable supervision, support and plentiful experience have encouraged me in all the time of my academic research.

I would like to extend my sincere thanks to Ato Surafel Abdisa (PhD Candidate) for his unconditional support, patience and suggestion he have given me for the successful completion of the research. And Mr Ephraim GMM production manager, for he has given me a lot of information which I used as input for the thesis to be a success.

Finally, I would like to express my gratitude to my family and friends. Without their tremendous understanding and encouragement in the past few years, it would be impossible for me to complete my study.

Samson Tesfaye

November, 2021

ABSTRACT

The aim of this research is to develop discrete simulation model of inventory management system with the help of Arena software, identify the existing problem within inventory management system of the factory, and finally propose a better remedial solutions. This research is a case study on GMM Garment Factory that located in Addis Ababa, and producing different clothing items for foreign markets, by importing most of its raw material inputs. The questions set to provide answer to this research were "how the current inventory management system of the factory operates", and "how the identified problem of the system be resolved so as to operate the system at a minimum cost". This study is a cross sectional research, utilized discrete dynamic simulation-modeling methods to address the issues of stochastic nature of demand and supply sides of the factory. The sample selection was purposive from the record of the warehouse, and in-depth interview with the personnel of the factory. The items selected for this study were from both raw materials inputs and finished products.

The finding of the study is that GMM garment factory has been facing problem of stock out and capital tied up. Because of stock out, the factory has lost about Birr 2,987,410 revenue in May 2019, and also lost about Birr 1,785,078 revenue from foreign customers in August 2020. There is a capital tied up worth of Birr 445,675 that resulted from unplanned procurement of raw material inputs for the production of protection masks for COVID 19 pandemic. The stock out and capital tie problems of the factory emanated from poor inventory management system which can be resolved through introducing inventory management system model, and be able to reduce total inventory cost from Birr 847,003 to Birr 597,915 of which difference could increase the factory's revenue and profit from the initial one by about 29%. Therefore, this improvement in revenue and profit of the factory can happen by simply decreasing stock-out, waiting time and avoiding tied up working capital so that inventory cost of the factory can decrease to a minimum level.

Key words: *Inventory management, discrete event simulation, and Arena simulation*

ABBREVIATIONS

GTP - Growth and Transformational plan

MOFED - Ministry of Finance and Economic Development

PLC - private limited company

COVID 19 - corona virus disease of 2019

WIP - work in progress

MRO - Maintenance, Repair and Operations

ITR - Inventory turnover ratio

SOR - Stock out rate

CSL - Customer service level

HML - HML Classification

ABC - Abc classification

EOQ - Economic order quantity

LIFO - Last in first out

BOQ - Batch Order Quantity

DES - Discrete event simulation

PAN - Arena process analyzer

ERP - Enterprise resource planning

KPIs - Key performance indicators

BH - Button holing

BA - Button attach

SAM - Standard allowed minute

SNLS - Single needle machine

FL - Float lock machine

USA - United States of America

IFRS - Financial reporting and analysis software

CMT - Cut make trim process

TABLE OF CONTENT

List of tables

List of Figures

LIST of Equations

LISTS OF ANNEXES

CHAPTER 1 : INTRODUCTION

1.1: BACKGROUND

The garment sector in Ethiopia is becoming more important than ever. Its vitality emanated from the policies of the government that emphasize more on export orientated and labor intensive economic sectors. For example, the government planned to export about USD 2.18 billion worth of product by improving the capacity of production, productivity, and competiveness of this sector; and yet the actual earning, during the planning period, was only about 35% of the target (MOFED, 2015).

In Ethiopia, many garment factories produce either one or more than one products. For the country, the importance of these factories are their contribution to the country's economic growth and development through saving or earning foreign currency by producing either import substitution or export oriented products, respectively.

To be more competitive in international market, these industry needs to produce more products effectively and efficiently. Among the factors that enable them to produce more products is to introduce new-ways of managing their inventory system.

Therefore, this research has been conducted on one of a privately owned garment factory, called GMM Garment PLC., with the aim of establishing simulation model, analyzing and determine the minimum cost of inventory management system.

1.3: STATEMENTS OF THE PROBLEM

Study shows (Rosas, D. S, 2020,) that inventory management is not immune from encountering problems. According to Sonko (Sonko, M. L., 2020) the three major problems that encountered the decision makers during inventory managments are: how much to order, when to order and at what frequency to review status along time to meet customer demand. These problems have been encountered due to bad flow of information between demand and supply of raw materials, finished goods, spare parts, market strategy, and type, values, and shelf-life of different products. These problems can also be resulted in underproduction, over production, stock-out, and raw materials delivery problems that further implicate negative effect on both the cost and the revenue of a business entity. Hence, properly managing inventory in uncertainty situation helps the industry to overcome these challenges.

Likewise, since most of the garment industries in Ethiopian are in a stiff competition; demand for and supply to (lead-times) their products are also uncertain or fluctuating from time-to time, forcing managers to make decision on dynamic and uncertain situations. According to Ethiopia Textile Industry Development Institute (ETIDI), this stiff competition is affecting their selling price, inventory level and cost of inventory (ETIDI, 2019). Thus, there is a huge need in the garment industries to place inventory management models properly and accurately by considering stochastic behaviors of demand, and lead-time of supply.

Furthermore, many garment industries in Ethiopia are lacking consideration of uncertainty and stochastic behavior of demand and supply while managing inventory. Lack of considering uncertainty and stochastic demand and supply, poor inventory management that result in stock-out and tied-up capital due to stockpile or inventory, and in this regards, GMM Garment PLC cannot be an exceptional. According to the in-depth interview conducted with operational officer of GMM garment PLC, the factory has encountered stock-out during the year, leading to sales order loss of Birr 2,083,698 revenue (sales) in May 2019 and August 2020. These sales order losses were Birr 1,785,078 (86%) from 6650 pcs of Shirt order and Birr 298,620 (14%) from 2,297 pcs of T-shirt order. Additionally, during COVID 19 pandemic the company faced raw material stock-out. This stock-out was one the causes for a considerable decrease in raw material inputs that led to decrease in producing-finished products due to decline in average production capacity utilization from 73% to 51% (GMM, 2020).

In general, lack of considering uncertainty and stochasticity while managing inventory will lead to stock-out and tied capital in inventory (warehouse). According to the discussion made with GMM Garment manager, the factory encountered capital tied up on raw material, like woven fabric and other accessories for garment wear production. The other point that the company's CEO, chief operational officer, described was that GMM had ordered woven fabric of about 5,000 meters to manufacture mask for the protection of COVID-19 in December 2020; and yet, unfortunately, has not be able to manufacture the mask and the fabric, and the raw material is still in the store, holding Birr 445,000 that should have been used to buy other raw materials or fabrics (Management, 2021).

1.4: Questions of the Study

Based on the above stated problems, and findings; this research tries to answer two questions. These questions are:

- How do inventory management looks like in GMM garment industry?
- How successful is the implementation of discrete event simulation in reducing inventory related costs of GMM factory?

1.5: Objectives of the Study

The objectives of this study have presented in two categories- general and specific. Each of these objectives presented according to their categories, below.

1.5.1: General Objective

The general objective of this study is to develop an inventory management model by using discrete event simulation for GMM Garment PLC Factory to enable it manage its inventories well in the future.

1.5.2: Specific Objectives

To arrive at the above stated general objective, this study should sequentially achieve two specific objectives. These two specific objectives are:

- To assess how the inventory management is at GMM garment industry, measure the inventory management performance levels of GMM factory through finding out inventory turnover ratio and obsolete inventory,
- Develop inventory management model and give recommendations regarding reorder point, batch size and target stock that improve overall warehouse inventory management system of GMM garment industry.

1.6: Scope of the Study

It is clear that many researchers conducted studies on inventory management in different factories, including textiles and garment. Moreover, inventory management for the garment industry plays a great deal to improve productivity and export performances. Furthermore, even if GMM PLC is relatively small company, but having suppliers from abroad and has fluctuating demands for its products from the same; it has still a poorly formalized inventory management system.

Note that the term ‘inventory’ commonly includes raw materials, Work-in-Progress (WIP), finished goods, spare parts and utilities for maintenance, repair, and overhauling activities (MRO) in this study, and yet *“raw materials, and finished goods inventories”* are the only inventories considered.

1.7: Significance of the Study

This research has a multifaceted significance. As mentioned above, this research uses “Discrete Event Simulation” as a technique to manage inventory. The use of this model is to find out a solution for problems of GMM PLC inventory management system. From the findings of this research, other garment companies can benefit by conducting similar tasks to address similar problems in their respective inventory management process and operations. Additionally, other researchers can use the findings of this study and do other researches on different type of inventory.

The other significance of this study is for the government. Assuming that, after adapting this model and solving the problem of uncertain demand and lead-time, the cost of the company is expected to decrease. Because of cost-cut, the contribution of the company to the government revenue in the form of profit and other taxes, including foreign currency gain could increase. Increased in government revenue can contribute to the country’s Homegrown Economic Development.

1.8: Limitation of the Study

Inventory management is a vast concept. As discussed earlier, it has wider areas to cover. However, when studying inventory management cases, it is obvious that there will be limitations. One of the limitations of this research is that, it only uses two products, T-Shirt & shirt, and four raw materials, woven fabrics, knitted fabrics, sewing thread and buttons nevertheless; the output of this factory is more than these two items. This research demands more detailed data and information from various sources. However, it was difficult to obtain complete data and information due to time constraints and others restrictive policies of GMM Garment PLC.

1.9: Organization of the Study

The documentation of this research organized under five (5) chapters. Chapter 1 is the introductory part that includes the background study, including problem statement, questions, objectives and significance as well as limitation of the study. Chapter 2 presents the reviewed literatures while chapter 3 discussed the methodology of the study. The result and discussion, and conclusion and recommendation parts presented under chapter 4 and 5, respectively.

CHAPTER 2 : LITERATURE REVIEW

2.1. Inventory Management System

Inventory management System is a crucial part of management of supply chain as it provides flexibility and confidence in both the production and sales activities. This is because inventory managers could encounter several issues during production and selling. According to Marcilic (Marcikic, 2009) problems related to inventory management may include or characterized by holding cost, stock out cost, restocking (replenishments) delays and uncertainty in demand. Thus, it is unequivocal that managing inventory to address these inventory management problems.

Inventory management system should take into accounts key factors like uncertainty, complexity, dynamic interaction between events and the system as a whole. When one tries to consider the above characteristics while trying to manage inventory, it becomes more complex (Neetu, 2011); and thus, it is advisable to use simulation since it is a reliable and dependable tool for evaluating and development of several results in a few seconds using different inventory control techniques.

Thus, this study on simulation based inventory management analysis in a garment industry was focused on the application of discrete event simulation approach. This approach, discrete event simulation, is applied in inventory management under uncertain demand, supply lead-time together with manufacturing uncertainties so that optimum values for reorder point, target stock and batch size is calculated that can result low inventory related cost and low customer waiting in line.

2.1.1: Inventory

In this study, inventory is simply means any asset that owned by a producer. Inventory may include finished goods to produce or sale within certain period, besides goods in the process of production or work-in-progress - materials waiting for production process. Without inventory, a factory cannot produce its product, and as a result, will not be able to fulfill its customer demand. Inventory management plays vital role in smoothly running an industry. Hence, inventory is a lifeline and a key for long-term profitability of the industry (Khanirunisa, Z. U., 2020).

According to different scholars that made studies on inventory management, it is quite clear that excess or lack of inventory will certainly affect the performance of a company. A company with poor inventory performance bound to lose money due to high inventory storage, purchase, stock damage, and/or stock run-out. Therefore, as a remedy, implementing inventory management system could help managers in eliminating holding of undesirable amount, excess or too small, of inventory; otherwise, inventory could become costly to a company (Ririm Panday, N. W., 2020).

Firms obviously hold inventories to fulfill their customer's orders. However, holding inventory has cost that is coming with it. These costs could be storage, insurance or other type of costs. Each holding cost applies to average inventory level over a period. The distribution of average holding cost is in the form of selling price, and/or cost per unit of stock. Thus, inventory managers must proactively decide on time to replenish and on the quantity of inventory items for each item of their products to hold; and thus, enable the industry maximize its expected profit under stochastic customer demands while minimizing the cost that related to inventory and stock-outs (Walkato, W. Y., 2020).

2.1.2: Inventory Management

Customer demand and lead-time are the most fluctuating factors when we are considering inventory management. Hence, a company should have a safety stock to care for customer needs. Additionally, in order to satisfy customer need, it is important to know how much to produce and hold based on statistical seasonal demand (Tamwa, A, 2014). But, before considering inventory management, classification of inventory must be in place. Classification of inventory helps the factory in reducing the need to control a plentiful of item in the inventory. Additionally, classifying inventory helps reduce wastage of time and money (Duangun Kritchnchai, W.M., 2015).

Besides classifying inventories, clothes can also be classified as "conventional clothes", in which demand is said to be "constant"; and "fashionable clothes", in which demand is said to be *"discrete and random"*, or *"sequential and random"*. In general, demand for clothing is highly fluctuating in relation to customer preference that needs having optimum inventory level. Therefore, unpredictable demand of the customer naturally may leave garment industries with challenges (Nucamndi-Guillen, S., Moreno, M. A., & Mendoza, A, 2018).

It is obvious that inventory management is a major challenging issue for the garment industry. This is because garments are with very unstable demand and have short life cycles, ranging from 3 to 6 months. Short life cycle of garment arises from globalization and the now-and-then fashion changes. Therefore, it is highly recommended to consider managing inventory effectively (Rahul Patil, 2015).

Based on the above facts about inventory management and others in mind, different scholars have tried to give different definition for the meaning of "inventory management". However, though not identical in contents, the meaning of all definitions culminated down to the same meaning. Among the scholars that give definition to inventory management first is Stevenson B. as presented below:

> "*Inventory Management is defined as a framework employed in firms in controlling its interest in inventory. It includes the recording and observing of stock level, estimating future request, and settling on when and how to arrange (*Stevenson B., 2010).''

Secondly, other scholars also gave their own definitions. For instance, Inventory Management is defined as "logistic activities that help to utilize space for goods storing, storing them properly, and asking for the use of proper classification of the goods to be stored". In general, all of the authors emphasized on "Effective Inventory Management" as their common goal (Anwaruddin Tanwari, A. Q, 2000).

Thirdly, effective inventory management has also a great deal of advantages in reduction of cost of inventory holding and stock-out. Inventory management also helps in production efficiency, lead-time of delivery, and hence increases the overall efficient performance of the industry Victoire, M, 2015).

2.1.2.1: Challenges of Inventory Management

Inventory management is still not immune from encountering problems. According to Rosas (Rosas, D. S, 2020), the three problems that can encounter inventory management on which Sonko (Sonko, M. L., 2020) further discussed are that while making decisions "how mch to order, when to order" and "at what frequency to review status" along time to meet customer demand are the major one. Inventory management problem mainly occur due to bad information flow between demand and supply. For proper and efficient coordination, there has to be information on factors that determine demand and supply. Information on these factors may include raw material inventory, finished good inventory, spare parts, market strategy, manufacturing type, value, shelf life, demand for the inventory and others. Therefore, according to some researchers the above-mentioned problems may result in underproduction, overproduction, stock out, and delay in delivery of raw materials.

According to Waters (Walter, J, 2003), underproduction occurs when the production rate falls below the demand of customers. This happens when the industry does not holds safety stocks due to one-to-one relationship with customers; and such problem leads to lost sales due to customer's dissatisfaction. There is also empirical evidence that lost sales resulted from error in demand forecasting where Nike had lost about 100 millions in its sales (Charette, R, 2005).

Overproduction is occurring when the industry produces more than the demand for its product. Ali, S. Ahsan (Syed Ahsan Ali, 2020) reported on this fact that over production leads to unnecessary usage of store space that leads to building bulk of inventory in warehouse, and thus resulted in tying-up cash that should be used for other purpose.

Stock-Out is the main source of customer dissatisfaction when there are no finished goods to respond to their demand. This problem was evidenced by empirical facts that Wall Mart lost about 3 Billion USD due to stock-out of its merchandize (Osyk, B. V, 2006). Additionally, can be calsulated as
Stock out equals to number of order or 1- fill rate (politecnico di milano, 2018)

As reported by Muller (Muller, 2011), problem of "delay raw material delivery" is the problem of lead-time. When there is delay of raw material delivery, much time is wasted while waiting on order by supplier to deliver, and this leads to disruption of production process. According to Abramovitz (Abramovitz, M, 1954) the problem of inventory management is the dynamic nature inventory in the world. This dynamism relates to demand and lead-time fluctuations; and can be observed during inventory movement from its dispatching location to its destination.

Therefore, a solution propossed a scholar (Morden, T, 2004) is that the problem of poor inventory management performance can be resolved by establishing a set of good inventory policy to help employees be work stress free and also help the employer/ manufacturer develop a cost effective manufacturing and marketing situation.

2.1.2.2: Classification of Inventory Costs

Piasecki (Operasi, a. Piasecki, 2001) classified inventory related cost into three categories. These categorized costs include ordering cost, holding cost, and shortage or stock-out cost. *"Ordering cost"* comprises administrative, transportation, and inspection costs. *"Holding-costs"* are costs that incurred by a firm for having inventory on hand. Holding cost that sometime called "*carrying costs*" comprise Storage space costs, handling costs, property taxes, insurance and obsolescence losses. The final cost is *"Stock-out Cost"* that resulted from not having enough stock on hand to meet customers' demand. Costs in Stock-out category are a bit hard to quantify despite very important for a firm. Besides, *Stock-out Cost* can contribute to sale loss when customers not remain loyal to a firm.

2.1.3: Importance of Inventory Management

One of the vital advantages of inventory management is to make a firm to be competitive in a market. Being competitive through implementations of appropriate inventory policies affect inventory related costs and resulting in a greater customer services (Mateo Garcia-Esquettini, a. R-G, 2018), Planning and controlling of inventory from the raw material stage to the customer is important. Inventory management is concerned with collective or overall inventory and single items management. It helps in tracking the flow of inventory to satisfy its customer. Therefore, inventory management has direct relation with the company's future profitability and expansion. For instance, comparison between costs in relation to inventory and the benefit of holding inventory shows the importance of having inventory management system; if an industry is to be successful in its inventory managing, it is required to reduce its inventory cost to improve its profitability (Kastay, K. A. 2014). Inventory management has also great impact on labor and capital productivity, as well as returns to scale in the industry (Rajeev S, 2010).

When an industry put more money in inventory that it is to sale, it would face shortage of budget. If there are no enough inventories in industry's stock, services to its customers will be compromised by reducing the amount of its sales. To mitigate stock shortages, industries frequently "backorder" items or tell customer that they are "out-of-stock" that further leads to loss of customer to other manufacturers. Likewise, when industries, most of the time, hold excess inventory; they are also obligated to spend more cost on holding stock in warehouse; and this is by sacrificing their profit gains

(International Transport Association , 2015)[1]. Therefore, the right amount of inventory has effect on increasing the capacity of production and productivity of the industries that would have positive effect on their future profit (Vision C, 2013).

2.1.4: Factors Affecting Inventory Management

2.1.4.1: Planning, Recording, Staffing & Funding

There are different factors that can affect inventory management, and these factors are inventory-planning, record keeping, staffing and funding. ***It is clear that "Planning"*** is a process to determine the optimum level of quantity of inventory for right product at the right time for the future use. Since inventory directly relates to "cash flow", it must be in line with the capacity of the industry so as not to encounter resource constraints.

According to Takim, (Takim, S. A. , 2014), inventory plan may include determination of "re-order" level of stock and establishment of "maximum" and "minimum" inventory levels. If a firm fails to make and follow its inventory plan properly, then it is bound to fail. Therefore, during the planning process, it would be better to involve the suppliers into the planning processes. Velthoen (Velthoen, J, (n.d)), also reported on the effect of good inventory plan that would enable the company to achieve its goal of obtaining higher profit by efficiently purchasing, producing, and selling goods. With the help of automated inventory plan, firm can prevent inventory mismanagement and theft. Automated technology will help the industry to be able to order, receive, manage, and vend any inventory in an efficient manner. In general, note that inventory panning is the core factor that could be influencing the success of any industry.

