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The application of six sigma to improve textile factory inventory costs

Abdalla N Salih and Ghofran M Salah *

Faculty of Engineering, University of Greenwich, Central Avenue, Chatham, ME4 4TB.

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Abstract

In the textile industry, the inventory management is pivotal for sustained success in a competitive business environment. This research, informed by an investigation into data from previous research conducted in textile factories, systematically explores the application of Six Sigma principles to address challenges in inventory management. The study utilizes the Define, Measure, Analyse, Improve, Control (DMAIC) framework to investigate and enhance inventory practices. Initiating with the Define phase, the research articulates existing issues through the project charter, setting the stage for the subsequent phases. In the Measure phase, Pareto analysis identifies key contributors to the inventory costs, including materials such as "Cotton 1/30" and "Cotton 1/24," which collectively constitute 75% of inventory costs. It is noteworthy that these materials are crucial components used in production processes, as revealed by insights from the previous research.

This important discovery forms the basis for the Enhancement phase, in which the research strategically applies a Just In Time (JIT) system, resulting in a 50% reduction in the level of inventory for "Cotton 1/30" and a 70% reduction for "Cotton 1/24". Two Production Withdrawal Kanban cards as well as seven Production Instruction Kanban cards for "Cotton 1/30" and "Cotton 1/24" are required for the execution. This strategic shift aligns with market demand and results in a significant 55% decrease in holding costs.

Keywords: Inventory Management; Six Sigma; DMAIC; Textile Industry; JIT; Kanban

1. Introduction

The foundational tenet of Six Sigma is that efficient input management leads to effective control of process outputs [1]. Originally developed as a data-driven strategy for improving quality at Motorola in 1986, Six Sigma blends qualitative and quantitative methodologies. It is expressed using the function y = f(x). In this case, y is the outcome and depends on x, the inputs [1]. Its main goal was to use statistical techniques to reduce manufacturing process variability and eliminate defects [2]. Under CEO Jack Welch's direction, General Electric widely implemented Six Sigma in the 1990s, demonstrating the methodology's efficacy in reducing costs and enhancing quality. This cemented Six Sigma's position as an essential instrument in industrial engineering and quality management [2]. Six Sigma methodology is noteworthy for its ability to visualize process flows, monitor performance, analyse data, and identify potential failure modes. It is based on the DMAIC framework, which stands for Define, Measure, Analyse, and Control. The framework is a systematic approach that starts with problem identification and ends with the implementation of long-term solutions [1]. As Just in Time (JIT) production replaces Six Sigma, Kanban plays a key role as a visual cue-based system that uses cards or signals to indicate inventory replenishment needs or start production operations [3]. Governed by Kanban rules, the system explicitly constrains work-in-process (WIP), aiming to systematically diminish inventory levels while ensuring seamless material flow [4]. Numerous studies emphasize critical factors for successful Kanban implementation, including effective demand identification and communication, stable forecasting methods, production schedules, and supply chain visibility [5]. Signage and bins indicating workflow status and capacity play a vital role in regulating

* Corresponding author: Ghofran M Salah

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material movement based on agreed-upon rules [6]. Achieving a balance in Kanban quantities is imperative, minimizing WIP and preventing transportation bottlenecks, often requiring pilot testing [7].

Objective

The main study objective is to investigate the potential utilization of the Six Sigma methodology, coupled with Just-In-Time (JIT) principles, as a strategic approach to minimize the inventory levels and associated costs within a textile factory.

2. Literature review

A study conducted in spar part plant in Malaysia, the implementation of Six Sigma methodology aimed to lower the total inventory costs for the spare parts [8]. Following the Define, Measure, Analyse, Improve, and Control (DMAIC) the project began by identifying the main issue: a consistent 9% annual increase in inventory value, resulting in significant expenses. The Define phase involved establishing a project charter, and setting a goal to reduce the costs by 20%. In the Measure phase, information on inventory values in Ringgit Malaysia (RM) from 2015 to 2017 was collected, revealing a total inventory value of almost RM351 million in 2016 [8]. After identifying the crucial components causing the problem, the list of 25 factors was reduced to just 9. After entering the Improve phase, elements such as lengthy lead times and duplicate parts were examined and enhanced. Approved solutions were put into practice during the Control phase [8]. The results displayed a notable drop in inventory levels as shown in figure 1, from RM350,973,450 to RM303,632,021—a 13.5% reduction, though falling short of the 20% target set in the Project Charter. The study's application of the DMAIC method was successful, and the inventory value was significantly reduced; nonetheless, the reduction fell short of the initial goal [8].

Figure 1 I Chart of total project tracking [8]

The implementation of the Kanban system in a manufacturing setting is evident in a study by Adnan. The study outlines the meticulous steps taken prior to Kanban implementation, including the design of the Kanban flow, considering criteria such as process distance and information conveyance [9]. Gathering relevant manufacturing parameters and customer forecasts over three consecutive months was crucial to establishing the takt time, aligning with peak volume requirements [9]. Calculating the number of Kanban's involved using the Toyota formula ensured synchronization with actual customer needs. As illustrated in figure 2 [9], authorization and replenishment were significantly aided by Production Withdrawal Kanban (PWK) and Production Instruction Kanban (PIK), which in turn led to a substantial reduction in in-process and finished goods inventory by 52% and 55%, respectively.

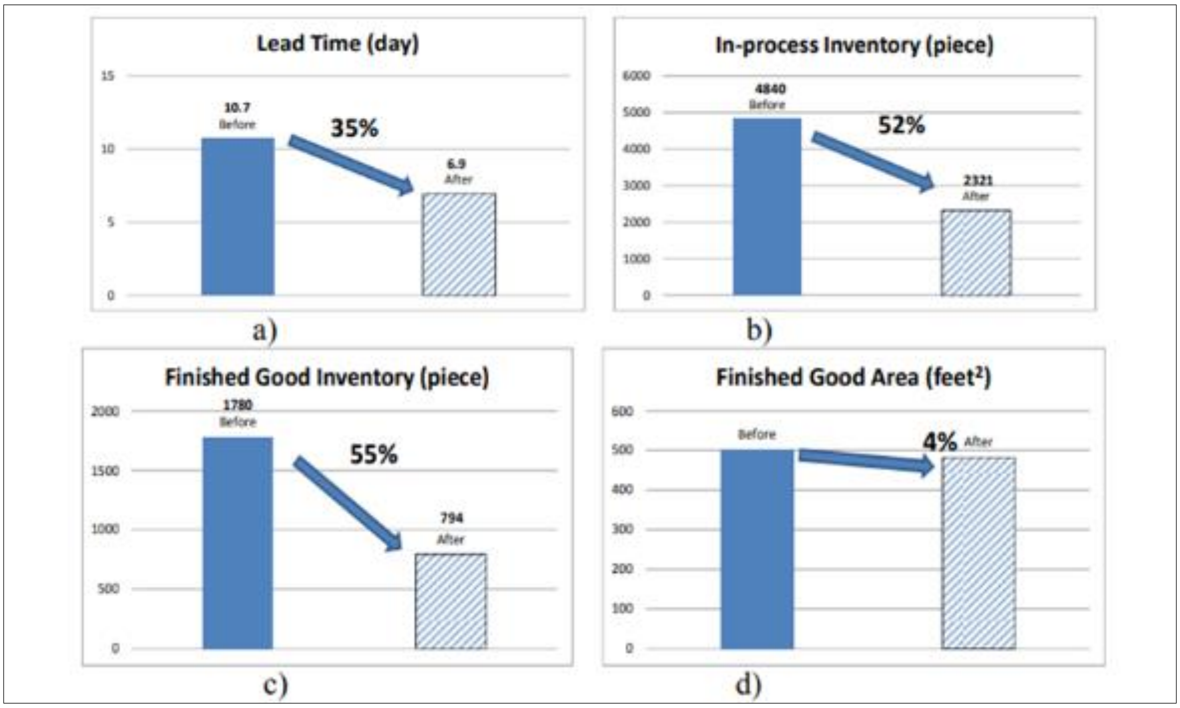

Figure 2 Improvements after implementing the Kanban system [9]

The study showcases improvements in manufacturing lead time and space efficiency, with a reduction from 10.7 to 6.9 days and a decrease in the finished goods area from 504 to 483 square feet [9]. In conclusion, the systematic implementation of the Kanban system positively transformed manufacturing capabilities, enhancing resource efficiency and reducing operational costs [9]. This comprehensive commitment to Kanban is vital for achieving effectiveness, satisfying customer demands, and aligning manufacturing pace with market needs [9].

3. Methodology

This study employs the Six Sigma DMAIC methodology to investigate and address inventory cost reduction in the textile industry.