Amirah (Amirah, A, 2017) has reported on lack of stores record keeping and unavailability of adequate stationeries that have direct effect on efficient inventory control. For receiving and issuing of goods, Amirah examined the stock procedures, which were not in line with the policies and regulation of the Ministry, and these were negatively influencing the efficiency of inventory control. Amirah finally found actions related stock discrepancies during reconciliation of stock balances, and misappropriation of stock and poor stock control recording.

2.1, 4.2: Uncertainty in Inventory Management

Inventory management has had highly complex problems due to the existence of stochastic demand and supply. According to (Rajendran,H. S, 2020), demand and supply uncertainty is the main issue in inventory management. However, different industries need to take much more account on the uncertainty that attributes to their demand and supply. As a result, inventory management requires having the manufacturers and the suppliers to be able to increasingly innovative and cost efficient in supplying raw materials and producing finished goods and services. They should, in a proper and outstanding ways, deal with inventory related cost by taking into account the uncertainty of demand and supply. Some uncertainties that classified under inventory management are manufacturing, demand, and supply uncertainties.

Manufacturing uncertainty may take place when supplier and manufacturer's machineries breakdown, workers tied-up with other works, and errors occurrence that may affect the flow of materials. This uncertainty may cause production bottlenecks and poor product quality, which leads to customer dissatisfaction with the products or services.

Demand uncertainty may happen when irregular orders placed by customers, leading to poor manufacturing forecast, which may further lead to over production or under production. Due to overproduction, the company may incur high inventory cost on itself or due to under production the company may not be able to satisfy customer's need.

Supply uncertainty may take place because suppliers are not always perfect. For example, suppliers may fail to keep promises of delivery of items; and this in-turn may result in higher lead-time. According to Davis (Davis, T, 1993), higher lead-time could be the cause for poor service level and poor delivery of products to customers.

2.2: Measurement Techniques of Inventory Management

The major aim of any inventory management is to provide high quality service with low total cost. To meet this goal different industries use different inventory management techniques. There are a number of metrics that developed to facilitate good inventory management. Among these metrics, inventory turnover ratio, stock-out rate and customer service levels are discussed below. These tools are used to measure efficiency in inventory management in an industry to uncover ways to optimize industry's operations and profitability.

2.2.1: Measurement of Inventory Turnover Ratio (ITR)

In order to obtain or know how inventory management performance is measured, David (Anderson, Sweensey, Williams, Camm, & Martin, 2012) has discussed, including variables that to be used. "Inventory turnover ratio" calculated *"by dividing cost of goods sold by average inventory levels"*. During the process, it is important to know the beginning and the ending inventory levels to calculate an average inventory level of a firm. In general, Inventory turnover ratio shows how effective inventory management is.

2.2.2: Measurement of Obsolete Inventory

During inventory management, obsolete Inventory should be identified. The identification of these types of inventory help management of any industry understands how much of its inventory investment is worthless. Thus, action to dispose of the obsolete items, or perhaps selling it may contribute a small amount of cash to the business (Bragg, 2021).

2.2.3: Measurement of Customers Service Level (CSL)

Customers Service Level (CSL) simply answers if there is stock-out or not. CSL is the probability of not losing sales, and so, ideally, CSL should be close to 100%. To calculate CSL, first binary point "1" and "0" should be established. In this regards, "1" is stand for 'no-stock-out' while "0" is for 'stock-out'. For example, if demand is greater than inventory, '0' should be assigned to show 'stock-out'; otherwise "1" should be assigned to show 'no-stock-out'. At the Second stage, all the points for each observation would be sum up and then divided by number of observation to get average CSL of the company (Dias, Luís M. S.; Vieira, António A. C.; Pereira, Guilherme A. B.; Oliveira, José A., 2016). The flowchart of this part has been given under the memthodological part of this research.

2.3: Inventory Control Policies

Managing inventory is not cheap. Unfortunately, inventory manager are bound to manage large number of inventory using the best method of management. In so doing, they are supposed to diminish inventory related cost and simultaneously increase customer satisfaction. In a multiproduct inventory system, not all items held in stock are equally profitable; and for this reason, it is very necessary to give more focus on high-value, high-usage items than treating all items equally. To distinguish one item from the other in the inventory setting, these items are required classification that should be used by their managers. Among these classifications, ABC is the most used one to propose appropriate inventory control policy.

ABC classification is a technique that helps inventory managers perform selective inventory control by focusing on high-value, high-usage items than other items in the inventory system (Rizkya, R. M. , 2020). Many organizations use the ABC classification technique to manage their inventory – exercise tight control over a small number, usually up to 20%, of high-value items.

Moderate control over a larger number, about 30% of items in stock, of moderately expensive items; and simple control over a very large number of items, about 50% of items in stock, of low-value items (CGMA, T.C, 2021). Therefore, based on this narration, different policies explored; and then the best policy for this research proposed.

2.3.1: Periodic Review Policy

This policy is known as "Multi-Commodity Inventory-Location Model Under an "R", "s", "S' periodic review policy. This policy is the improvement of the periodic review policy in a **single commodity scenario** to multiple commodity scenarios. In this inventory control policy, inventory levels reviewed after 'R' periods. If the inventory level is lower than "s" level, then an order is placed to reach the target amount "S" (Claudio Araya Sassi, G. P.-B.-J., 2020).

2.3.2: Fixed Order Quantity Policy

This policy is an instruments of continues review order of fixed quantity that is placed when there is depletion of inventory to the level of reorder point (R). The notation "R" & "Q" used to represent the reorder point (R) and the fixed order quantity (Q), respectively. In this policy, theoretically, the inventory level is checked constantly; but in reality, it is quite clear that many industries check their inventory periodically at the beginning or end of each workday (Mirmohammadi, S. T. , 2015).

When this policy is compared with the previous one, it is more responsive. When it is more responsive, it meant that the policy reacts to "Stock-outs" quite faster. The order quantity placed from this policy is not entirely up to what the company use. The fixed order quantity always dictated by the suppliers. For example, a supplier may insist to place a minimum order of 30 and must be a multiple of 10. Thus the order size is going to be 30, 40, 50, etc. (Thomas Willemain, P., 2019).

2.3.3: Order Up-to (Min Max) Policy

Order-up-to is a continuous Inventory Control policy. The shorthand notation for this policy is (s, S), and sometimes called small "s", & big "S" where small "s" is the reorder point while big "S" is the order-up-to level. This policy is more commonly known as "Min", "Max".

When to order: Orders placed as soon as the inventory drops to or below the Min. As with (R, Q), the inventory level is supposedly monitored constantly, but in practice it is usually checked at the end of each workday (Thomas Willemain, P., 2019)

2.4: INVENTORY MANAGEMENT IN ETHIOPIA

Different scholars concluded that effective inventory management is very vital for both the manufacturing and the service sector to meet customer need and be able to have smooth manufacturing process. Having this in mind, Ethiopian manufacturing sector tried to deploy effective inventory management system. Among these studies, the study conducted on MSE was one of them. The study was on the impact of inventory management on the MSE sector of Ethiopia, specifically in Arsi zone. This empirical study tried to investigate impact of inventory management practices on competiveness and organizational performance. The study found that inventory management practices have a direct positive impact on the competitive advantage and organizational performance of micro and small-scale enterprise (Balda, D. A., 2018).

According to the result of other study conducted by Yigezu (Yigezu, M. A., 2021) on Messobo Cement Industry on Minimizing Total Inventory Cost of the Mechanical Spare Parts, using ABC analysis, HML classification and EOQ tools, for this industry, there was a decrease in inventory cost from 2,691,813.23birr/year to 2,337,017.54birr/year, saving 354,795.69birr/year (13%).

Further study made to assess inventory management practice was on Hawassa Textile factory. In this study, ABC classification & LIFO method used as the only inventory management tools. The study found that due to lack of more advanced and variety tool to manage its inventory, the company face problems of incidences of service interruption, delay, and excessive stock, stock out of spare parts of machine, and delays in delivery for customers. So, it was advised in the study that the company should deploy inventory management tools like, ABC, BOQ and EOQ (Wako, E., 2018).

2.5: Simulation Modeling & Inventory Management

2.5.1: Simulation Modeling

Among different tools used in managing inventory like forecasting and using experiences, simulation is a widely used tool for inventory management. According to Anderson & others (Anderson, Sweensey, Williams, Camm, & Martin, 2012), the use of simulation modeling is to establish an inventory management system for the products of an organization of which products have had an uncertain demand. This tool is helpful to generate a large number of random numbers to achieve optimal level of results. Obtaining optimal level of result is to improve or find out an optimal level of inventory under uncertainty condition of demand and lead-time. When simulation is applied, it is to help in reducing inventory cost significantly; and so simulation modeling preferred over others for its efficiency & effectiveness (Tesfaye Gashaw, K.J., 2014).

This research paper is a case study, conducted on GMM Garment PLC. It takes into account the importance of efficient management of GMM Garment PLC inventory, and as a result, inventory management model used as a tool. According to the interview made with the staff of the factory, GMM PLC has been repeatedly encountering inventory related problems due to the variability of customer demand and supply lead-time irregularity. To resolve this, this study has conducted an analysis by using a "*one-way approach of discrete event simulation*"-based inventory management model to come to better result.

2.5.2: Significance of Simulation

Simulation is naturally appealing to a user because it mimics what happens in a real system or what perceived for a system that is in the design stage. During simulation, the output of simulation should directly correspond to the outputs recorded from the real system; so, it is possible to develop a simulation model of a system without uncertainty assumptions, unlike that in statistically distributed random variable of mathematically solvable models that use assumptions. That is why simulation is frequently being a technique of choice in problem solving (Jerry Banks, John S. carson II, Barry L. Nelson, David M. Nicol, 2005). According to B, Jerry, the seven (7) most significant reasons why simulation is the most important are:

- Its flexibility in using it in both simple and complex systems;
- Its ability to test large and/or complex systems without being limited to the number of rules and variables, which are to put into the system; and thus be able simulate incredible amount of scenarios (iteration);
- Its isolation from the real-world system; and creation of numerous amounts of insights without ever touching the system of the real world; which makes simulation significantly beneficial for big environments, without losing money & quality of products;
- Its capability of addressing the "What if" theoretical questions;
- Its capability to study the impact of different, and interrelated variables in a manufacturing or in any other sectors that have thousands of machines, logistical supply chains, materials & human resources. It can address how manufacturing operation affect bad weather, worker's strikes, & social unrest that hinder access to raw materials, etc.;
- Its capability to provide **time compressed** information on long-term event to happen.
- It capability of testing complications, be it induction of new machine in a factory, or introduction of new process in a system to see it if it works or not. Therefore, simulation modeling provides a wide range of business benefits by objectively predicting the results of actions before they happen in the real world.

2.5.3: TYPES OF SIMULATION MODELING

2.5.3.1: Static vs. Dynamic Simulation Modeling

There are different types of simulations; the first one is "Static" while the other is "Dynamic". Static simulation is concerned with the relationship of event that not affected by time while the dynamic simulation model is affected by time. The most commonly known static simulation is Monte Carlo simulation model. Regarding the dynamic simulation, it sub-divided into two namely continuous and discrete event simulation models. Continues simulation model deals with event at point in time while discrete event simulation model deals with events in period, i.e., considers events within two period of times, which makes this model to be discrete event model (Russano, E., 2021). Therefore, Discrete-event systems simulation is preferred to other modeling for this research in which the state (event) variable changes only at a discrete set of time (Jerry Banks, John S. carson II, Barry L. Nelson, David M. Nicol, 2005).

2.5.3.2: Discrete Event Simulation Modeling

Inventory management system evolves with dynamic systems; this is because that as time passes-by, inventory levels also changes from time to time. These changes are in-line with changes in supplier's delivery and customer's demand levels. Therefore, as proposed by Banks, discrete event simulation model to efficiently & effectively manage inventory management system chosen (Jerry Banks, John S. carson II, Barry L. Nelson, David M. Nicol, 2005).

Additional to the inventory management studies made on the textile and garment sector, different scholars did a study on the printing sector inventory management. According to the study made on artistic printing enterprise, and found out that Simulation is considered as a very important tool for the industry especially, in the area of inventory control. Additionally, the study on inventory management simulation evaluates the existing printing process and inventory management of the industry and found that very poor utilization of resources and there are no considerations of holding cost and or ordering cost while placing order for inventory (Tesfaye Gashaw, K.J., 2014).

2.5.3.3: Arena Software for Simulation Modeling & Analysis

Arena software is used for modeling and simulation of any business. It is helpful to analyze the impacts of changes, which may include manufacturing process, warehousing and service systems. Among different gains from using Arena are customer services, customer management systems, supply chains that include warehousing, transportation, and logistics systems. The two (2) advantages of using Arena software are that it functions as both input and process analyzers.

As presented in Arena Simulation Users' Guides; "The Arena Input Analyzer functionality includes fitting a distribution to sample data. The user can specify a particular class of distributions and request the Input Analyzer to recommend associated parameters that provide the best fit. Alternatively, the user can request the Input Analyzer to recommend both the class of distributions as well as associated parameters that provide the best fit."

Likewise, "The Arena Process Analyzer (PAN) is a tool that can be used to execute Arena simulations and analyze the results. In PAN terminology, a Control is a decision variable that you may change, such as the value of an Arena Variable, the Capacity of a Resource, the Replication Length or Number of Replications. A Response is a simulation output that would evaluate, for example, average number customers in queue, and wait time or utilization. Their Scenarios defined by specifying the values of the controls, running the simulation and analyzing the results. PAN gives plots and confidence intervals for responses, as well as providing a statistical procedure for determining the "best" scenario."

2.5.3.4: Arena vs. Other Software

There are many tools used to analyze discrete event simulation. Nineteen (19) of these tools used for the study are given under six categorized cluseters. According to a study conducted and given with the help of figure 2, blow; among these noneteen (19) softwares, Arena has got the top rank in its preference to be used by scoring 9.9 for simulation puposes. The second is ProModel (7.6), while the third (7.2) is FlexSim. For the detail please refer to figure 2, below. According to Dias and the memebr of the study group, the result of Arena was verified by using different parameter to compare and analyze their strength and weakness, and thus found Arena the best tool of all others for discrete event simulation purpose (Dias, Luís M. S.; Vieira, António A. C.; Pereira, Guilherme A. B.; Oliveira, José A., 2016),

Figure 1: Summary of Final Score of each tool and Ranking Comparison 2006-2011

DES Tools	WSC	DOCS	REVIEWS	SOCIAL	WWW	Growth	tot. (WSC docs social WWW)	Rank 2016
Arena	10	10	10	10	9	10	9,9	1
ProModel	10	9	9	5	9	5	7,6	2
FlexSim	6	7	7	9	8	6	7,2	3
Simul8	6	7	9	7	6	8	7,23	4
WITNESS	8	8	9	7	8	4	7,2	5
ExtendSim	7	8	8	4	5	5	6,2	6
Simio	6	6	4	5	8	9	6,1	7
Plant Simulation	1	6	7	6	7	8	6,1	8
AnyLogic	8	8	8	2	5	7	5,92	9
SIMPROCESS	9	10	4	1	6	4	5,0	10
AutoMod	9	6	7	1	4	4	4,83	11
Micro Saint	4	5	5	0	10	4	4,8	12
QUEST (Delmia)	3	6	4	3	8	4	4,8	13
Enterprise Dynamics	5	4	7	4	4	6	4,8	14
ProcessModel	4	5	1	4	10	3	4,7	15
SimCAD Pro	3	2	5	3	3	5	3,7	16
GPSS World	7	6	2	0	3	4	3,18	17
SLX + Proof 3D	7	3	3	1	3	3	2,9	18
ShowFlow	3	2	5	0	5	0	2,4	19

Source 1: Proceedings of the 2016 Winter Simulation Conference: Figure 8 , PP 1066

2.6: Summary of Literature Review

So far, discussion was made on inventory, including its definition. Inventory management with its definition, problems of inventory management and factors that influence it with its cost classification reviewed or discussed. On inventory management, additional points, like uncertainty issues in inventory management and techniques to use it to measure its optimum cost (ITR, SOR & CSL) discussed, and this is besides discussion on inventory control policies for inventory management. Inventory management in Ethiopia in different sectors, including textile sectors also reviewed, and used to clearly reformulate the study problem, question and objectives of this research.

Inventory management is vital to any industry so as to play a humongous role since it may be custom-made to reduce costs and boom profits while satisfying customer’s demands by ensuring balanced items of stock are sustained at the right quantity, time and place. Thus, inventory management is seriously used in different industries that use different techniques while managing their inventory. Among the different techniques; economic order quantity, just in time, ABC analysis, continuous review system models and periodic review system models are used repeatedly.

Additionally, when trying to manage inventory, one must consider uncertainty both demand of customer and delivery of the supplier. Due to such uncertainties, the current world is using different tools, which make life easy while managing inventory. Among the different tools to mage inventory, Excel, ERP, and simulation software was found.

Furthermore, the literature reviewed made points on simulation and inventory management that help in selecting appropriate simulation model, either statistic or dynamic, is presented. Since managing garment industry is dynamic and is affected by time, inventory management using discrete-event-simulation is quite advantageous because it is able to simulate the real system and help generate different future scenarios that help in managing inventory. Here, when comparing the static simulation with the discrete event simulation, which is dynamic, one of the limitations observed in static simulation, is that, the simulations do not care about the effect of time on a system. While the dynamic simulations, are concerned with systems, which was affected by time passage. Inventory management was considered as dynamic in which time affects order placed by customer and inventory level of the company. This makes this study to be different from most research conducted in the country. Finally, to choose appropriate tools for discrete event simulation modeling and analysis, from nineteen software identified, Arena simulation software were selected and applied throughout this study. In general, the literature review was conducted to get full insight in inventory management.

In general, limitation observed while reviewing literatures were;

- The real world is vague and full of uncertainty. This fact makes static/deterministic approaches usually unsuitable due to excessive simplicity and relying on mean values. Thus, discrete event simulation is advisable to solve uncertainty problems and needs further studied.

- Country wise, there is not enough research done for the inventory management of the garment industry with discrete event simulation. Most of the researches done on inventory management are on either the traditional economic order quantity inventory management system or they use ABC inventory classification system. Additionally, the researchers have done on the inventory management in the Ethiopian manufacturing sector targeting the medical sector. However, there are not enough studies done for the garment industry inventory management.
- While reviewing literatures it was found that even though there are inventory management researches done for multiple products, at the same time, still there is not enough inventory management in the garment industries, especially on managing multiple garment inventory products.

CHAPTER 3 : METHODOLOGY

3.1: Research Design

This research is to conduct a case study in a privately owned garment factory called GMM Garment PLC, found in Ethiopia. The purpose of this study is to establish simulation model to analyze the inventory management system of the case factory. For the data collection, the preferred and used sampling methods were purposive sampling method. The targeted data sources were primary and secondary data sources. Here, almost all of the data collected are from retrospective information.

3.2: Data Source, Collection, & Tools Used to Collect the Data

3.2.1. Primary Data Collection

Primary data collected from GMM PLC procurement, production process, and inventory records; including from in-depth interview made with GMM management and other staffs. Additionally, time study data collection from production line was major primary data source. Time study was made by developing formats, which enable the data collection to go smoothly. Other data like current inventory level, target stock, reorder point, supplier lead-time, revenue generation of finished products from list to top and different inventory related costs are collected through interview by developing questionnaire please refer annex 8 for interview questions.

3.2.2. Secondary Data Collection

The secondary data like customer demand and supplier lead-time for this research obtained from different reports, company's stock cards, research and/or journal findings, including from other relevant documents. Due to its internal policy, there were a bit limitation to get access to data on purchase and sales record to see the cost effectiveness and profitability of GMM in its operation.

3.3: Data Analysis

The collected data we analyzed using the Pareto chart, inventory related mathematical calculations and simulation-modeling tool of Rockwell, Arena simulation software. After using, Pareto chart to select the samples for the study, other data in relation to the selected samples were collected and analyzed using simulation modeling procedures, as described in the next sections.