3.1. Define Phase

In this phase, a comprehensive plan is outlined to overhaul the inventory management system, acting as both a guide and a mutual agreement between the project team and stakeholders. The Project Charter, as illustrated in Figure 3, provides insight into the difficulties encountered by inventory management in the textile sector, encompassing concerns about demand forecasting and the significant expenses linked to inventory upkeep. The charter is designed to streamline these processes, reduce costs, and establish the groundwork for addressing these prevalent problems. It articulates a compelling business case, underscoring the project's significance in terms of cost savings and operational efficiency.

Project Charter	
Project name	
Improvement of inventory management system	
Project overview	
Problem or issue	Poor performance of the inventory management processes of the textile sector i.e., Demand planning, lead times, high carrying costs of inventory.
Purpose of project	Optimize inventory management processes of the textile sector & reduce inventory costs.
Business case	This project is aimed at to optimize the organizational processes related to inventory management i.e., implementation of JIT to reduce carrying costs of inventory. It would help save inventory costs.
Goals / metrics	Inventory level, Inventory carrying cost
Expected deliverables'	Improvement in inventory management processes measured through reduce in inventory levels.
Project scope	
Within scope	The project's scope includes collecting of information, evaluating, analysing and improving the inventory management practises in a textile industry using six sigma DMAIC methodology to improve overall cost-effectiveness, optimise inventory levels, and lower carrying costs.
Outside of scope	The initiative does not, however, cover more extensive technical aspects of the manufacturing of textiles.
Resources	
Support resources	Data, Analysis software's
Benefits and customers	
Process owner	Improve inventory management system processes
Key stakeholders	Textile industry, company owners, management, staff
Final customer	Inventory department
Expected benefits	Improve performance of inventory management system processes & reduce inventory costs by 35%.

Figure 3 The Project Charter

3.2. Measure Phase

Utilizing Pareto charting to prioritize data, the primary objective of the DMAIC project's Measure Phase is to assess the factory's inventory and management performance. This method is crucial for identifying critical elements that have a big impact on inventory costs. The Pareto principle is applied to help prioritize these important areas, directing efforts to solve the most important problems first in order to achieve efficient improvement and cost savings. Five different product categories are produced by the plant; each is linked to a particular manufacturing table and is in line with the necessary demand. These products are Cotton 1/24, Cotton 1/30, Cotton 20/80, Beka 50/50, as well as Cotton 35/65 [10]. Table 1 provides an overview of the inventory costs related to each type of material so that it may be determined which material has the largest influence on overall costs. It is possible to identify particular materials that make a substantial contribution to the factory's expenses by closely examining the data in the table.

Table 1 Total Inventory Costs [10]

Material Type	Total Inventory Cost($)
Cotton 1/30	23992.39
Beka 50/50	6321.00
Cotton 20/80	3302.40
Cotton 35/65	6352.61
Cotton 1/24	11708.69