3.3.1: Methods of Simulation Model Design Process (Steps)

As presented with *figure 3*, in the next page, to undertake a thorough and sound simulation study, 12 steps are supposed to be followed. These steps are:

- Formulation of Problems that to be resolved:
- Objective setting to answer the study questions:
- Model Conceptualization and/or virtualization: Once the objectives of the simulation are well set, the next step is to build a conceptual model of the real world system using mathematical and logical relationships.
- Collection of Data to input them into the model; the study tried to collect data, which is up to date from the real system. After the collection of the data, probability distribution representation of the data is identified. Here, when identifying the probability distribution representation, arena input analyzer was used. Additionally, when trying to identify the probability distribution representation through the input analyzer, the study considered evaluating the goodness of it test on the fitted data. Here, goodness of fit test is done through, in-site of the researcher, list square error and chi-square test p value. Here, when there are relatively more than one list square error probability distributions, the study considered evaluating the chi-square test p-value. Moreover, when considering the p-value, the study took the higher p-value probability distribution representation of the data.
- Model translation (coding) by using Arena software;
- Verification of the model to check whether design is working properly or not; the verification process is done by debugging the model step by step, By locating the flow paths (logic flowchart) as the model is animating/simulating. Moreover, the final way for the verification of the model is done by running the model under various settings of the input parameter, and checking that the model output results are sensible.
- Validation – model calibration by undertaking iteration process, and then compare the model against the actual system behavior by using the discrepancies between the two to improve the model. For the simulation model to be validated as a real system representative, the model is

compared against the output of the real system. Here, the study checked if the real system is in line with the output of the model made using simulation. Thus, for this study, for the inventory management system, number of entities entering the simulation model must be closer or equal to the number of entities entering the real system. Additionally, this manufacturing system is validated through the comparison of number of products produced per day by the model versus the number of products output of the real system. These outputs values must be equal or closer to each other. This was done using hypothesis tests (Güner, 2008). using output of both the real system and simulation with a 95% confidence interval, the steps are described as follows:

The hypotheses are:

H0: μField = μArena

H1: μField ≠ μArena

$$t_0 = \frac{\mu_F - \mu_A}{S_p\sqrt{\frac{1}{n_F} + \frac{1}{n_A}}}$$

Equation 1: Initial confidence value …………….. **(Güner, 2008)**

$$S_p^2 = \frac{(n_F - 1)S_F^2 + (n_A - 1)S_A^2}{n_F + n_A - 2}$$

Equation 2: pooled mean variance ……………... **(Güner, 2008)**

Where,

μ_F is the mean throughput from the field

μ_A is the mean output rate from the ARENA model

n_F is number of field samples

n_A is number of replications or runs of the model

S^2_F is variance of throughput from the field

S^2_A is variance of output rate from the ARENA model

S^2_p = is the pooled mean variance

- Experimental Design that is to be made concerning the length of the initialization period, the length of simulation runs, and the number of replications to be made of each run. Here, this study the experimental design is concerned with the replication number for the model. Thus, the study used the following steps for fining the number of replication that the simulation should run.

Step one: input initial replication number in the simulation model and run it fully/till the end.

Step two: find out values/output of the simulation for each replication

Step three: find the average and standard deviation of the values of / outputs of each replication number.

Step four: find out the half width of the output which we are concerned of from the simulation report.

Step five: use the following formula and student t test table in annex 1 to calculate the proper number of replication for the simulation model.

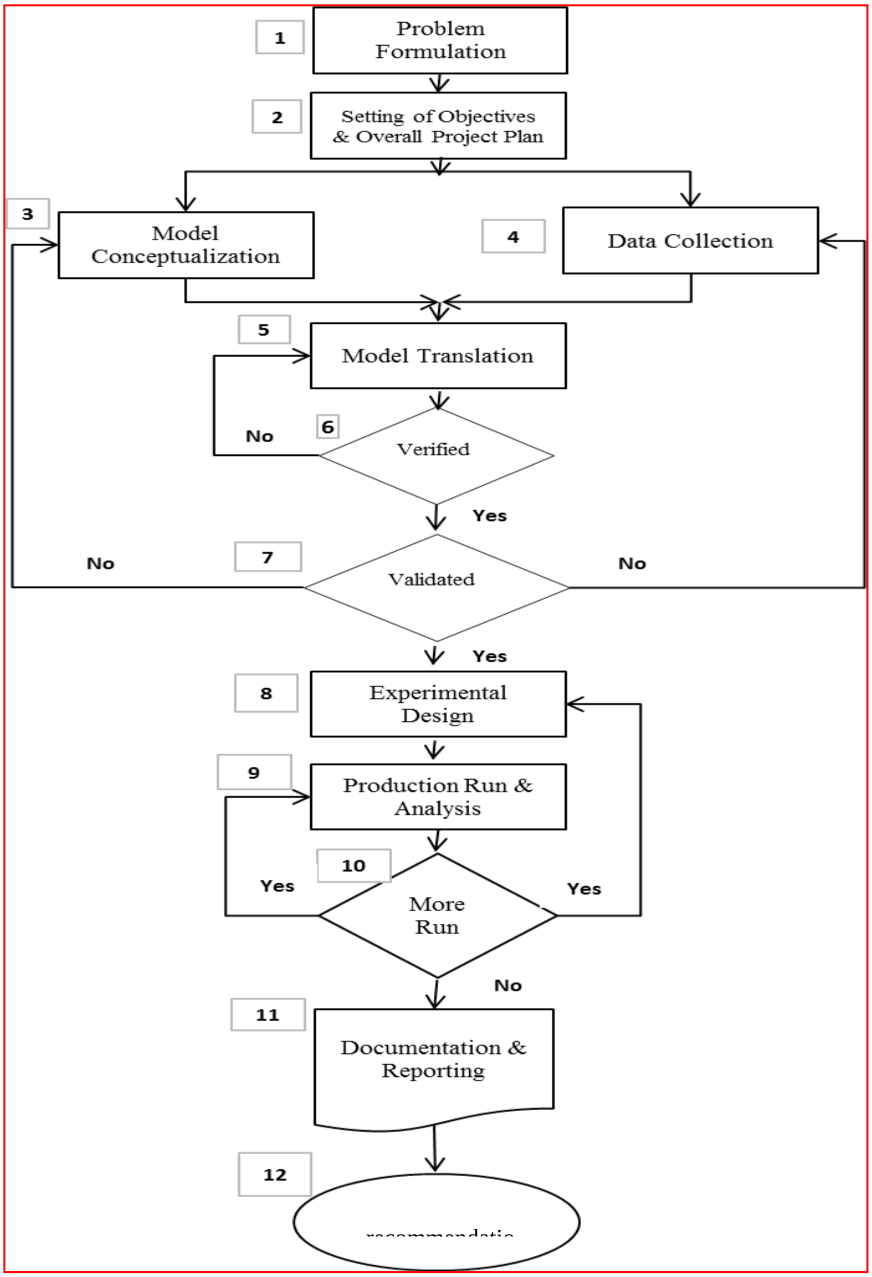
$$n = t_{2n-1,1-\alpha/2} \, (s^2/h^2)$$

Equation 3: replication number . . . . (Kelton, 2015)

- Model product run & analysis;
- More run, if necessary;
- Recommendation for the purpose this model developed for (Jerry Banks, John S. carson II, Barry L. Nelson, David M. Nicol, 2005).

Furthermore, as the best alternative software to use for simulation and analyis, based on the study conductted; Arena was verified, using different parameter, and ranked the best alternative software vs. others for discrete event simulation modeling and analysis (*See Figure 1*).

Figure 2: Visualized Steps in Simulation Model Study



Source 2: Jerry Banks, J. S. (2005). *Discrete-Event System Simulation FouRTH EDITION.* Pearson Book

3.4: SAMPLE SIZE

In this study, Pareto analysis was used to sample & select study products that are the most revenue generating. The revenue generation is shown in annex 3 Please refer the figure below.

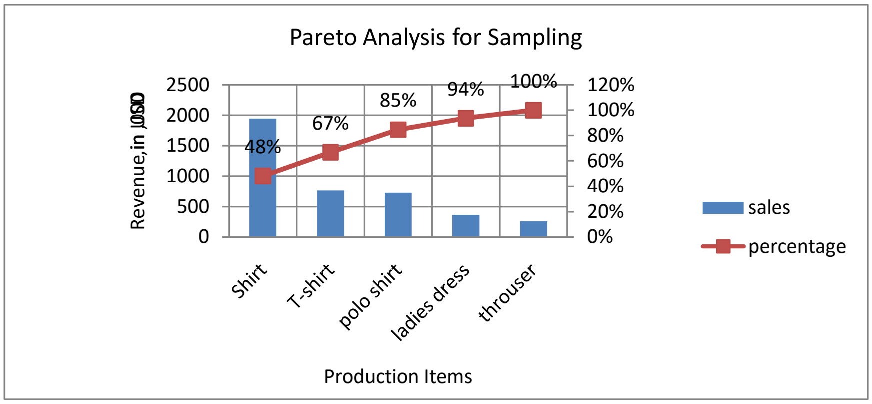


Figure 3: Sales Pareto chart

The revenue generated from the sales of the products of T-Shirt and Shirt of the factory is accounting for about 80% of the total revenue obtained by the factory. Additionally, since the most revenue generating products are selected to be shirt and T-shirt, the study also chose raw materials that are their inputs. These raw materials are : knitted fabric, woven fabric, sewing thread and buttons (*See* Table 1, below*)*.

no	Study sample	list
1	Raw materials	Woven fabric, knitted fabric, Sewing thread and button
2	Finished goods	Shirt and T-shirt products

Table 1: Study samples

After the overall data was collected, a one-year demand and supply data were selected from & taken for the purpose of the study. To model the inventory management system of GMM garment industry.

CHAPTER 4 : RESULTS & DISCUSSIONS

4.1: DESCRIPTIVE RESULTS

4.1.1: GMM Garment PLC Profile

GMM Garment PLC is a privately owned limited company, established in Addis Ababa, in 2004. The owners of the factory are three Female Ethiopian entrepreneurs. They have established this factory on 2,000 M^2 land size, in Nifas Silk Lafto Sub City, Woreda 12. GMM Garment factory has employed 310 permanent employees, and most of them are females. GMM Garment Factory has been producing different kinds of garments and textiles for export market. Among are, shirt, T-shirt, jacket, trousers and masks (Managment, 2021)

This factory is producing many types of garment for different customers found in the local and international markets. Like other in garment industries, GMM garment factory has two-inventory management system that includes raw materials warehouse for raw materials, garment accessories, machine spares. The other is warehouse for finished goods. The major products that produced in this factory are shirts, t-shirts, women dress, trousers, polo shirt and masks whereas shirts and t-shirts are the target of this research.

4.1.2: Data Presentation on Inventory Control Policy

For this study, GMM garment industry inventory seen as a raw materials and finished goods. Here the raw materials are knitted fabric, woven fabric, sewing thread and button while shirt and T-shirt are listed as finished products.

4.1.2.1: Inventory Control Policy for Raw Materials

GMM garment industry use the min-max (S, s) inventory control policy while managing their inventory. Here, the factory has a target stock level, a replenishment point and order quantity. The order quantity would be according to the size of the current inventory, target stock and the replenishment level. This means, the raw material amount that the company orders when the current inventory level reaches the replenishment point and or if the current inventory level is below the replenishment point. Thus, when this point reached the factory orders the amount of target stock minus current inventory level. However according to the information from factory, there is no policy that attached to manage thread and button raw material. These two raw materials are just bought once a year based on the yearly production capacity of the industry since the capital needed is lower to buy them, as presented with Table 2, below.

no	Item type	unit	Target stock	Initial inventory	Replenishment level
1	Knitted fabric	kilogram	45,000	25,000	20,000
2	Woven fabric	meter	250000	170000	100000
3	Sewing thread	gross	-	1350	-
4	buttons	gross	-	105	-

Table 2: inventory type with level for raw material

4.1.2.2: Inventory Control Policy For Finished Products

Similar to raw material, GMM garment industry manages its finished goods inventory using the fixed order quantity (R, Q, r) inventory control policy. Here, R targets stock, Q is order quantity or batch size and r is the reorder point in which inventory is replenished, according Table 3, below.

no	Item type	unit	Target stock	Initial inventory	Reorder point level	Batch size
1	shirt fabric	pcs	118000	25000	10000	900
2	T-shirt	pcs	5000	600	1000	1752

Table 3: inventory type with level for finished product

Additionally, holding cost is determined for all raw material storage, that include knitted fabrics, woven fabric, sewing thread, and buttons even if their holding cost are not the same. According to the in-depth interview conducted with warehouse operator of GMM garment, 50% of the warehouse held by woven fabric, while 30%, 15% held by knitted fabric, finished products, respectively. The remaining 5% space is to both thread and button inputs.

The discussion on the results of this research is to answer the questions that set, and then achieve at the established objectives. The process of achieving these objectives include: measuring the existing inventory management performance; determining the inventory management model with minimum inventory related cost, and lower customer waiting in line and give recommendation on how the manufacturing department should be performing better.

Discussion with Key Informant- COO- on GMM Stock-out Policy

According to the industries chief operational officer (COO), the company at least encounters stock out twice a year for the woven fabric. This stock out is measured in number of required inventory. Thus, for the woven fabric the stock out per year reach 9177 meter this yields 6650 pcs of shirt. For the knitted fabric most of the order is through the CMT process and due to that stock-out do not occur that much. However, for the company's clothing line, which uses a make to stock system, stock out occur once within two years. Therefore, according to the COO of GMM garment stock out of 1,422 pcs of t-shirt, which comes from 711 kg of knitted fabric, may occur.

4.1,2.3: Uncertainties in Managing GMM Garment inventory

In inventory management, uncertainty makes difficult for businesses to maintain the inventory at its optimal level. When one says uncertainty, it includes demand uncertainty, lead-time uncertainty and manufacturing uncertainty (manufacturing bottlenecks). Like different manufacturing industries GMM garment industry also face the demand and manufacturing uncertainties. The following figure shows the demand uncertainty of both shirt and T-shirt, as fluctuate from time-to-time (See Figure 5).

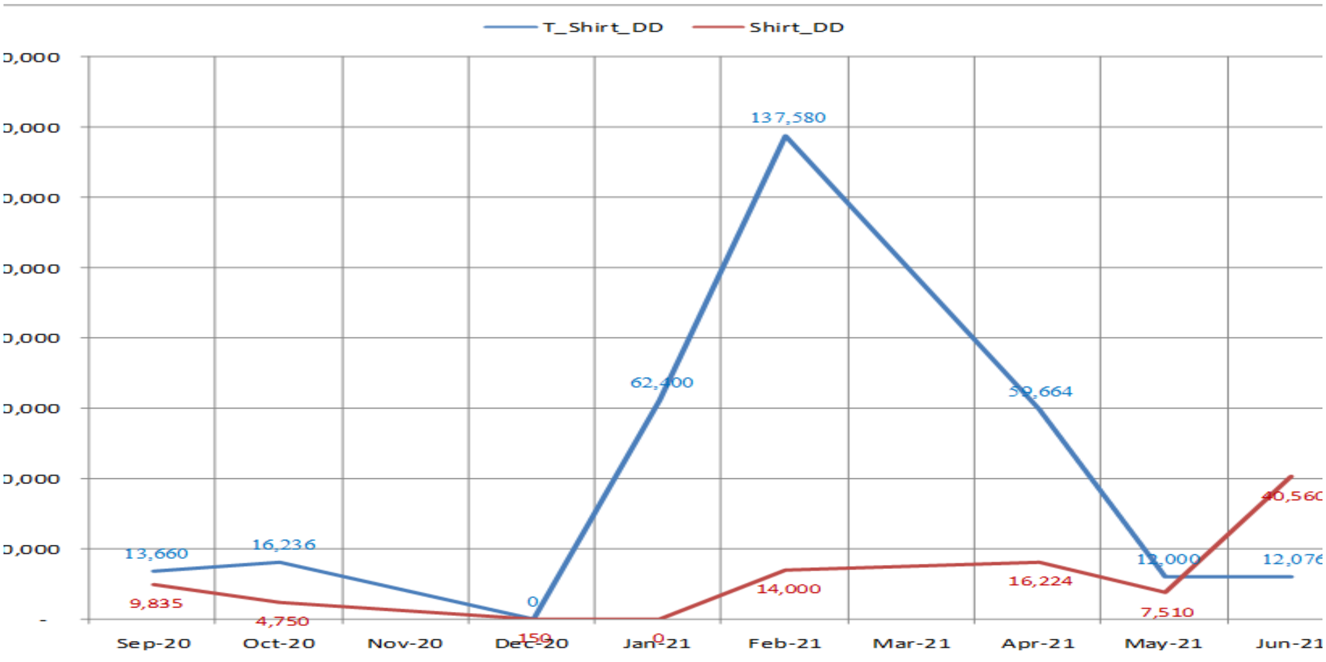


Figure 4: Shirt and T-shirt demand

As presented with the same figure. T-shirt order fluctuates from 0 orders in December 2020 to 40,566 in June 2021. For the shirt, the demand order fluctuates from 150 in December 2020 to 88,860 in February 2021, both indicating demand's uncertainty.

4.1.2.4: Capacity Utilization Level of Available Resources

Furthermore, the factory's demand and lead-time uncertainties have huge impact while managing inventory. The uncertainties can be the bottlenecks to hinder manufacturing process. Here, the production bottlenecks are the resources with poor utilizations and process that resulting to a lot of waiting time. Therefore, after modeling the production section of GMM garment factory, different results in relation to poor capacity utilization and high waiting time found. According to the following figures, poor capacity utilization for production of the shirt (See Figure 6) and T-shirt (See Figure 7) observed. For the details, the data inputs for modeling the production section capacity of the factory to produce shirts and T-shirts given in Annex 4 and Annex 5, respectively.

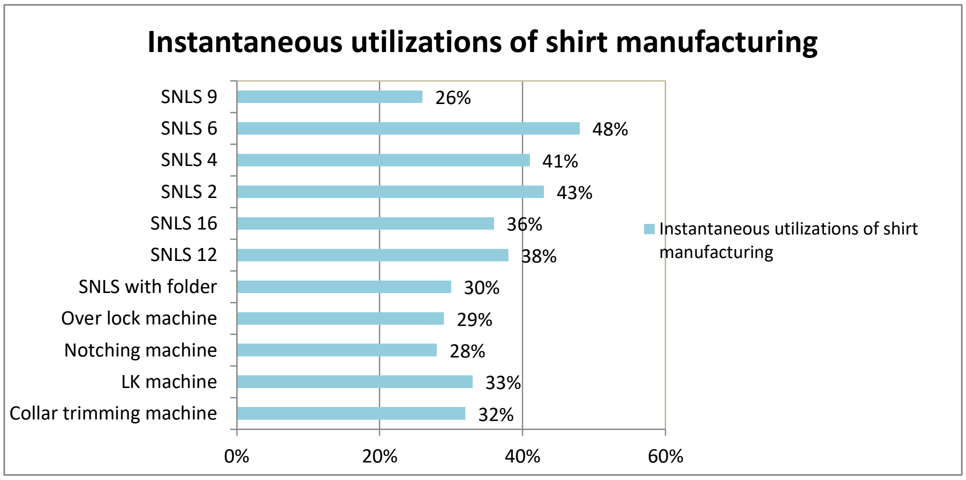


Figure 5: shirt manufacturing poor utilization of resources

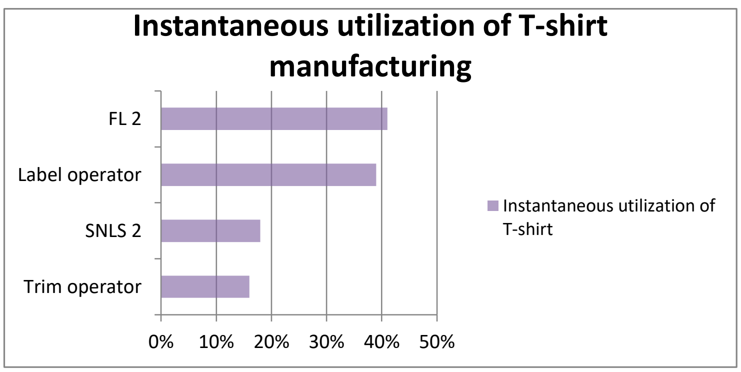


Figure 6:T-shirt manufacturing poor utilization of resources

To produce shirt, the factory should pass through 34 processes, as presented in the annex parts of this document (See Annex 4) . However, among these 34 processes of shirt production, 11 of them were producing below their capacity, as their instantaneous capacity utilization is below 50% (See figure 6, above). This capacity underutilization could lead to lower productivity and high lead-time for the delivery of products, which further lead the factory to face customer backlash.

Similarly, among the 15 process of T-shirt production process, 4 of them have poor capacity utilization that can impact on the productivity of the manufacturing process (See Figure 7). Therefore, like underutilization of capacity during the production of shirt, this could also lead to poor customer satisfaction due to poor sales service delivery.

4.1.3: Performance Indicators of Inventory Management

One of the Key Performance Indicators (KPIs) for measuring the performance level of inventory management of GMM Garment factory is the inventory movement that particularly related to inventory turnover and occurrence of obsolete inventory.

Inventory turnover ratio indicates the movement of inventory while the occurrence of obsolete inventory indicates how poor or inadequate the inventory management system operates. Therefore, using the data collected for the period that range from July 2020 to July 2021, measurement for both products-shirt & T-shirt presented below.

4.1.3.1: Inventory Turnover Ratio of Shirts & T-Shirts (July 2020 To July 2021)

The Results of Inventory Turnover Ratio of Shirts:

ITR = cost of goods sold / average inventory level

Average inventory = (beginning inventory + ending inventory)/2

Beginning inventory 2,229 pcs of shirt

Ending inventory 1,804 pcs of shirt

*ITR = 93,029*130 birr / ((289,800 birr+234,600 birr)/2)*

ITR = 12,093,770 birr /262,200 birr

ITR = ***<u>46.12 times</u>***

Therefore, according to the result obtained for ITR, above, shirts have been on-hand for about 7.6 days (365/46.12 = ***7.6 days).***

The Results of Inventory Turnover Ratio of T-Shirts:

ITR = Cost of goods sold / average inventory level

Beginning inventory 3,511 pcs of T-shirt

Ending inventory 4,395 pcs of T-shirt

*ITR = 313616*80 birr / ((456471 birr+571428 birr)/2)*

ITR = 25089280 birr/513949 birr

*ITR = **48.81times***

*Similar to the shirt, according to the result obtained for ITR, above, T-shirts have, therefore, been on-hand for about 7.4 days (365/48.81 **= 7.4 days.***

*inventory days on hand for T-shirt would be 365/48.81 = **7.4 days***

Since the factory is international exporter, specifically exports its products to the USA, it is clear that it could face stiff competitions from all-over the world. In this regards, export, GMM is not doing well, and this is according to the apparel industries that exported their product to the US market. Therefore, a benchmark for performance of good inventory turnover of apparel industry, 148 days or every 2.5 days inventory-sales-out for the year 2020 used as a best indicator (readyratio, 2021).

4.1.3.2: Obsolete Inventory

It is clear that manufacturing industries must come up with a plan for when different types of inventory become obsolete or dead. As mentioned in the problem statement of this study, GMM garment factory has made excess order amount of fabric to manufacture mask, and yet not be able to manufacture any mask and the imported inputs rather become obsolete because of poor demand and supply forecast and inadequate inventory management system to determine inventory on-hand. Hence, this obsolete inventory still ignored for more than a year and is costing the company a holding cost and ordering costs in addition to the tied up capital of about 445,000 birr with which it purchased. Thus, total inventory cost for the obsolete inventory is: 40,000 for transportation and 290,000 birr for ordering, 330,000 birr.

4.1.4: Costs of Inventory Management

4.1.4.1: Inventory Ordering Cost

Here in this study ordering costs is in the form of transportation cost and salary for the purchase order preparation to the accountant. See the following table:

no	Ordering cost Types	Cost (Birr/Year)
1.	Transportation cost per delivered order (from port Djibouti to Addis Ababa) for two shipments with 40 feet container. for both woven and knitted fabric	40,000
2.	Transportation cost per delivered order inside Addis Ababa for thread and button.	2,500
3.	Purchase order preparation cost (yearly salary of one purchaser)	420,000

Table 4: ordering cost

It is important to note here that all the raw materials ordering costs assumed to be the same. Likewise, the purchase order preparation cost for the raw material also distributed according to the size in which the raw materials hold according to section 4.1. Therefore, the inventory ordering cost for the raw material is shown with table 5, below.

No.	Item type	Order frequency	Space holding	Maximum ordering cost (transportation + ordering cost for purchase deploying)
1	Woven fabric	2	50%	290,000 birr
2	Knitted fabric	2	30%	246,000 birr
3	thread	1	2.5%	2500+1050= 13,550 birr
4	button	1	2.5%	2500+1050= 13,550 birr

Table 5: total ordering cost

4.1.4.2: Inventory Holding Cost

These holding costs, as the detail of which explained below, includes salary, power,, insurance and depreciation.

1. **Salary of Warehouse Employees.**

   The salary of two employees working in the warehouse is about Birr 216,000/year where Birr 200,000/year for stock recorder, and Birr 16,000/year for warehouse security officer.

2. **Warehouse Electricity Costs**

   Electricity cost = number of lamps x the amount of wattage used (in kwh) x lights on per day x electricity rates For 2020 both 2021
   Electricity cost /day = 12x25 (0,025kw) x 10 hour x Birr 1.019= Birr 76/day
   Electricity cost /year =Birr 76.425 x 365 = Birr 27,895/year

3. **Insurance Cost Per Year Amounts Birr 90,000**

4. **Depreciation Cost of Racks**

   GMM stores its raw material on racks. Here, the holding cost resides on the depreciation of the racks.
   The industry has 25 section of 8 foot pallet racking system with three shelves, each purchased with 50,000 birr.
   Therefore, using the straight-line depreciation methods (SLD), depreciation rate per year is:
   Rack depreciation = (purchase price – salvage value)/use-full life
   = (50,000 - 45,000)/15 years
   = **334 birr/year**

Therefore, the calculation for holding costs could be, as presented below:

Holding cost per year = Birr. 216,000 + Birr 27,895 + Birr 90,000 + Birr 334 = Birr **334,229**

As described in the previous section. Inventory holding cost distributed according to the percentage of storage space occupation of each items of all the raw material. Before calculating holding cost for each item, note that not all items have equal holding cost, rather each it has holding cost with respect to the amount of space that it occupied in the warehouse. Thus, the holding cost for each raw material is shown in the table below.

No.	Item type	Space holding	Maximum inventory	current inventory	Average inventory	Holding cost (birr)	Holding cost per Item (unit)
1	Woven fabric	50%	250000mtr	170000mtr	210000mtr	166,947	0.79 birr
2	Knitted fabric	30%	45000kg	25000kg	35000kg	100,168	2.86 birr
3	thread	2.5%	1900 gross	1350 gross	1650 kg	8,347	4.39 birr
4	button	2.5%	154 gross	105 gross	129.5 kg	8,347	64.4 birr

Table 6: total holding cost

4.1.4.3: Total Inventory Cost of Raw Material

Total inventory cost of raw material is determined by averaging them as presented below.

Total inventory cost of the factory is equal to average total holding cost plus average total ordering costs that amount Birr 846,909 whereby 54% allocated to woven fabric and 41% to Knitted fabrics while 3% each allocated to thread & buttons, respectively. Thus, the average inventory total cost of GMM garment factory is presented with the following table (See Table 7).

No.	Item Type	Order	Inventory Ordering Cost (Birr/Year)	Holding Cost (Birr/Year)	Total Inventory Cost (Birr/Year)
1	Woven fabric	2	290,000	166,947	456,947
2	Knitted fabric	2	246,000	100,168	346,168
3	thread	1	13,550	8,347	21,897
4	button	1	13,550	8,347	21,897
	TOTAL				846,909

Table 7: total inventory cost

4.2: RESULTS OF SIMULATION MODELING & ANALYSIS

One of the steps of simulation modeling includes modeling inputs to represent proportionally in probability distribution expression of the all periodically available raw materials used for the production of shirts & T-Shirts. After modeling the inputs using the arena input analyzer software, the best-fit probability distribution expression selected & used in this study.

The collected data from sales report and stock card on demand arrival, and lead-time used to model and determine inputs for the shirt and T-shirt production. Figure 8 & Figure 9, below, show the size and arrival of shirt & T-shirt demands of GMM factory. It is quite clear to assume from the same figures, below, that both demand size and demand arrival rate are extremely stochastic. Based on the finding on the figures, below, the probability distribution of different inputs along with their respective expression and fitted diagrams presented with the table that follows (*See* Table 8). This data is the representation of input (raw material) and finished goods inventory models, respectively.

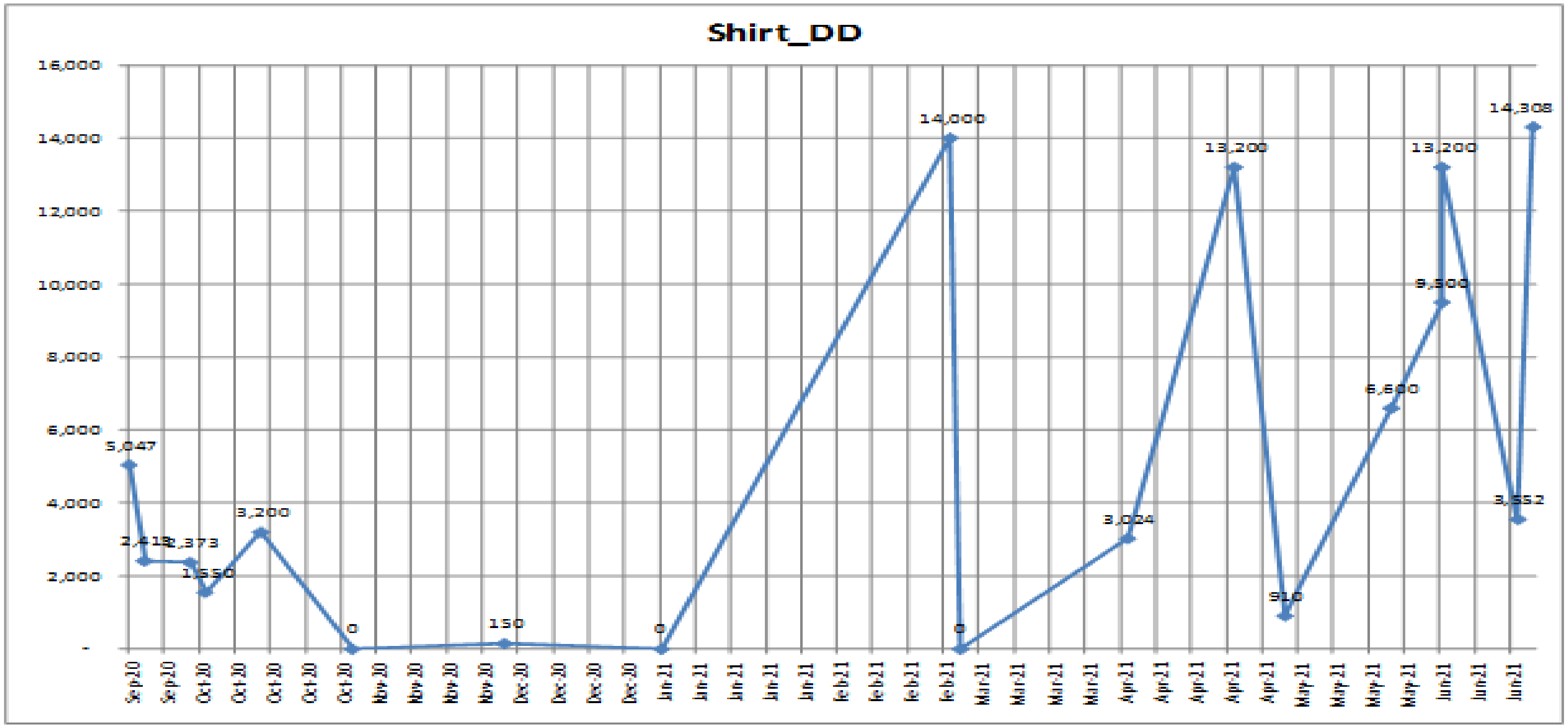


Figure 7: Trends of Shirt demand

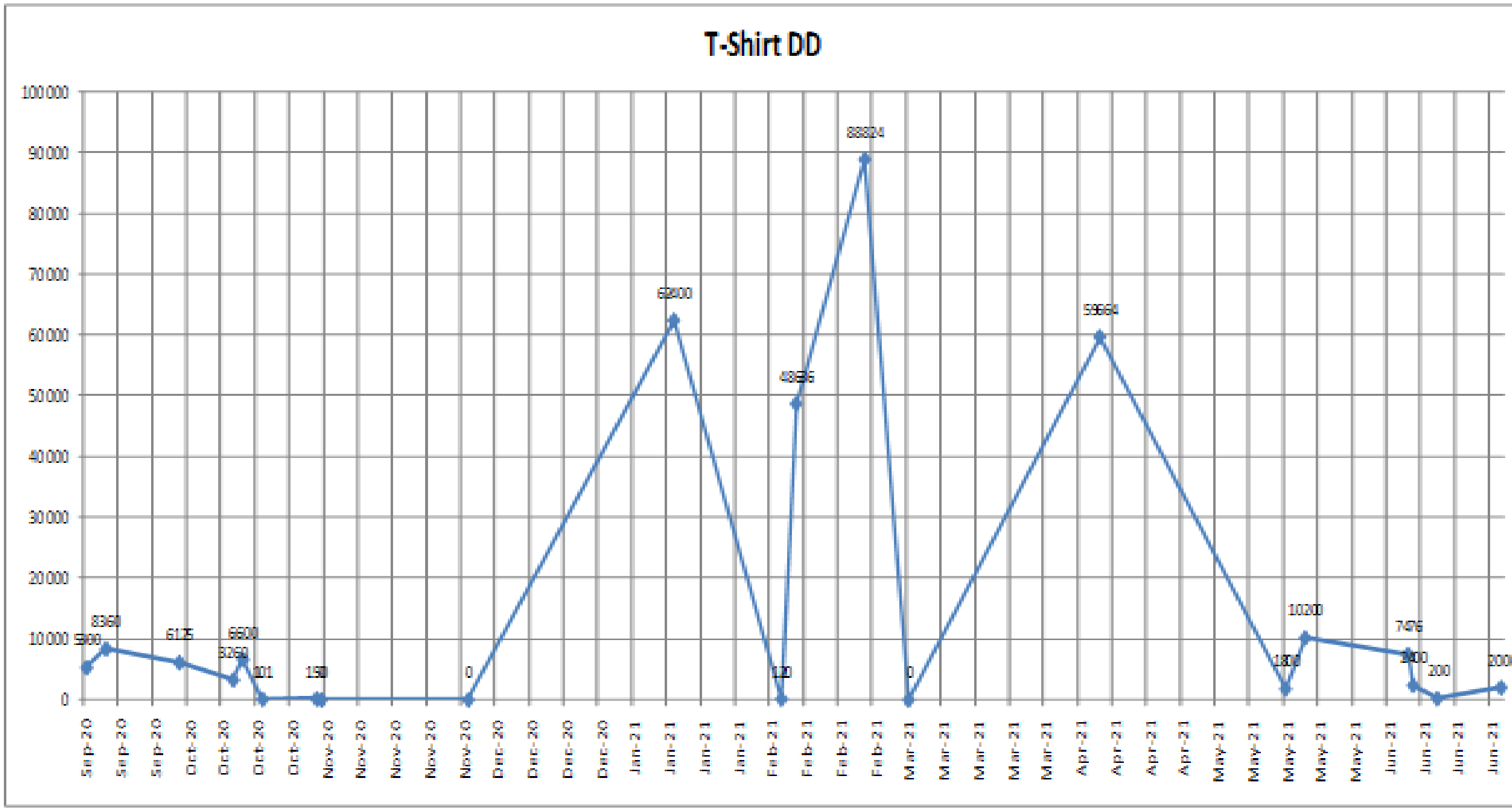


Figure 8: Trends of T-shirt demand

Table 8, below, further shows the probability distribution of different inputs along with their respective expression and fitted diagrams. This data are the representation of input for raw materials and finished goods inventory models, respectively. So, from the data used to develop Figure 8 & Figure 9, above, the probability distribution for both the demand size and arrival presented in the table below. This result was from the data collected from the stock card and other data sources of GMM garment factory.

Additionally, the data input for probability distribution function the input data for thread and button demand presented in the annex 2.

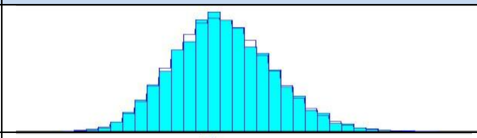
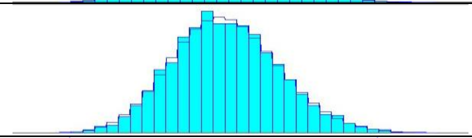
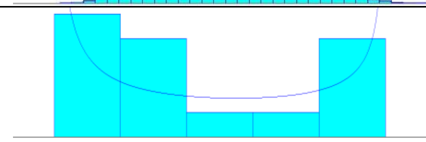
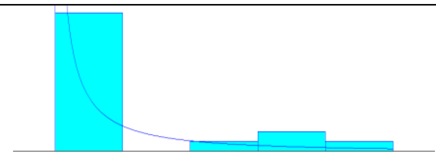
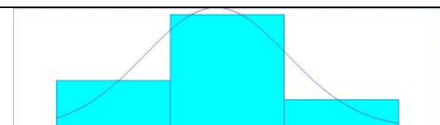
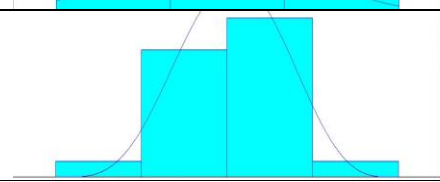
no	variable	Minimum error	Distribution expression	Distribution fitted diagram
1	Shirt Demand arrival	0.000141	POIS(16.7)	
2	T-shirt Demand arrival	0.000160	POIS(20.6)	
3	Shirt demand size	0.01848	150 + 1.42e+004 * BETA(0.349, 0.467)	
4	T-shirt demand size	0.017687	101 + WEIB(7.9e+003, 0.414)	
5	Button demand size	0.001031	NORM(1.9, 0.624)	
6	Thread demand for shirt	0.000804	0.5 + 4 * BETA(5.38, 5.02)	

Table 8: Probability distribution of model inputs

4.2.1: Model Descriptions for Raw Materials Inventory Management System

After the data collected and converted into their respective probability distributions functions, the next step was modeling the system by using Rockwell Arena. The inventory system flow for the raw materials that modeled has shown in the figure below (*See* Figure 1). Note here that this model of the system is similar to all the raw material expect, the input to get the results are different as per the respective item, that is woven fabric, knitted fabric, thread and button.

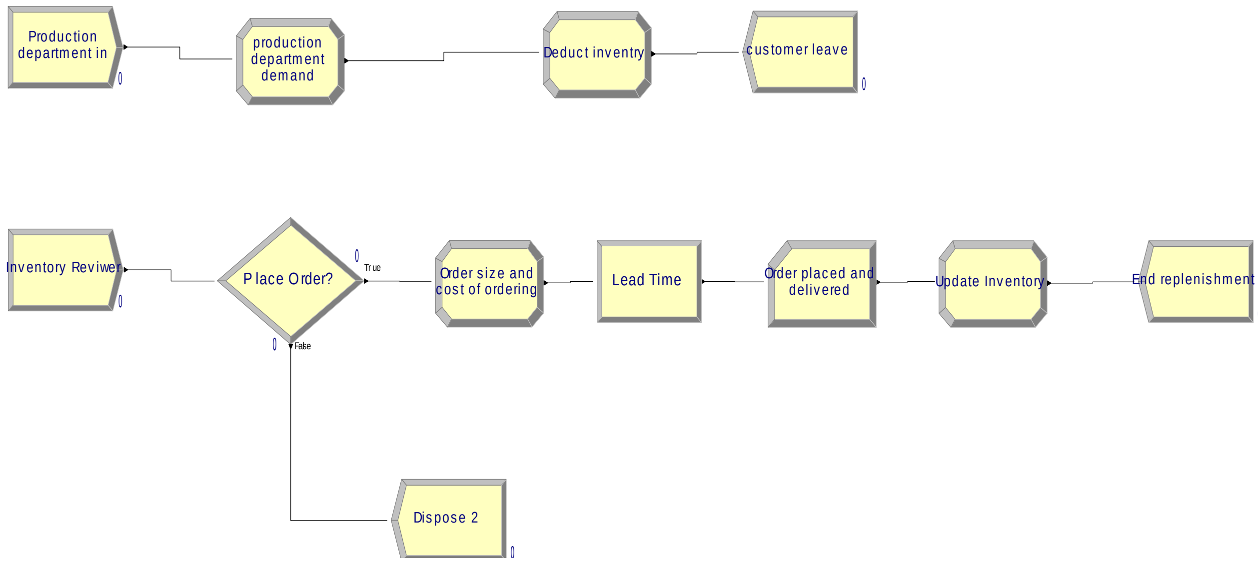


Figure 9: Raw material inventory management model

According to the above figure (*See Figure 10*), the upper part of model shows that either the customer of the finished products or the production section for the raw material comes to the inventory (warehouse) to get what it demands. After placing its demand, the warehouse keeper checks its inventory. After checking the inventory, if the demand of the production department is lower than the inventory on hand, then the customer or the production section will get what it asked for and leave the system. However, if the demand of the customer is higher than the inventory on hand, the customer gets what is on hand of the warehouse and leaves the system. Here, the remaining unfulfilled demand would be counted as a stock out or shortage.