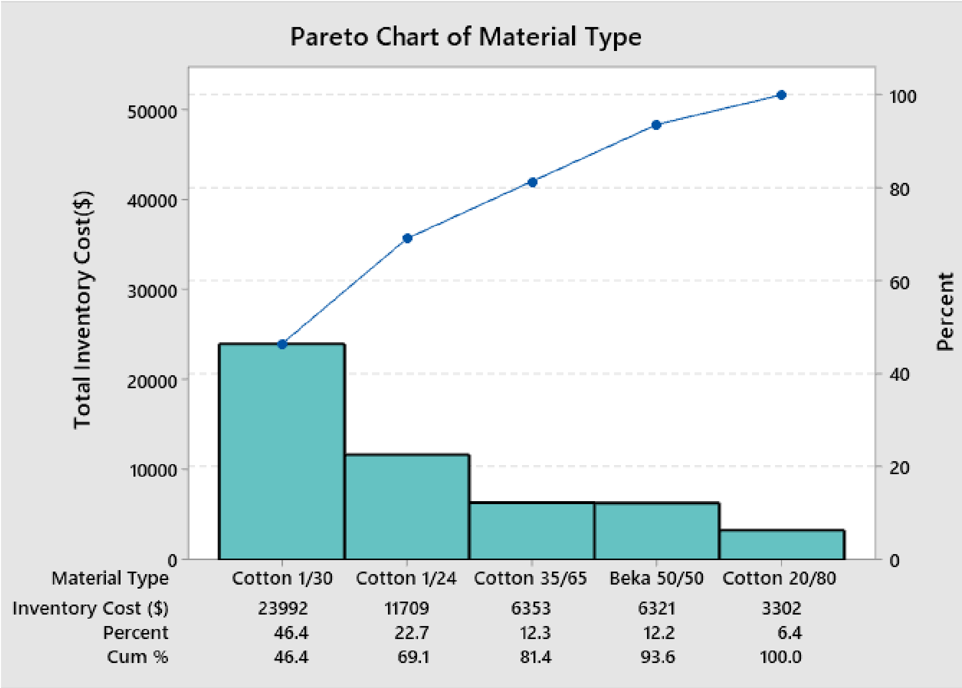

Figure 4 A Pareto Chart

Figure 4 shows a Pareto chart that illustrates the study of different material costs. It shows the total cost of inventory for "Cotton 1/30," "Cotton 1/24," "Cotton 35/65," "Beka 50/50," and the "Cotton 20/80." Interestingly, at $23,992.39, or 45% of the total material expenses, "Cotton 1/30" has the highest total inventory cost. "Cotton 1/24" makes a $11,708.68 contribution, or 22% of the total cost of the materials. Regarding the total expenses for material, "Cotton 35/65," "Beka 50/50," and "Cotton 20/80" contribute 12%, 12%, and 6%, respectively. Owing to the substantial influence of "Cotton 1/30" and "Cotton 1/24", which collectively account for about 70% of the total inventory expenses, the focus of next studies and enhancement initiatives will be on streamlining the handling and application of these two expensive commodities. Achieving significant cost savings and improving the factory's financial performance are the objectives. To develop focused methods for maximizing inventory costs, more investigation into the potential and difficulties related to "Cotton 1/30" and "Cotton 1/24" will be conducted. Expanding on the understandings from the Pareto analysis—which highlighted 'Cotton 1/30' as the main factor driving inventory costs—the subsequent stage of data collecting entails precise measurements of material amounts. Table 2 is an essential source of information that offers a thorough overview of the factory's 'Cotton 1/30' T-shirt output over the previous three years, broken down by quarter. This extensive dataset includes production quantities, order receipts, and the quantity of stored raw "Cotton 1/30" material.

Referring back to Table 2's analysis of the 'Cotton 1/30' production data, Figure 5, which is labeled "Production and Inventory Trends (Cotton 1/30)," provides a visual representation of the data. 'Total Quantity Out,' which indicates the amount of material used over those periods, is distinguished from 'Total Quantity In,' which represents the cumulative quarterly orders held in inventory prior to being used in production.

An examination of the 2018 data displayed in the figure reveals a notable discrepancy in which 'Total Quantity In,' totaling 114,000 units, exceeds 'Total Quantity Out,' by a significant margin, suggesting an inventory buildup plan. The 'Total Quantity Out' of 108,000 units shown in this figure suggests that a sizable portion of material is not immediately transformed into finished goods. The difference between the quantity used or leaving ('Total Quantity Out,' which increases to 112,850 units) and the inventory amount ('Total Quantity In,' which stands at 118,000 units) is getting closer as 2019 goes on. This is a step in the direction of effective inventory control—an improvement in inventory management in line with production demands. The circumstances in 2020, however, are very different. At 42,000 units, the amount of merchandise coming in about equals the amount of goods going out (41,100 units). The COVID-19 pandemic's operational effects are to blame for this notable decline in "Total Quantity In," which forced inventory management procedures to be quickly adjusted in response to shattered supply lines and varying demand. 2019 saw an average of 18,000 inventory as the result of applying the formula (Beginning Inventory + Ending Inventory)/2. The beginning inventory used for this computation was 18100 units, which was the ending inventory for 2018, while the ending inventory for 2019 was 5,900 units. It is crucial to remember that the lack of information on the 2017 ending inventory made it impossible to calculate the average inventory for 2018. Additionally, even though the 2020 data is calculable, it may not precisely reflect standard operations because of the possible impact of the COVID-19 pandemic, which could cause unexpected variations in the levels of inventory.

Table 2 Cotton 1/30 T-Shirts' Factory Production [10]

Factory Production				**Avg Inventory**
Year	Quarter	Quantity (Piece)	Out	
2018	1st	40000	38000	18000 units = 1500 unit per month
	2nd	35000	33000	
	3rd	22000	20000	
	4th	17000	17000	
2019	1st	60000	58000	
	2nd	18000	16200	
	3rd	21000	19650	
	4th	19000	19000	
2020	1st	10000	10000	
	2nd	17000	16100	
	3rd	3000	3000	
	4th	12000	12000	

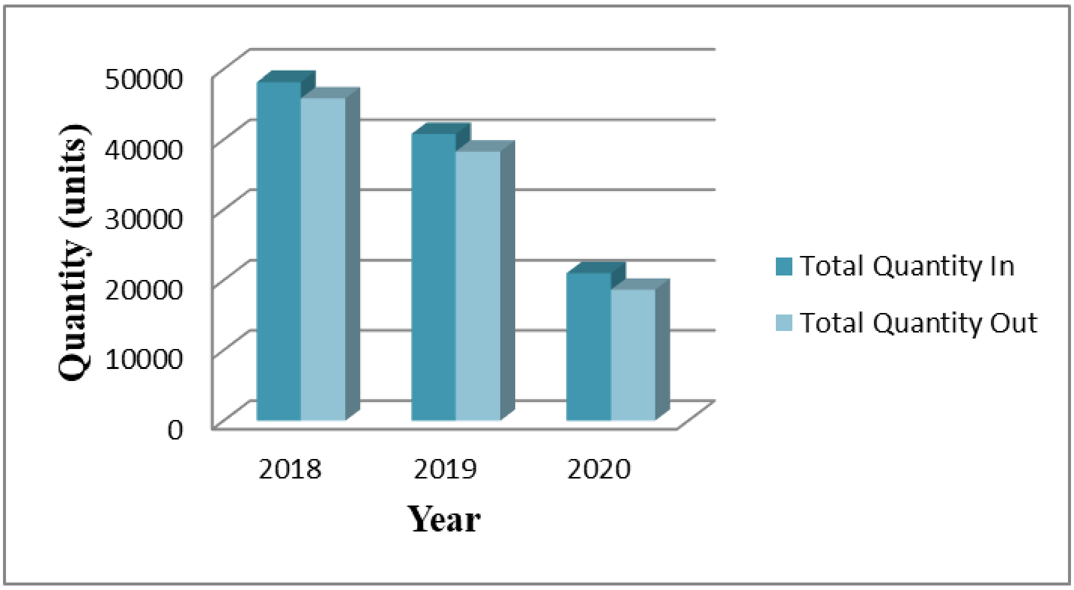

Figure 5 Production and Inventory Trends for Cotton 1/30

As for the study on Cotton 1/30, Table 3 below provides a comprehensive summary of the production parameters for T-shirts with the label "Cotton 1/24" throughout a number of quarters. This analysis is deemed crucial due to the material's substantial impact on total inventory costs, a revelation derived from the Pareto chart assessment. The scientific rigor applied in this examination involves meticulous observation and documentation of production figures, fostering an evidence-based understanding of the intricate dynamics underlying 'Cotton 1/24' T-shirt manufacturing. This systematic approach aligns with scientific principles, ensuring a comprehensive exploration of the material's role in inventory expenditures within the specified timeframe.

Table 3 Factory Production of Cotton 1/24 T Shirts [10].

Factory Production of Cotton 1/24				**Avg Inventory**
Year	Quarter	Quantity (Piece)	Out	
2018	1st	12500	11500	12 000 units = 1000 unit/ month
	2nd	11000	10000	
	3rd	6300	6300	
	4th	18400	18100	
2019	1st	10300	10300	
	2nd	9700	9700	
	3rd	12400	12400	
	4th	8420	5900	
2020	1st	3500	1200	
	2nd	2300	2300	
	3rd	9200	9150	
	4th	6000	6000	

The data presented in Table 3 above is presented graphically in Figure 6 below. With 12,500 units produced and 11,500 distributed in the first quarter of 2018, the production performance for 'Cotton 1/24' in 2018 starts out strong and shows a close match between supply and demand. Through the second and third quarters, this pattern holds steady, with a slight excess in production over output, which guarantees a smooth movement of inventory. Nonetheless, production rises to 18,400 units in the fourth quarter, with a minor discrepancy between the items produced and those delivered.