Additionally, it is quite important to know that in the model there will not be lost customers since the warehouse and the production section work together and the customers never cancels order. In other word production section, the customer, and the warehouse, the supplier, are one unit. Moreover, it is important that every time we see a shortage within the system it mean that there is a stock-out.

Furthermore, as described elsewhere in this document, the inventory control system for the raw material inventory management system is the min- max system which is also known as (s, S) inventory control system at the warehouse.

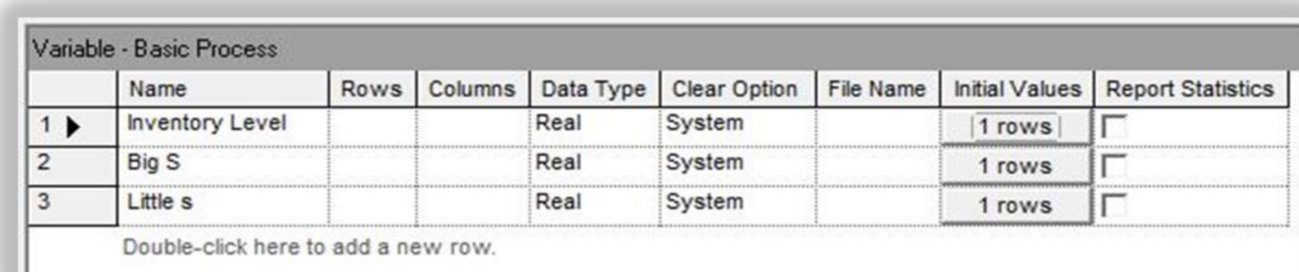
Here, the second part of the model below the production section demand flow, shows how the inventory of the industry reviewed. The inventory reviewer comes every month to review inventory if the inventory level is less than or equal to small s, then the reviewer will order amount of Big S, target stock, minus current inventory level. Here, inventory level is filled until it reaches big S, the target stock. The other major part of the model is that the time it takes for the delivery to reach the industry. This time is the lead-time. The lead-time modeled in the system as a uniformly distributed function, which is between 60 days and 180 days for both the woven and knitted fabrics. But, for the thread and button, GMM gets it raw material from local importers and it take no more than one day.

There are different variable that are fed into arena while modeling the inventory management system. Therefore, for the modeling of the simulation, the study used initial values, which are shown in the table below.

no	Item type	unit	Target stock, big S	Initial inventory	Replenishment level, little s
1	Knitted fabric	kilogram	45,000	25,000	20000
2	Woven fabric	meter	250,000	170,000	100,000
3	Sewing thread	gross	-	1350	-
4	buttons	gross	154	105	85

Table 9: initial values for raw material simulation modeling

These above data is inserted into arena using the variables tab in the Dialog spreadsheet. This is shown in the figure below.



Variable - Basic Process

	Name	Rows	Columns	Data Type	Clear Option	File Name	Initial Values	Report Statistics
1	Inventory Level			Real	System		1 rows	
2	Big S			Real	System		1 rows	
3	Little s			Real	System		1 rows	

Double-click here to add a new row.

Figure 10: variables inputs in arena simulator

Additionally, other variables with initial values inserted in the simulation. These variables are:

- **Total ordering cost:** this value is found in chapter four table 5
- **Holding cost per inventory:** this value is found in chapter four table 6
- **Number of stock-out:** the number of stock out, is inserted as the amount of woven fabric which cannot be satisfied. The following table shows the number of stock out raw material occurrences in the factory while managing inventory. But for the simulation number of stock out is inserted as the following formula;

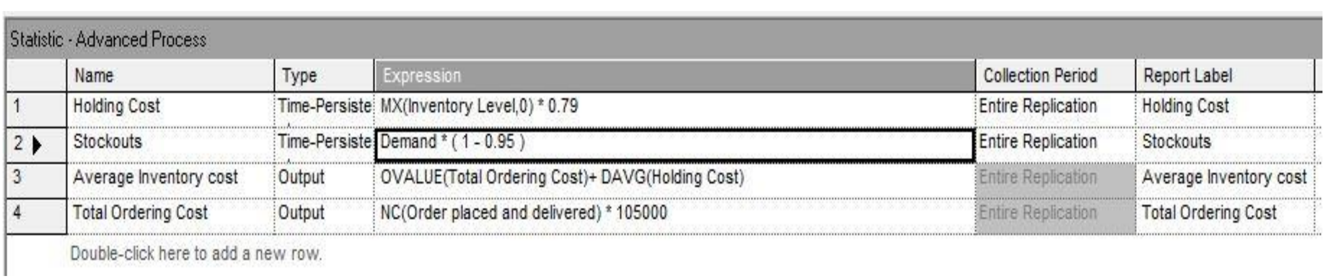
  Stock out = number of order (1- fill rate).

  The fill rate assumed as 95%.

no	Item type	Stock out number per year	Number of order
1.	Woven fabric	9177 meters	2 (order 1 = 5,372 mtr and order 2 =3,805 mtr)
2.	Knitted fabric	7112 kg	2
3.	thread	zero	1
4.	Button	zero	1

Table 10: current stock-out of raw material in GMM

The table above shows, the amount of stock out occurred in the factory. The stock out of woven fabric occurred twice form two different orders. The stock out for the knitted fabric occurred during one order. These, values are inserted the simulation modeling tool, Arena, statistics spread sheet. See the figure below. Note that the figure below shows only for the woven fabric.



Statistic - Advanced Process

	Name	Type	Expression	Collection Period	Report Label
1	Holding Cost	Time-Persiste	MX(Inventory Level,0) * 0.79	Entire Replication	Holding Cost
2	Stockouts	Time-Persiste	Demand * (1 - 0.95)	Entire Replication	Stockouts
3	Average Inventory cost	Output	OVALUE(Total Ordering Cost)+ DAVG(Holding Cost)	Entire Replication	Average Inventory cost
4	Total Ordering Cost	Output	NC(Order placed and delivered) * 105000	Entire Replication	Total Ordering Cost

Double-click here to add a new row.

Figure 11: initial statistic input in arena simulator

4.2.2: Simulation Replication Number

Before using the output data of the simulation, the study tried to calculate the number of replication to find the optimum value for the simulation with the help of the following formula;

$$n = t^2_{n-1,1-\alpha/2} (s^2/h^2) \text{ …………… (Kelton, 2015)}$$

<u>Where</u>:

n is number of replication

$t^2_{n-1,1-\alpha/2}$ is t-score value

s is standard deviation of the sample

h is half width of the sample.

Alpha is one tail, alpha/2 is two tail value.

Alpha = 1 - confidence interval

Confidence interval is taken as 95%

In addition to the above formula, it is advisable to use the student t distribution when we are talking the standard deviation of a sample. In this case, the sample size is 10. This sample is taken by the researcher's convenience. Here the sample size may be taken as whatever value. Additionally the size of the sample is lower than 30, thus we use the student t distribution.

After running the simulation for initial replication number of 10, we get a half width of 11,574.58; and average values for number of shirt assembled for each replication is shown in the table 11 below.

replication	Value
1	255395
2	215149.05
3	23001.86
4	234156.78
5	263761.58
6	251736.94
7	254545.54
8	236250.15
9	223761.28
10	254691.99
Average	221245.017
Standard deviation	71388.58
Half width	11574.02

Table 11: woven fabric inventory management model replication number

The initial number taken for replication taken is 10. Thus, degrees of freedom will become n-1, that is, from where the initial replication number used to simulate the model. Hence, degree of freedom is nine. The half width of 11,574.02. Taking 95 percent confidence interval, α = 1- confidence interval, 1- 0.95 = 0.05. This is one tail value. Moreover, the two tail value will be α/2 = 0.05/2 = 0.025. After finding the above values from t-student distribution table, the t score value became 2.093. Hence, inserting all the values found in the above formula the number of replication required is 86. Note that, this replication number is used for all raw materials throughout the raw material inventory management system simulations.

4.2. 3: Model verification and validation

To verify the model, the study checked the function of the model under extreme conditions. One condition was single entities is sent to the system and follow it through the model logic. This entity output was in line with the predicted output by the modeler. This entity sent to see if the level of inventory decreases as demand increases. Additionally, one entity, with demand higher than inventory on hand, was sent through the system to trace and soon after the entity pass the predicted step, the model placed order. Here, the researcher expected that at the predicted level of inventory, order would be placed. Finally, as expected, order was placed. Thus, the simulation was verified.

After the verification process, the model was validated. The validation of the model is made by comparing how many times per year that an inventory reviewer, entity 2, got into the system. Thus from the real system it was found out that inventory is review every 180 days. Similarly, when the simulation output was checked, inventory reviewed twice per year. Thus, the model was validated. Additionally using the hypothesis method the model was validated (*See* Table 12, below).

Actual customer demand from the real system		**output from Simulation**	
Sample Data:	642,434,801,1025, 1014,1069,370,661,98,462	Simulation output:	655,434,801,1025, 1014,1069,370,661,98,462
Sample size (n_F)	10	No of rep. (n_A)	10
Mean Value (μ_F)	659.6	Mean Value (μ_A)	658.9
Variance (S_F^2)	104021.6	Variance (S_A^2)	103993.43
Std deviation (S_F)	322.5238	Std dev. (S_A)	322.48013

Table 12: woven fabric inventory model validation

From the results obtained from the above table and inserting it in the formula for hypothesis test mentioned above, Sp is calculated to be 322.5, which in turn makes the t_0 values 0.011. From 't' table at 95% confidence interval, $t_{\alpha/2,n1+n2-2} = t_{0.025,18} = 2.28$ (please refer APPENDIX – 1)

Since $t_0 < t_{\alpha/2,n1+n2-2}$, it implies that there is no significant difference between the means. Therefore, the simulation model is valid. Similarly, the model verification and validation process took place and the model is found to be valid.

4.2.4: Results of Raw Material Simulation Model

The main aim of modeling this raw material inventory of the system is to decrease inventory related cost while decreasing the stock outs. Therefore, after modeling the inventory management system of all raw materials, different scenarios generated so that a system with values which decreases both inventory relate cost and number stock out be achieved. The scenarios were generated using Arena process analyzer. The results forms the process analyzers for each raw material given below.

4.2.4.1: Results of Woven Fabric Inventory Management System Model

The following table (*See* Table 13) shows that the inventory cost and the number of woven fabric stock-out has decreased significantly. Here, the inventory cost decreased from Birr 456,974 to Birr 358,615. Additionally, the number of stock-out decreased from 9177 meters to 702 meters while holding cost increased from Birr 166,947 to Birr 193,615. This is due to the number of order quantity increased since the company is going to place once.

No.	Item type	Before				After			
		Ordering cost (Birr)	**Holding cost (Birr)**	**TT invent cost (Birr)**	**# of stock out (Mtr)**	**ordering cost (Birr)**	**Holding cost (Birr)**	**TT Inven. Cost (Birr)**	**# of stock out (Mtr)**
1	Woven fabric	290,000	166,947	456,947	9,177	165,000	193,615	358,615	702

Table 13: simulation result for woven fabrics inventory

However, this value will only apply to be true if the target stock is taken as 280,000 meter and little s (replenishment level) 200,000 meters. The following figure shows the predicted values how the inventory cost in-relation to the customer demand looks like; the raw data was got form the arena simulation of the shown in the following figure (*See* figure 10).

Figure 13 shows how the demand fluctuates highly throughout the simulation time. but, as can be seen from the figure, the inventory cost is kept between Birr 270,000 and Birr 350,000.

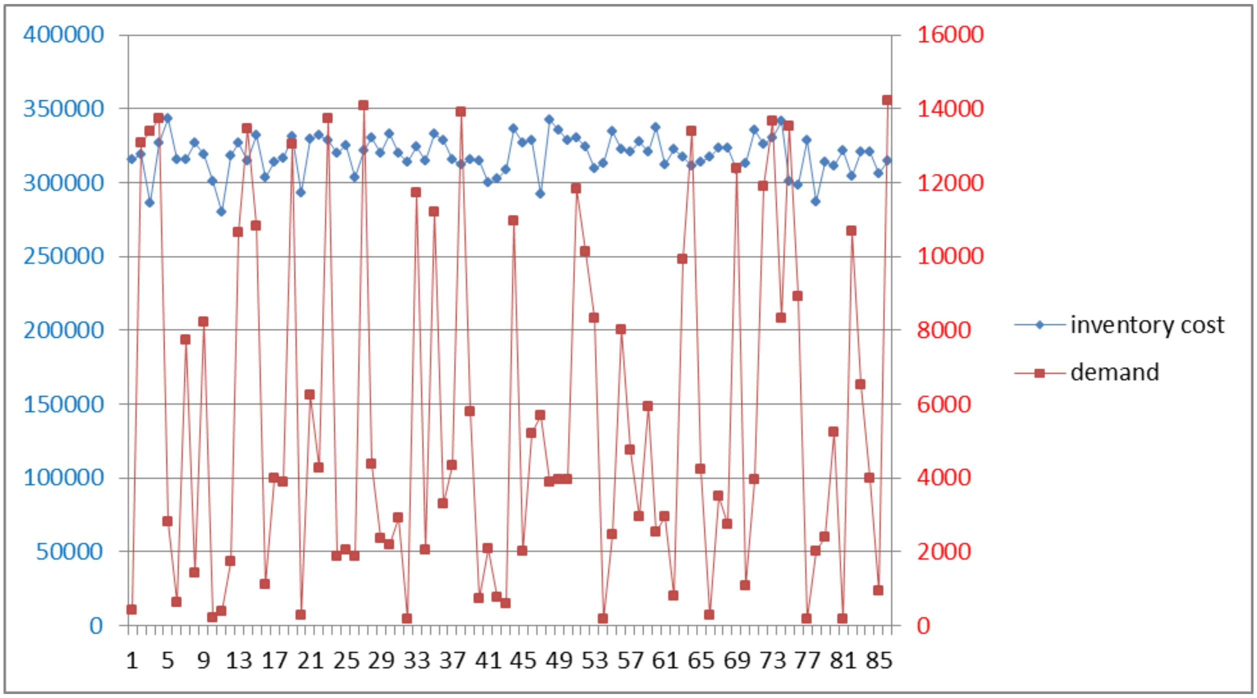


Figure 12: Inventory cost VS demand chart for woven fabric

4.2.4.2: Results of Knitted Fabric Inventory Management System Model

The following table (*See Table 14*) shows the before and the after inventory related cost of knitted fabric which was got through similar procedure of getting the results for the woven fabric.

No.	Item type	Before				After			
		ordering cost (Birr)	Holding cost (Birr).	TT inventory cost (Birr)	# of stock out (kg)	inventory ordering cost (Birr)	Holding cost (Birr)	total inventory cost (Birr)	# of stock out (kg)
1	Knitted fabric	246,000	100,168	346,168	711	103,000	134,738	197,738	130

Table 14: simulation result for knitted fabrics inventory

According to table 14, the inventory cost and the number of knitted fabric stock-out has dropped. The inventory related cost decreased from Birr 266,168 to Birr 197,738. Additionally, the number of stock-out decreased from 711 kg to 130 kg while holding cost increased from 100,168 birr to 134,738 birr.

Similar with the woven fabric ordering, the increase is due to the number of order quantity increased since the company is going to place once. However, this value will only apply to be true if the target stock is taken as 55,000 meter and little s (replenishment level) 25,000 meters. The following figure shows the predicted values how the inventory cost in-relation to the customer demand looks like; the raw data was got form the arena simulation result of the shown figure 10 above ..

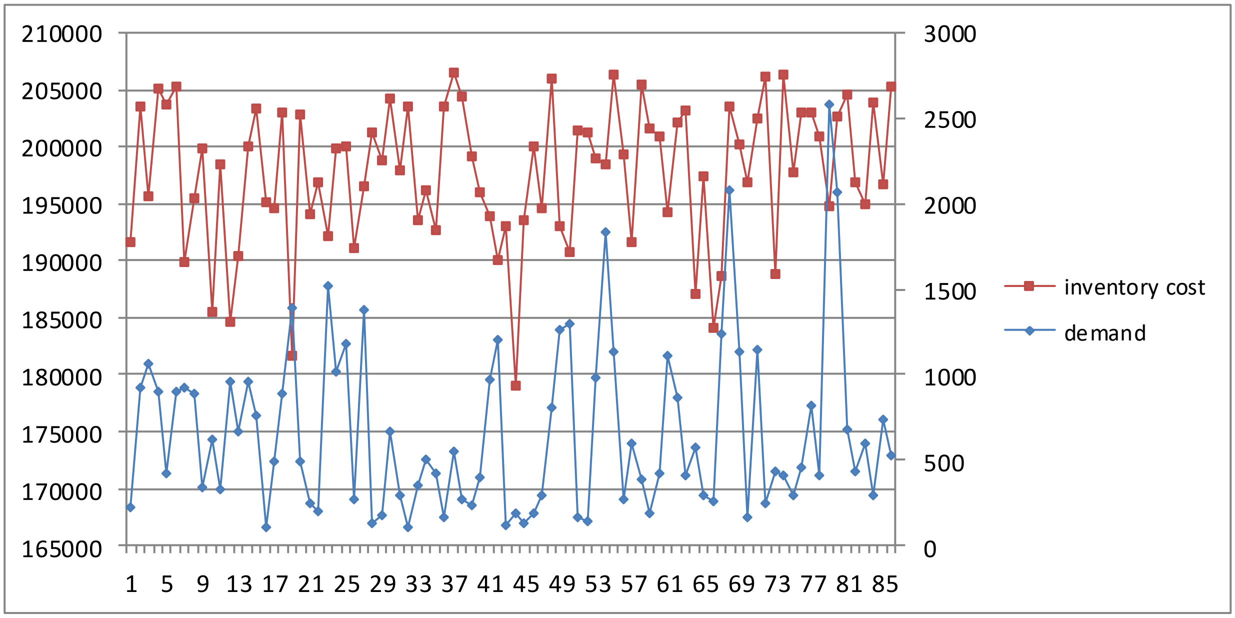


Figure 13: Inventory cost vs demand chart for knitted fabric

When the company implement a target stock and replenishment level as shown in the above paragraph for the knitted fabric raw material inventory management system, then as can be seen from the above figure even if the demand fluctuates highly throughout the simulation time, the inventory cost is going be kept between 180,000 birr and 207,000 birr.

4.2.4.3: Results of Thread Inventory Management System Model

According to the company, 1900 packs of sewing thread cones are ordered every year. There was no policy that the company deploys to manage thread inventory by considering uncertainty and EOQ rather it uses fixed order quantity depending on yearly production. Therefore, the holding cost is calculated by using the percentage of area of which thread inventory hold as discussed above while calculating the holding cost for each inventory type.

Therefore, since there was no target stock or reorder level for thread inventory, the research tried to come up with inventory control policy that can yield a bit lower inventory related cost. thus, according to the simulation model output, it is suggested that the target stock to be 1400 gross and 1320 gross as replenishment level would yield the following inventory related cost with no stock out. Thus, this study suggests to strictly following this policy.

			Before					After				
No.	Item type	Order	inventory ordering cost	Holding cost	total inventory cost	Stock-out	Max inventory held	inventory ordering cost	Holding cost	total inventory cost	Stock-out	Max inventory to hold
1	Sewing thread	1	13,550 birr	8,347 birr	21,944 birr	0	1325	13,550 birr	6146 birr	19,696 birr	0	1400

Table 15: simulation result for sewing thread inventory

The above result shows that the inventory related cost increased. Still there will not be any stock-out. And in addition to the no stock out, the company may benefit from the result because the target stock and replenishment level are get by considering uncertainty of demand. it considered uncertainty also.

The result seen from the above table it can be noted that, the inventory related cost increased. But, the there would be no stock-out this increase the company would increase its thread inventory related cost. However, this result is got by considering the stochasticity behavior of the demand for thread, which the industry did not consider while it was managing its thread inventory.

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4.2.4.4: Results of Button Inventory Management System Model

Similar with the thread inventory, GMM garment do not have any policy implemented. Here, we can conclude that GMM uses fixed order quantity) since it is fixing demand and ordering based on that. Here, GMM only orders Buttons once a year depending on yearly production of Shirt. GMM manufactures 250,000 shirts yearly. Each shirt requires 11 buttons. Thus, yearly demand for shirt would become 2,750,000. Therefore, the study tried to implement the min-max inventory management model by considering stochastisty of demand to suggest the holding cost, ordering cost and total inventory cost would be as follows (*See* Table 16);

No.	**Item type**	**Before**						**After**				
		Order	inventory ordering cost	Holding cost	total inventory cost	Stock-out	Maximum inventory held	inventory ordering cost	Holding cost	total inventory cost	Stock-out	Maximum invention held
1	button	1	13,550 birr	8,347 birr	21,944 birr	0	154	13,550 birr	8316 birr	21,866 birr	0	142

Table 16: simulation result for shirt button inventory

The above table shows the inventory related cost would increase if the company deploys a min max inventory management system for the button inventory. Here, target stock should be 154 gross and the replenishments level should be 100 gross of thread. This result was got by considering the stochastisity behavior of demand just like the above models.

4.2.4.6: Results of Total Inventory Cost of Raw Materials

Since, this part the study talked about different inventory costs for different types of inventory, namely, woven fabric, knitted fabric, thread, and button. Thus, the following table shows the total inventory cost for all types of inventories.

no	GMM garment industry total inventory cost			
	Item	**Before (Birr)**	**After (Birr)**	**Difference (Birr)**
1	Woven fabric	456,947	358,615	98,332
2	Knitted fabric	346,168	197,738	148,430
3	thread	21,944	19,696	2,248
4	button	21,944	21,866	78
Total		847,003	597,915	**249,088**

Table 17: Total inventory cost before and after

From the above table it can be seen that the total inventory cost decreased by 169,088 birr. Additionally, the data shown can be further analyzed by using the Pareto chart as follows;

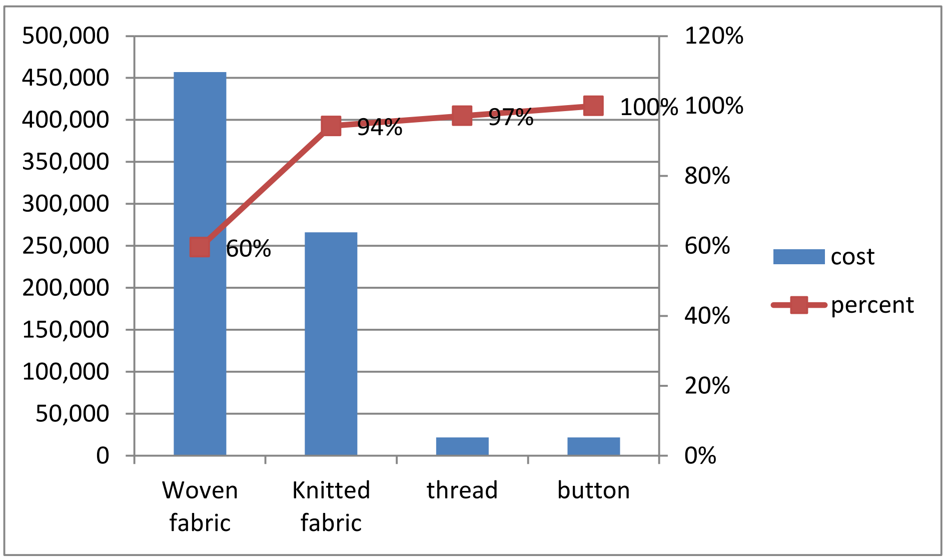


Figure 14 Pareto chart result for total inventory cost of raw materials

As seen on the Pareto chart above shows that 80% of the inventory related cost comes from the woven fabric, which is 20% of the total inventory, and the other 20% inventory cost comes from knitted fabric, thread and buttons. there, it can be seen that the most important raw material inventory of GMM garment industry is Woven fabric and needs more attention.

4.3: DISCUSSIONS ON RESULTS OF FINISHED PRODUCT INVENTORY MANAGEMENT

4.3.1. Shirt &T-Shirt Inventory Management System Model Description

Under this subtitle, the researcher has undertaken on the simulation modeling for T-shirt and Shirt. However, since the modeling flow for both products has similarity, for description of this model, only one product used to demonstrate the model below:

In general, the model shown below in figure, the demand for T-shirt come in to the system and this demand is then checked if it can be fulfilled or not from the on hand inventory. If the demands of T-shirt are lower than the inventory on hand, then the customer is going to be accommodated and leave the system satisfied. Nevertheless, if the demand is higher than the inventory on hand, then the customer given a choice to wait for his demand to be fulfilled. Therefore, if the customer is willing to wait, then the production process will be on to produce the demand backorder. However, if the customer do not chose to wait for the demand to be manufactured, and this incident is considered as a customer lost since the customer leaves the system unsatisfied due to the occurrence of stock-out.

To summarize the process of the model with the following figure (*See* Figure 16), the system has three outlets after checking inventory on hand in comparison with the demand of the customer. The first outlet is where customer demand is lower than the amount of the products in the warehouse; the second outlet is where the customer waits for production to meet its demand while final or the third outlet is where the inventory of the industry is to be replenished.

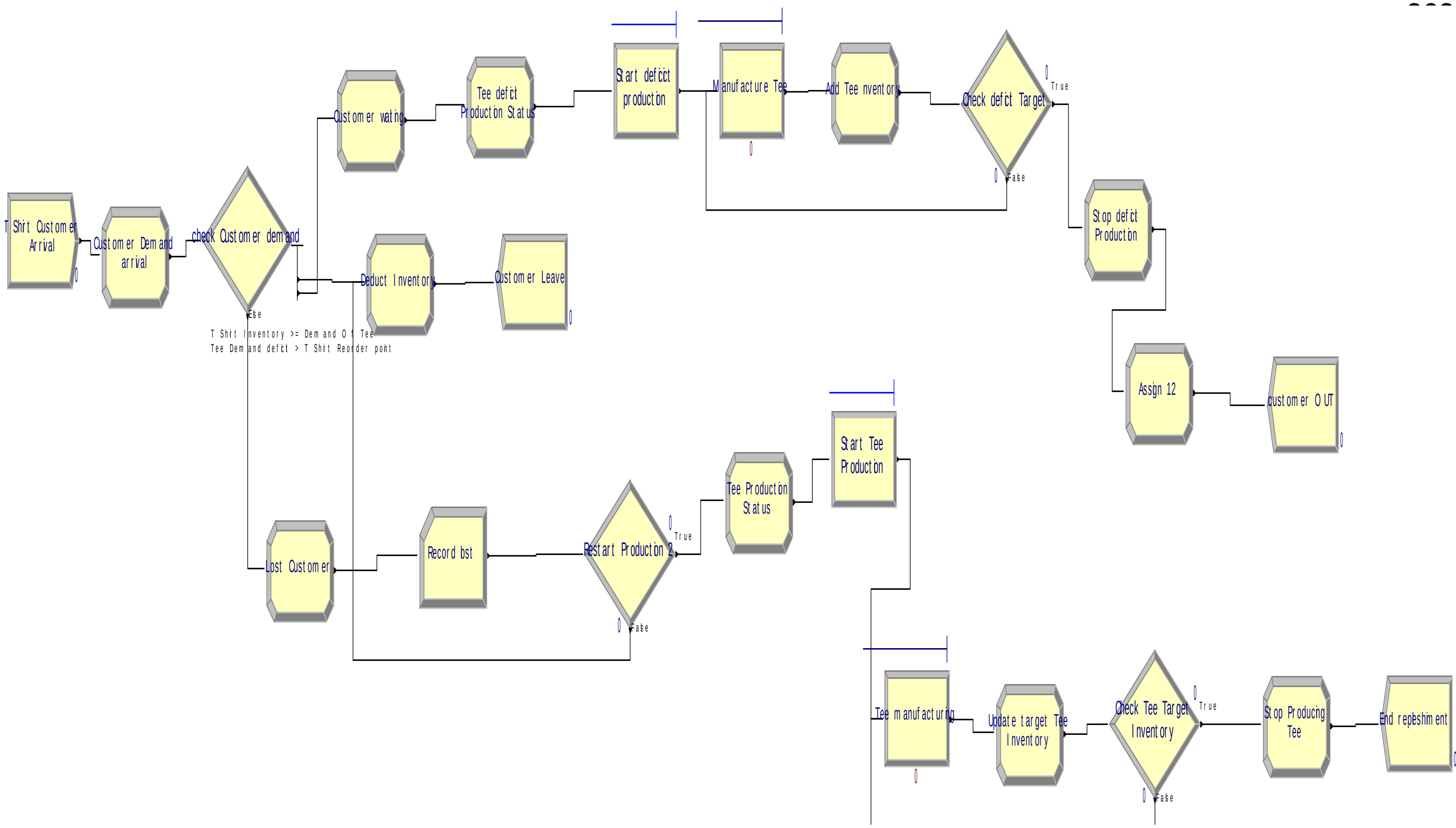


Figure 15: Finished goods inventory management simulation model

As shown in the above figure, after considering and comparing inventory on hand and demand size, if demand size is higher and customer is willing to wait, then manufacturing process will proceed (second outlet). However, before manufacturing proceed, demand deficiency is calculated.

4.3.1.1: Modeling Inventory Deficit for Finished Product with Arena Software

Demand deficiency is the difference between the inventories on hand and the demand size of the customer. Again, after calculating this demand deficit, manufacturing process will proceed (circled with broken line). Here, manufacturing process will be on or off using the assign mode using Production deficit Tee value (circled with unbroken line). When Production deficit Tee is equal to one then production for the deficit starts. This value is detected by scanning this condition at hold block. See the following figure 17.

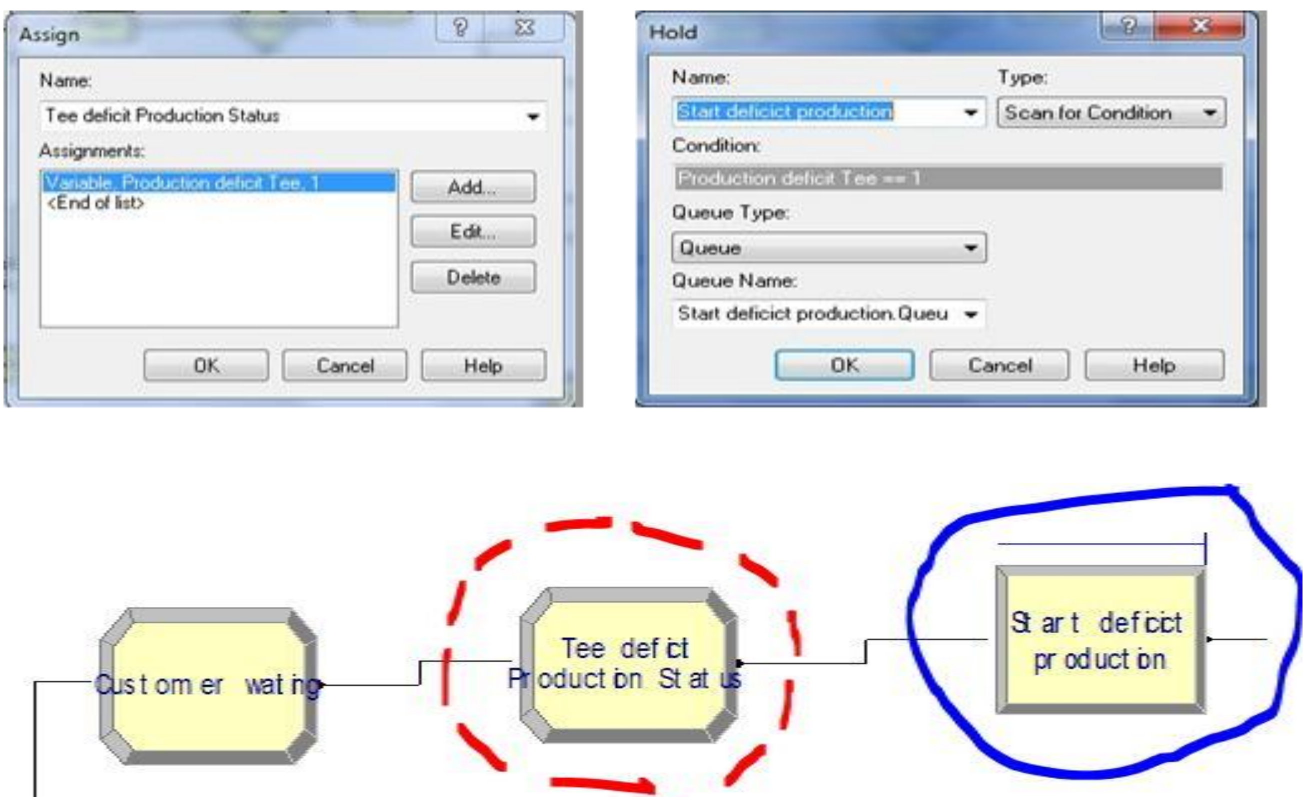


Figure 16: Deficit modeling in Arena simulator

After detecting the start of manufacturing signal, manufacturing process will proceed. After manufacturing the batch size shown circled in dotted line in the figure below, inventory level is updated by adding the manufactured products to the inventory on hand shown circled by full line. Then, target level is checked shown by the arrows in the figure below. If the target level of manufacturing the deficit did not reach then the manufacturing process will continue until the goal is reached. However, if the system reaches the target level, then it will end the manufacturing process. Thus, after ending the manufacturing process, inventory is deducted and given to the customer and the customer leaves the system see figure 18 below.

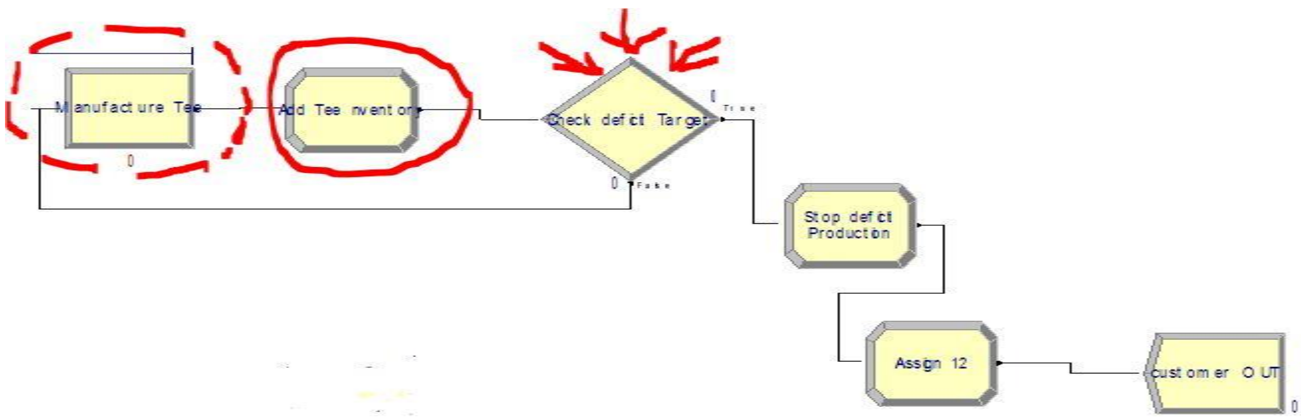
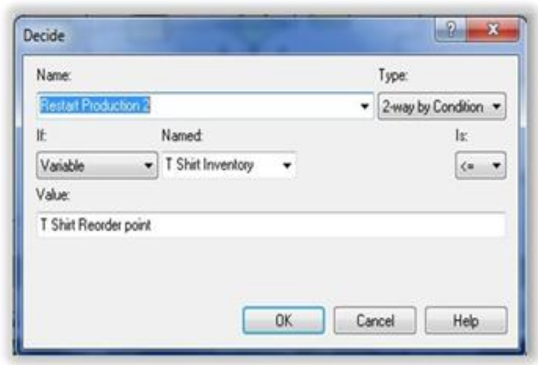


Figure 17: inventory-updating and customer service scheme in Arena simulator

The other point within the system is the third outlet, shown circled by dotted line, where the system replenishes the inventory as shown in the figure 19 below. The system considers the min max inventory control system. Here, the replenishment process starts if the inventory level reaches or get lower than the T-shirt reorder point. By the time the T-shirt or Shirt reorder level is reached, then the ordering process starts. This ordering process is made using the decide block and two way by condition type. This two way by condition is to show two orders; the first one is that, if the inventory level do not reach the replenishment level, then this means the inventory level is higher. Thus, replenishment process will not start. Moreover, the second condition is for when the inventory level reached the replenishment level. At this point the replenishment process will start. See the following figure to see how it is made together with the figure showing the third outlet above and decide block below;



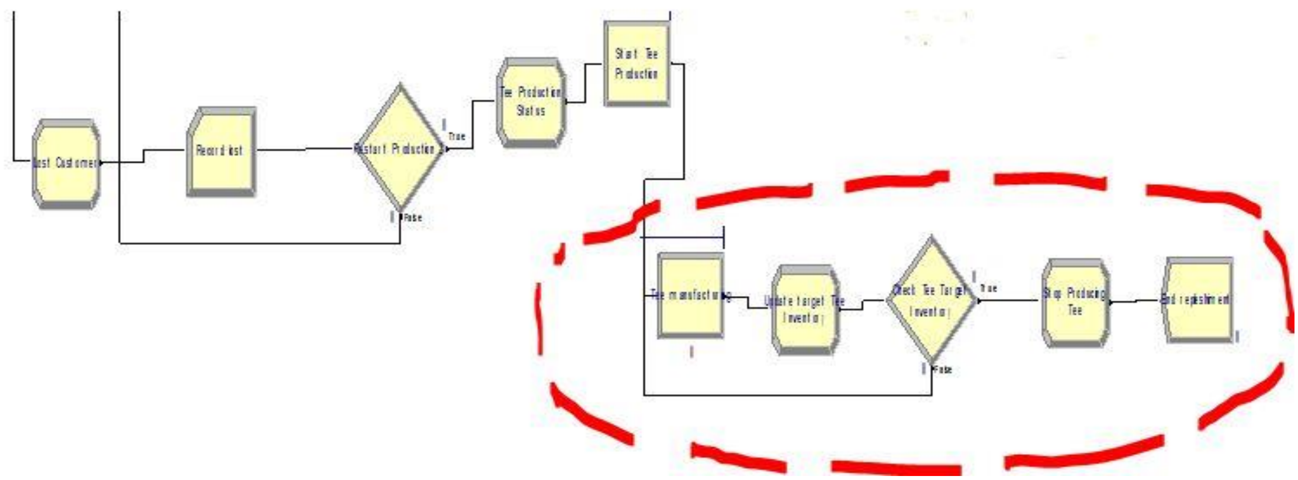


Figure 18: Inventory replenishing scheme in arena simulator

The other point to describe in the third outlet is that the point where inventory is updated until it reaches the target level. This process is shown circled in a circled line in the above figure. Here, if the inventory target level is reached the replenishment process stops. However, if the target level is not reached the replenishment process will continue until it reaches that target level.

The second outlet of the decided block shows the case where inventory level is higher than the reorder point. At this outlet, there will not be nor order placed for the manufacturing department. Similar with the manufacturing of the demand deficit on the above system, the manufacturing of replenishment order will start by assigning the starting condition on the assign block and search for that condition on the hold block next to it. After manufacturing the order, inventory is updated and the system end production by setting the starting condition to zero and disposes the entity. The figure below shows the full T-shirt inventory management system.

4.3.2. Simulation Model Replication Number

For this model, replication number used was 24 for both the T-shirt and Shirt finished goods. This number got after using the confidence interval method.

4.3.3. Model Verification & Validations

Similar to other models verification and validation, the basic element for the verification of this model is to send one entity to the system and study the output. This entity output was in line with the predicted output by the modeler. Again similar with the verification process for the woven fabric raw material and knitted fabric inventory management model, one entity sent to see if the level of inventory decreases as demand increases.

The model was verified by using the number of entities entering the system. For T-shirt inventory management model. The entity considered for validation that customer demand was coming to the system; and the validation process of the coming of the customers to the system was given with the following table (*See* Table 18, below).

Actual output		output from Simulation	
Sample Data:	101, 120, 150, 200, 1800, 2000, 2400, 3260, 5300, 6125, 6600, 7476, 8360, 10200, 48636, 59664, 62400, 88824	Simulation output:	110, 153, 195, 277, 547, 610, 1220, 1227, 1579, 1736, 2569, 4240, 4596, 9065, 17543, 20162, 77766, 80355
Sample size (n_F)	18	No of rep. (n_A)	18
Mean Value (μ_F)	17423	Mean Value (μ_A)	12441
Variance (S_F^2)	741602970	Variance (S_A^2)	621742700
Std deviation (S_F)	27232	Std dev. (S_A)	24934

Table 18: T-shirt product validation table

From the results obtained from the above table and inserting it in the formula for hypothesis test mentioned above, S_p is calculated to be 26109, which in turn makes the t_0 values 1.717. From ‘t’ table at 95% confidence interval, $t_{\alpha/2,n1+n2-2} = t_{0.025,34} = 2.101$ (*See* Annex 1).

4.3.4: Results of T-Shirt & Shirt Simulation Model

In the T-shirt, sales system of GMM garment industry CMT process and make to stock system are implemented. CMT process, cut make trim, is where the customer provides the raw materials and the factory gives service of manufacturing. The make to stock system is a system where the industry produces its products for the clothing line it got. Thus, for the T-shirt sales customers in whom they comes for service waiting is inevitable. Therefore, the aim of this model is to decrease the number of clothing line customer, waiting for their product to be manufactured. Similarly, GMM garment industry has make to stock inventory system and CMT sales system. Thus, the model tried to show reduce the number of clothing line customers waiting for order to be filled.

Additionally, this finished goods inventory management model provides the best possible scenarios of batch size, target stock, and reorder point in which there would be lower customers waiting in line.

4.3.4.1: Results of T-Shirt Inventory Management System Model

The following figure 20 shows different scenarios and their respective values. According to the figure scenario six is the best possible scenario in reducing waiting customer tremendously. As can be seen from the figure, scenario one is status of the company. Therefore, in comparison with scenario one scenario 10 has reduced waiting customers by 9. However, if the difference between inventories considered, there will be high capital tied up if scenario 10 is used. Thus, scenario 5 was selected to be optimum.

	Scenario Properties				Controls			Responses	
	S	Name	Program File	Reps	T Shirt Batch Size	T Shirt Reorder point	Target Stock of T Shirt	Waiting customers	T Shirt Inventory
1		Scenario 1	3 : tshir finis	24	1752.0000	1000.0000	5000.0000	13	6472.881
2		Scenario 2	3 : tshir finis	24	1600.0000	2500.0000	5000.0000	11	5493.519
3		Scenario 3	3 : tshir finis	24	1600.0000	2500.0000	5500.0000	11	4642.921
4		Scenario 4	3 : tshir finis	24	2000.0000	7000.0000	10000.0000	4	5421.457
5		Scenario 5	3 : tshir finis	24	1600.0000	7000.0000	10000.0000	5	7645.714
6		Scenario 6	3 : tshir finis	24	1600.0000	8000.0000	10000.0000	4	8937.861
7		Scenario 7	3 : tshir finis	24	1600.0000	7000.0000	8000.0000	5	7706.336
8		Scenario 8	3 : tshir finis	24	1700.0000	8000.0000	9000.0000	4	8095.007
9		Scenario 9	3 : tshir finis	24	1800.0000	8000.0000	10000.0000	4	7464.220
10		Scenario 10	3 : tshir finis	24	1752.0000	8000.0000	10000.0000	4	7040.464
11		Scenario 11	3 : tshir finis	24	1752.0000	6500.0000	8000.0000	5	7446.637

Double-click here to add a new scenario.

Figure 19: T-shirt inventory management model scenario

Additionally, from the simulation output figure 20 , it can be seen that, in order for the company decrease its customer waiting and the inventory on hand to decrease, it has to have a batch size of **1752** and reorder point of **8000** and target stock of **10000 pcs** of inventories.

4.3.4.2: Results of Shirt Inventory Management System Model

Similar to T-shirt inventory system model, the aim of shirt inventory management system modeling was to reduce the number of customer waiting for their order to be fulfilled. Thus, according to the output result of the simulation model the following results were obtained (*See* Figure 21).

	Scenario Properties				Controls			Responses	
	S	Name	Program File	Reps	Shirt Batch Size	Shirt Reorder point	Target Stock of Shirt	Waiting shirt customers	Shirt Inventory
1		Scenario 1	1 : the shirtb	24	900.0000	10000.0000	118000.0000	1	8122.642
2		Scenario 2	1 : the shirtb	24	900.0000	12000.0000	118000.0000	0	9612.780
3		Scenario 3	1 : the shirtb	24	1000.0000	12000.0000	118000.0000	0	9316.133
4		Scenario 4	1 : the shirtb	24	850.0000	12000.0000	118000.0000	0	9112.565
5		Scenario 5	1 : the shirtb	24	850.0000	10000.0000	100000.0000	1	8370.977
6		Scenario 6	1 : the shirtb	24	900.0000	12000.0000	100000.0000	0	9612.780

Double-click here to add a new scenario.

Figure 20: Shirt inventory management model scenario

As can be seen from the process analyzer output file above, figure 21, the company will have at least 1 customers waiting every year. Here, the batch size, reorder point and target stock of the shirt inventory is 900, 10000 and 118,000 respectively. These, batch size, reorder point and target stock yield at least 1 customer waiting for order to be filled. Therefore, if GMM wants to lower customer waiting it must have 850-batch size, 12000-reorder point and a target stock of 118,000 inventories. When the company implements the above model there will be no one waiting for shirt production. Additionally, zero customers waiting means higher customer satisfaction.

CHAPTER 5 : CONCLUSION & RECOMMENDATIONS

5.1. CONCLUSION

This research aimed to develop an inventory management model, which reduces inventory related cost. Through deep interviews with GMM staff members, inputs for the study were identified and used. Thus, it was found out that the factory does not have a good inventory management system. Inventory is managed through traditional way and order for raw material is made when there is demand. As a result, the company faced high inventory related costs and stock-outs.

After studying into the inventory management system of GMM garment industry, the study found out that there are different products manufactured within the industry. These, include shirts, polo shirts trousers, ladies dress and mask. Among this inventories or products made in GMM shirt had the highest revenue generation ability. From the Pareto chart result it was found out that shirt made 80 percent of the revenue for the company. In addition to the revenue generation, the industry had a cost related to storing inventory in the factory. Among the inventory cost, the highest was from woven fabric, a raw material which is used to manufacture shirt. Thus, it was quite clear that both the raw material and the finished good needs attention while trying to manage inventory.

From the results of the collected data, which was necessary to make the inventory movement simulation model, the study found out that the company uses a min max inventory management system for fabric inventory while it does not have any inventory controlling policy for managing raw materials like thread and button. Here, for the fabrics, even if the company employs a min max inventory control policy, it had not considered the historical data about the demand and supplier lead-time trends. Therefore, after the collection these data, it was found out that the demand for both shirt and T-shirt is stochastic. Stotahcstic behavior of demand and lead time surely affect the inventory management system of the industry. Additionally, the other factor which affect inventory management system is the manufacturing uncertainty residing in the manufacturing section of the industry. Manufacturing uncertainties found in the industry are expressed in terms of manufacturing bottle neck. Therefore, after carefully examining the manufacturing section of both shirt and T-shirt, it was found out that different bottleneck process which are potential factors that may affect the customer service of the industry. Among these bottle necks, Trim operator, single needle machine at the binder close process, Label operator and float lock stich machine 2 has poor utilization and Entity coming from shoulder top stich, Entity coming from front neck line top stich, shoulder attach process and binder close process have high waiting time and are listed within the shirt manufacturing process. Similarly, single needle machines (2, 4, 6, 9, 12 and 16), single needle machine with folder, lock stich machine, over-lock machine, and collar trimming machine are listed within the T-shirt manufacturing process. Therefore, it is advisable to look into this poor utilization process in the future.

The study also found out that there is an inventory that is obsolete and is still costing the company in both storing it and in the capital spent to acquire it. Thus, this inventory needs attention to. Thus, the study recommends selling it with lower price since inventory ties up money.

Furthermore, if the inventory, which ties money is not moving fast or the items in inventory is not sold, it will be hard for the company to operate. Thus, it is very critical to know how the inventory management is performing using key performance indicators like inventory turnover ratio. Therefore, the turnover ratio of GMM explained that, GMM sells its products every 46 and 48 days every year for shirt and T-shirt respectively. This also explained that every inventory made sales within 7.6 days and 7.4 days for both shirt and T-shirt respectively. This turnover ratio value looks good. However, since the factory is an international exporter and specifically exports products to the USA, it has big competitions with other companies. According to collected data on ready ratios, IFRS financial reporting and analysis software, the benchmark for good inventory turnover of an apparel industry was 148 days or every 2.5 days inventory made sales out. This value was taken from companies, which sell their products in the USA. Thus, GMM is not doing that well according to the apparel industries who work in putting their product to the US market. Generally, for the company to be more competitive in the international market, it needs to move its inventory faster. Thus, in order for the factory to move its products fast, it needs to have a good and efficient inventory management system.

Having the above facts in mind, the study developed two inventory management model for six inventory items namely; Shirt, T-shirt, woven fabric, knitted fabric, thread and button. This inventory management model included inventories of raw material and finished goods for both shirt and T-shirt. As stated in data collection and analysis, it was identified that total inventory cost of the company mainly are from raw material; namely woven fabrics, knitted fabrics, thread and button. This total inventory cost accounts to about 767,003 birr/year. However, after development of the discrete event simulation model for inventory management, the factor's total inventory cost reduced to 597,915 birr. The company can save 169,085 birr/ year from raw materials as stated in result of the simulation model. However, this result will only be achieved if and only if the industry employs an inventory management policy of min max system with a target stock level of 280000 mtr And replenishment level of 200000mtr for woven fabric, target stock of 55000mtr and replenishment level of 25000mtr for knitted fabric, target stock of 1400 gross and replenishment level of 1320gross For thread and a target stock level of 154 gross and replenishment level of 100 gross for button inventory.

In addition to the raw material inventory management system model, the study developed an inventory management model for both shirt and T-shirt products. The aim of theirs finished goods inventory management model was to reduce, the customer waiting in line for the order to be fulfilled. Thus, according to the model made, with batch size of 1752 pcs target stock of 10000 pcs and reordered level of 8000 pcs customers waiting for T-shirt order will be reduced from 13 to 4 Similarly with the batch size of 850 pcs target stock of 118000 pcs and reorder level of 12000 pcs customers waiting for shirt inventory will be reduced from 1 to 0 Having said that, since the industry employs both CMT process and make to stock system, for the CMT process it is inevitable for the customer to wait in line.

Finally, as the study suggests using the recommended model would be advantageous while trying to decrease inventory related costs. Decreased cost can mean increased revenue. When revenue increases the income tax collected by the government would increase. Additionally, if the cost reduced be used as an employee incentive, employee loyalty would also increase. Employee loyalty would result in a longer term of good productivity and reduced cost of training for new employees. Therefore, the study highly recommends the implementation of this discrete event simulation for managing inventory of this garment industry.

5.2. Recommendation

When one considers managing inventory, it is crucial not to forget the uncertainties due to customer demand and suppliers delivery. Additionally, inventory must be managed smartly. Here smartly means, usage of simulation. Using simulation helps test different scenarios without any additional cost. Thus, as can be seen from the research result, it is quite clear that factories could save a tremendous amount of money if they manage inventory scientifically. Thus, saving money can result a good revenue generation which lead to high profit tax collection by the government. In general, managing inventory scientifically, can be a win-win situation for both government and factories Therefore, there should be a government-factory policy that would mandate the use of scientific inventory management system by manufacturers. This, mandate may be checked and enforced through industry development institutes.

The study tried to address 6 items in two of inventories, raw material (woven, sewing thread, button and knitted fabrics) and finished products (T-shirt and shirt). Furthermore, the study used a discrete event simulation tool, Arena, to develop the models to manage these inventories. Here, for the finished products the current batch size is different from the recommended batch size by 248 for the T-shirt manufacturing and by 100 for the shirt manufacturing. Thus, adding extra one working hour for each product per year, would enable the industry to reach the desired bath size level.

Putting all the above-mentioned points in mind, it is advisable to use simulation for other type inventories like spare **parts**, **elastic band,** and **other garment products** as well. Additionally, if other researchers could do study on the effects manufacturing section productivity relation to inventory management cost of a company.

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ANNEXES

Annex 1: Student T-Distribution Table

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

Annex 2: Inputs for Demand

a. Thread demand data

no	shirt production per day	thread	number of cone (thread/118)	In gross, number of cone/12
1	212	23320	197.6271186	16
2	256	28160	238.6440678	20
3	411	45210	383.1355932	32
4	409	44990	381.2711864	32
5	218	23980	203.220339	17
6	259	28490	241.440678	20
7	176	19360	164.0677966	14
8	303	33330	282.4576271	24
9	196	21560	182.7118644	15
10	186	20460	173.3898305	14
11	320	35200	298.3050847	25
12	235	25850	219.0677966	18
13	338	37180	315.0847458	26
14	341	37510	317.8813559	26
15	324	35640	302.0338983	25

b. Button demand data

no	shirt production (daily)	button demand (shirt demand*11)	button demand in pack (button demand/1700)
1	212	2332	1
2	256	2816	2
3	411	4521	3
4	409	4499	3
5	218	2398	1
6	259	2849	2
7	176	1936	1
8	303	3333	2
9	196	2156	1
10	186	2046	1
11	320	3520	2
12	235	2585	2
13	338	3718	2
14	341	3751	2
15	324	3564	2

Annex 3: Finished Products Revenue Generation

Item	Year	sales	cumulative	percentage
Shirt	2020	$1,948,620.90	$1,948,620.90	48%
T-shirt	2020	$762,570.40	$2,711,191.30	67%
polo shirt	2020	$728,661.21	$3,439,852.51	85%
ladies dress	2020	$362,458.20	$3,802,310.71	94%
trousers	2020	$260,252.30	$4,062,563.01	100%
total	**2020**	**$4,062,563.01**		

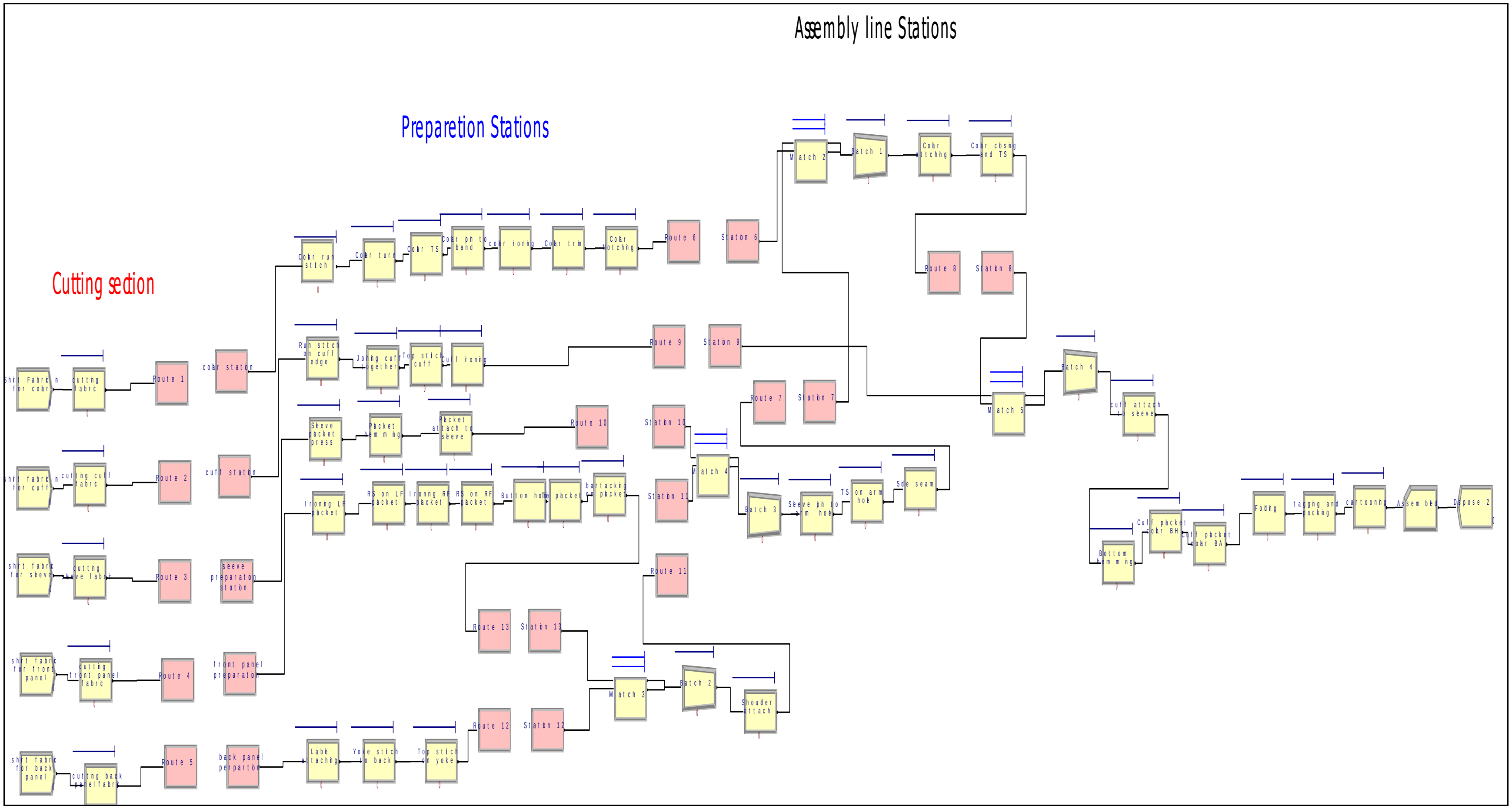
Annex 4: Manufacturing Section Cycle Time Model Inputs For Shirt

Cycle Time	total cutting SAM	ironing yoke and folder	ironing of sleeve	ironing side seam	collar pressing	folding shirt	rivan applying	tagging & packing	cartooning	collar run stitch	collar turn	collar TS	collar join to band	collar ironing	collar trim	collar notching	Run stitch on cuff edge	joining cuff together	top stitch cuff	cuff ironing	sleeve placket press
cycle time 1	1.28	0.812	0.41	0.3	0.13	1.2	0.46	0.53	0.24	0.27	0.18	0.23	0.58	0.49	0.18	0.19	0.21	0.4	0.22	0.3	0.4
cycle time 2	1.51	0.85	0.34	0.34	0.12	1.2	0.5	0.47	0.17	0.22	0.16	0.23	0.6	0.47	0.17	0.19	0.22	0.38	0.23	0.26	0.36
cycle time 3	1.48	0.8	0.42	0.29	0.12	1.17	0.55	0.5	0.18	0.29	0.16	0.25	0.58	0.49	0.14	0.14	0.22	0.34	0.22	0.29	0.42
cycle time 4	1.52	0.77	0.37	0.32	0.17	1.19	0.49	0.51	0.2	0.22	0.16	0.17	0.55	0.48	0.19	0.15	0.21	0.32	0.22	0.24	0.41
cycle time 5	1.54	0.83	0.36	0.3	0.18	1.2	0.52	0.55	0.2	0.26	0.16	0.15	0.55	0.42	0.12	0.12	0.16	0.32	0.24	0.28	0.35
cycle time 6	1.48	0.8	0.35	0.28	0.11	1.2	0.54	0.53	0.18	0.28	0.19	0.25	0.55	0.44	0.2	0.2	0.23	0.39	0.22	0.28	0.4
cycle time 7	1.479	0.83	0.4	0.35	0.19	1.23	0.45	0.5	0.24	0.24	0.13	0.25	0.61	0.47	0.18	0.2	0.17	0.35	0.24	0.26	0.42
cycle time 8	1.5	0.76	0.37	0.28	0.16	1.2	0.5	0.49	0.24	0.29	0.19	0.15	0.61	0.49	0.19	0.16	0.19	0.38	0.25	0.31	0.34
cycle time 9	1.52	0.82	0.4	0.27	0.16	1.25	0.49	0.46	0.22	0.22	0.12	0.2	0.53	0.43	0.2	0.18	0.19	0.34	0.28	0.25	0.41
cycle time 10	1.51	0.76	0.41	0.32	0.17	1.2	0.51	0.52	0.21	0.28	0.2	0.21	0.61	0.45	0.19	0.13	0.24	0.4	0.29	0.22	0.42
cycle time 11	1.48	0.82	0.35	0.28	0.17	1.2	0.49	0.53	0.24	0.22	0.16	0.25	0.55	0.43	0.19	0.19	0.23	0.35	0.28	0.28	0.4
cycle time 12	1.52	0.83	0.41	0.28	0.17	1.25	0.5	0.53	0.17	0.22	0.19	0.21	0.61	0.49	0.18	0.15	0.16	0.38	0.22	0.28	0.35
cycle time 13	1.48	0.77	0.37	0.28	0.17	1.2	0.54	0.53	0.24	0.27	0.2	0.2	0.61	0.45	0.12	0.12	0.24	0.35	0.23	0.26	0.42
cycle time 14	1.52	0.83	0.37	0.28	0.18	1.2	0.52	0.51	0.24	0.24	0.16	0.25	0.55	0.47	0.12	0.19	0.24	0.4	0.24	0.28	0.35
cycle time 15	1.48	0.76	0.37	0.3	0.17	1.25	0.54	0.55	0.21	0.29	0.19	0.25	0.6	0.47	0.2	0.12	0.21	0.34	0.24	0.26	0.4
cycle time 16	1.52	0.83	0.36	0.29	0.12	1.2	0.46	0.51	0.24	0.27	0.12	0.23	0.61	0.43	0.19	0.19	0.21	0.38	0.29	0.26	0.4
cycle time 17	1.48	0.8	0.4	0.28	0.18	1.2	0.49	0.47	0.24	0.26	0.16	0.25	0.58	0.49	0.19	0.15	0.24	0.32	0.24	0.28	0.42
cycle time 18	1.52	0.81	0.41	0.28	0.12	1.2	0.54	0.52	0.18	0.29	0.13	0.21	0.61	0.49	0.12	0.2	0.21	0.4	0.23	0.22	0.42
cycle time 19	1.54	0.8	0.41	0.3	0.13	1.19	0.55	0.53	0.18	0.26	0.16	0.25	0.6	0.44	0.14	0.19	0.19	0.34	0.22	0.24	0.4
cycle time 20	1.52	0.8	0.4	0.35	0.16	1.23	0.46	0.51	0.22	0.28	0.19	0.25	0.55	0.49	0.18	0.12	0.23	0.32	0.28	0.28	0.42

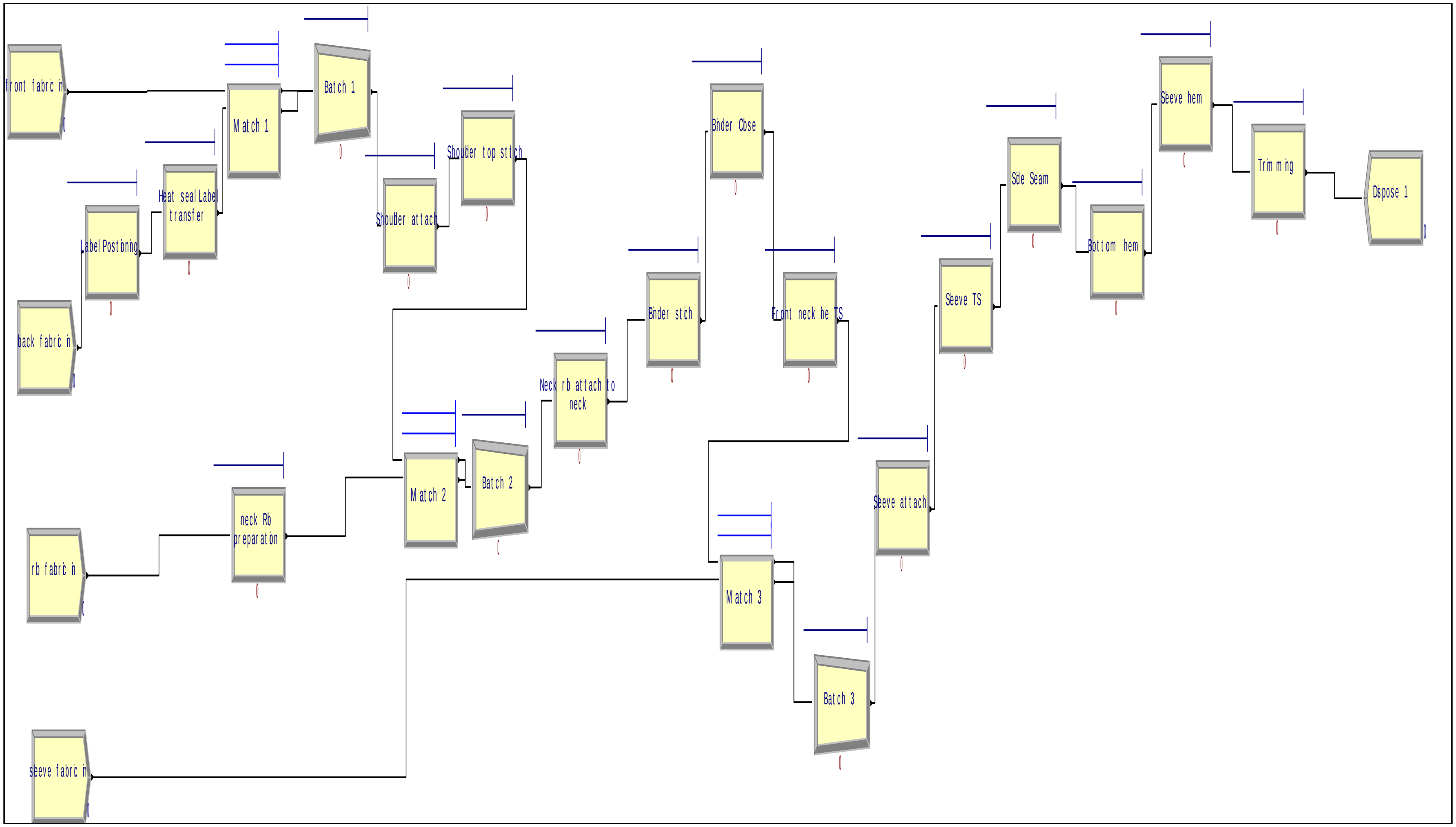
Cycle Time	placket attach to sleeve	ironing LF placket	RS on LF placket	ironing RF placket	RS on RF placket	button holing	tie placket	bartacking on placket	lable attaching	yoke attach to back	top stitch on yoke	shoulder attach	sleeve join to armhole	TS on armhole	side seam	collar attaching	collar closing and TS	cuff attach to sleeve	bottom hemming	cuff,placket ,collar BH	cuff,placket ,collar BA
cycle time 1	0.41	0.54	0.3	0.35	0.33	0.59	0.27	0.28	0.3	0.91	0.21	0.69	0.73	0.55	1.39	0.572	1.066	2.026	1.541	0.758	1.557
cycle time 2	0.37	0.56	0.38	0.41	0.26	0.54	0.3	0.34	0.37	0.92	0.16	0.72	0.76	0.61	1.36	0.52	1.117	2.025	1.498	0.715	1.582
cycle time 3	0.44	0.54	0.32	0.39	0.26	0.56	0.28	0.28	0.33	0.96	0.17	0.64	0.72	0.6	1.37	0.608	1.042	2.029	1.474	0.798	1.601
cycle time 4	0.42	0.54	0.29	0.43	0.26	0.59	0.25	0.37	0.33	0.94	0.16	0.74	0.72	0.59	1.35	0.536	1.046	2.047	1.477	0.769	1.576
cycle time 5	0.38	0.52	0.35	0.38	0.25	0.56	0.21	0.28	0.35	0.98	0.2	0.65	0.76	0.6	1.39	0.573	1.092	2.008	1.508	0.799	1.555
cycle time 6	0.4	0.49	0.33	0.43	0.29	0.58	0.26	0.36	0.32	0.96	0.21	0.72	0.76	0.58	1.43	0.561	1.111	2.044	1.558	0.731	1.598
cycle time 7	0.42	0.49	0.37	0.41	0.32	0.59	0.27	0.28	0.32	0.98	0.21	0.71	0.77	0.58	1.42	0.552	1.07	2.011	1.543	0.766	1.586
cycle time 8	0.38	0.5	0.35	0.38	0.27	0.56	0.3	0.38	0.37	0.98	0.19	0.66	0.77	0.54	1.42	0.614	1.078	2.038	1.532	0.738	1.608
cycle time 9	0.39	0.46	0.34	0.4	0.28	0.61	0.24	0.32	0.3	0.97	0.21	0.68	0.79	0.55	1.37	0.592	1.09	2.075	1.553	0.739	1.608
cycle time 10	0.42	0.55	0.31	0.41	0.29	0.56	0.25	0.37	0.33	0.95	0.22	0.68	0.7	0.54	1.44	0.605	1.09	2.03	1.526	0.786	1.547
cycle time 11	0.38	0.54	0.35	0.41	0.29	0.56	0.21	0.28	0.33	0.98	0.21	0.68	0.77	0.55	1.44	0.55	1.09	2.03	1.48	0.8	1.61
cycle time 12	0.41	0.54	0.32	0.38	0.29	0.59	0.26	0.28	0.33	0.98	0.17	0.69	0.77	0.59	1.44	0.57	1.04	2.04	1.51	0.77	1.58
cycle time 13	0.39	0.49	0.3	0.41	0.26	0.59	0.25	0.34	0.33	0.94	0.19	0.65	0.76	0.55	1.39	0.59	1.08	2.04	1.56	0.8	1.56
cycle time 14	0.42	0.52	0.3	0.41	0.29	0.59	0.27	0.28	0.33	0.96	0.16	0.69	0.76	0.55	1.37	0.57	1.08	2.03	1.53	0.74	1.58
cycle time 15	0.41	0.54	0.35	0.43	0.25	0.56	0.25	0.28	0.32	0.96	0.16	0.69	0.76	0.6	1.36	0.57	1.05	2.08	1.54	0.74	1.6
cycle time 16	0.42	0.54	0.35	0.39	0.28	0.56	0.3	0.36	0.37	0.96	0.21	0.72	0.73	0.58	1.43	0.57	1.08	2.03	1.54	0.77	1.6
cycle time 17	0.44	0.54	0.35	0.41	0.29	0.61	0.25	0.37	0.32	0.92	0.17	0.68	0.76	0.59	1.42	0.61	1.09	2.03	1.55	0.72	1.56
cycle time 18	0.39	0.54	0.38	0.43	0.28	0.59	0.25	0.37	0.32	0.98	0.21	0.68	0.76	0.55	1.37	0.59	1.05	2.05	1.54	0.77	1.58
cycle time 19	0.4	0.5	0.3	0.43	0.33	0.56	0.27	0.28	0.3	0.95	0.21	0.74	0.72	0.58	1.35	0.52	1.07	2.01	1.5	0.8	1.59
cycle time 20	0.42	0.54	0.32	0.35	0.32	0.56	0.21	0.37	0.35	0.91	0.16	0.72	0.73	0.58	1.35	0.61	1.07	2.04	1.5	0.74	1.6

Annex 5: Manufacturing Section Cycle Time Model Inputs For T-Shirt

	label position	HEAT SEAL LABEL TRANSFER	Shoulder ATTACH	SHOULDER TOP STITCH	NECK RIB PREPARATI ON	NECK RIB ATTACH TO NECH	BINDER STICH	BINDER CLOSE	FRONT NECK LINE T/S	SLEEVE ATTACH	SLEEVE T/S	SIDE SEAM	BOTTOM HEM	SLEEVE HEM
	0.216	0.293	0.503	0.329	0.735	0.466	0.126	0.616	0.566	0.805	0.912	1.109	0.851	0.53
	0.152	0.269	0.504	0.386	0.723	0.433	0.103	0.638	0.515	0.809	0.86	1.087	0.831	0.53
	0.204	0.218	0.565	0.368	0.739	0.444	0.086	0.638	0.52	0.835	0.914	1.119	0.874	0.51
	0.171	0.288	0.518	0.357	0.665	0.486	0.123	0.627	0.589	0.848	0.889	1.105	0.825	0.55
	0.223	0.246	0.512	0.345	0.677	0.47	0.13	0.59	0.531	0.876	0.923	1.062	0.892	0.46
	0.187	0.256	0.538	0.294	0.676	0.454	0.083	0.57	0.558	0.821	0.899	1.111	0.828	0.55
	0.25	0.258	0.489	0.334	0.714	0.442	0.062	0.604	0.57	0.839	0.935	1.053	0.861	0.46
	0.192	0.266	0.537	0.327	0.729	0.45	0.079	0.583	0.536	0.844	0.89	1.117	0.803	0.49
	0.249	0.22	0.489	0.341	0.656	0.472	0.107	0.554	0.491	0.869	0.908	1.056	0.857	0.53
	0.154	0.297	0.509	0.291	0.719	0.447	0.105	0.602	0.555	0.883	0.932	1.087	0.865	0.49
	0.173	0.285	0.576	0.304	0.653	0.421	0.063	0.563	0.51	0.884	0.899	1.103	0.81	0.47
	0.181	0.225	0.569	0.315	0.673	0.476	0.085	0.568	0.521	0.868	0.907	1.05	0.819	0.47
	0.219	0.261	0.528	0.362	0.74	0.506	0.136	0.635	0.552	0.879	0.928	1.035	0.863	0.46
	0.187	0.225	0.542	0.335	0.718	0.504	0.072	0.597	0.549	0.831	0.861	1.096	0.828	0.55
	0.182	0.233	0.575	0.356	0.704	0.483	0.127	0.64	0.558	0.836	0.914	1.102	0.835	0.54
	0.228	0.214	0.554	0.363	0.666	0.466	0.137	0.609	0.544	0.83	0.93	1.055	0.881	0.5
	0.18	0.2	0.504	0.311	0.736	0.485	0.128	0.587	0.56	0.897	0.914	1.096	0.899	0.50
	0.247	0.256	0.571	0.389	0.662	0.481	0.098	0.619	0.562	0.876	0.855	1.054	0.879	0.48
	0.241	0.288	0.539	0.358	0.723	0.419	0.105	0.62	0.507	0.857	0.85	1.066	0.875	0.47
	0.242	0.225	0.506	0.369	0.729	0.423	0.051	0.598	0.518	0.825	0.881	1.049	0.83	0.5


Assembly line Stations
Preparetion Stations
Cutting section

Annex 7: Manufacturing Model of GMM Shirt



Annex 8: Questionnaires

Name of the factory:	
Factory year of establishment:	
Factory employee number:	
Name of the interviewee:	
Interviewee position:	
Name of the interviewer:	

A. Management questions

1. Are inventory records balanced (and differences explained) on a regular basis? (Current inventory is adjusted at year-end by fiscal year-end physical counts.) Yes or No.
   1.1. If the answer for the above question is yes, what is the last reconciled inventory report suggests. You can list the last inventory on hand for both raw materials (only fabrics) and finished goods.--
2. Do departments compare quantities received against receiving reports, etc.? Yes or no.
   2.1. If the answer for the above question is yes, can you explain the last 1 month quantity received by your department.--
3. Is material released from storerooms only on the basis of requisitions which are approved by a responsible official of the department? Yes or no.--

4. Is adequate provision made for obsolete and inactive items in inventories? Yes or No. --------
   4.1. if the answer for the above question is yes, which inventories are obsolete and inactive

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B. Shirt fabric simulation input

5. What are your products? Please list them?
----1.--5.--
2.--6.--3.----
---4.-----------
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6. What is your most revenue generating product? Please list it from top to bottom.

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7. Do you manufacture shirt every day? Yes or No

   7.1. If the answer for the above question is no, then what is the interval that you produce shirt? Example, you may produce every day or every 3 days or….
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8. How much (woven) fabric do you put out from the warehouse? Please do not include the fabric which is sent to you for service?

   8.1. Do you put out woven fabric every day?
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9. What is the interval of your inventory review period?
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10. What is your order quantity?
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11. What is your target inventory?
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12. At what point inventory level do you place order?
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13. How long does it take for order to reach you?
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14. Salary for store keeper/s?

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15. Salary for your accountant that prepare purchase order?
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16. Do you have insurance for your warehouse? If yes please estimate it?
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17. Have you ever encounter a case where there is **no woven fabric** at the warehouse? To clarify the question…is there any stock out of woven fabric? Yes or No
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    17.1. If the answer for the above question is yes, please estimate how many time in a year this occur?
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18. Can you please describe your current inventory system management?

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19. How much wove fabric do you have in your inventory system currently? Please do not include the raw material sent to you for service.
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20. What problems does your company faced and is facing regarding inventory management?

C. T-Shirt product simulation input

21. Do you produce T- shirt every day? Yes or no. please.

    21.1. If your answer for the above question is no, please describe the interval in which you produce T-shirt.
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22. Do customers for T-shirt product order you every day? Yes or no please?

    22.1. If your answer for the above question is no, can please describe the interval in which the customer come in to order you?
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23. Do you have customers who wait for their order? Yes or no?

23.1. If the answer for the above question is yes, how long do you delay them till you fulfill their order?

23.2. Who the customer who wait for their order to be fulfilled?

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24. Do you have customers who do not wait for their order to be fulfilled if there is no stock? Yes or no.

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25. Do you have T-shirt target stock level? Yes or no please. Target stock is the amount of T-shirt inventory in the ware house that you company do not want to **exceed**

25.1. If your answer for the above question is yes, what is your T-shirt Target stock?.

25.2. Do you have T-shirt reorder point? Yes or no please. Reorder point for T-shirt is the amount of T-shirt inventory in the ware house reached and your company do not want the inventory level to be **below** this level.

25.3. If your answer for the above question is yes , What is your T-shirt reorder point for t-shirt? ---

26. How much shirt do you produce when the inventory of Shirt reach the reorder point? To clarify the question, what is your batch size? Please do not include the shirt you produce where the raw material is sent to you by your customer. Only include the shirt you make from the raw material you purchase.

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27. How long does it take you to fulfill customer T-shirt demand? You can describe it using maximum and minimum days.

D. Shirt product simulation input

28. Do you produce shirt every day? Yes or no. please.

28.1. If your answer for the above question is no, please describe the interval in which you produce shirt.

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29. Do customers for shirt product order you every day? Yes or no please?

    29.1. If your answer for the above question is no, can please describe the interval in which the customer come in to order you?

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30. Do you have customers who wait for their order? Yes or no?

    30.1. If the answer for the above question is yes, how long do you delay them till you fulfill their order?

    30.2. Who the customer who wait for their order to be fulfilled?

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31. Do you have customers who do not wait for their order to be fulfilled if there is no stock? Yes or no.

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32. Do you have shirt **target stock level**? Yes or no please. Target stock is the amount of shirt inventory in the ware house that you company do not want to **exceed**

    32.1. If your answer for the above question is yes, what is your T-shirt Target stock?.

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33. Do you have T-shirt reorder point? Yes or no please. **Reorder point** for T-shirt is the amount of T-shirt inventory in the warehouse reached and your company does not want the inventory level to be **below** this level.

    33.1. If your answer for the above question is yes , What is your T-shirt reorder point for t-shirt? ---

34. How much shirt do you produce when the inventory of Shirt reach the **reorder point**? To clarify the question, what is your batch size? Please do not include the shirt you produce where the raw material is sent to you by your customer. Only include the shirt you make from the raw material you purchase.

How long does it take you to fulfill customer T-shirt demand? You can describe it using maximum and minimum days. ---