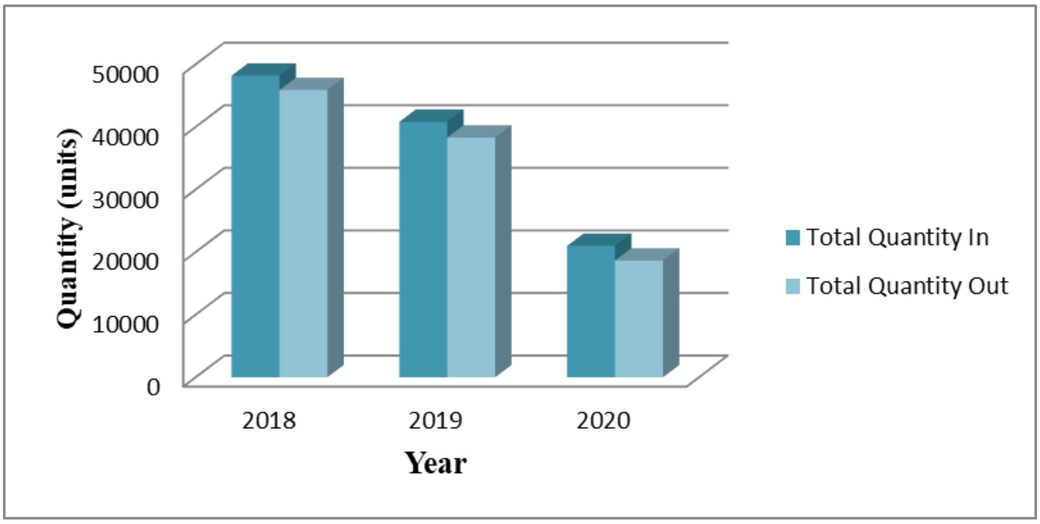

Figure 6 Production and Inventory Trends for Cotton 1/24

In 2019, the output and production of 'Cotton 1/24' are consistent with one another, demonstrating effective inventory control and demand prediction. During the initial three quarters, the production remains steady at approximately 10,000 units. Nevertheless, there is a noticeable decline to 8,420 units produced in the fourth quarter, along with a smaller outflow of 5,900 units, suggesting that there may have been a planned change in production or an unexpected decline in demand.

The statistics for 2020, particularly in Quarter 1, shows a huge disparity with just 3,500 units produced compared to a far lower distribution of 1,200 units. This gap illustrates how supply networks and output have been significantly impacted by the COVID-19 outbreak. The painstaking measuring process creates a thorough comprehension and precise ranking of inventory information, setting the stage for a deeper investigation during the Analyze stage. The next stage looks at the underlying factors that affect inventory management, and the data that has been prioritized will be used to direct specific improvements in the procedure.

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3.3. Analyse Phase

Advancement to the Analyze stage denotes a shift from measurement to a thorough understanding of the underlying reasons for inventory level disparities. The application of the Five Whys technique is the fundamental component of this analytical procedure. This approach takes a methodical approach to examining the significant inventory costs linked to 'Cotton 1/30' and 'Cotton 1/24' by exploring fundamental issues through focused interviews. The improvement phase's next initiatives will be built upon the resulting insights.

3.3.1. The Five Why Analysis

'Cotton 1/24, 1/30' has significant inventory costs. To analyze this, a Five Whys study is carried out with a series of iterative "why" questions. Using this strategy, the root causes of the observed issue will be carefully examined. The main goal is to identify the underlying cause of the increased expenses related to the stock of "Cotton 1/24, 1/30."

Problem Statement: The organization grapples with inventory cost challenges specifically attributed to 'Cotton 1/24' and 'Cotton 1/30.'

- Why is there an escalation in the inventory costs for 'Cotton 1/24, 1/30'?
- Answer: The prolonged storage of products beyond an optimal turnover period contributes to the cost increase.
- Why do products experience extended storage beyond the ideal timeframe?
- Answer: A lack of a precise inventory replenishment method or system is evident.
- What is the reason for the absence of a precise inventory replenishment mechanism or method for 'Cotton 1/24' and 'Cotton 1/30'?
- The existing replenishment mechanism inadequately considers variations in demand and inventory costs.
- Why does the current replenishment procedure not take lead delays and demand variations into account? The process has not been updated to accommodate current market volatility and relies on traditional push techniques.
- Why has the process not been modified to adapt to the current market conditions?
- The organization's application of procedural reviews and continuous improvement strategies is lacking. Long-term inventory storage is caused by the lack of a demand-responsive replenishment system, which is the main factor driving up inventory prices for "Cotton 1/24, 1/30." The organization's failure to recognize the financial consequences of overstocking results in a lack of policies that could mitigate inventory costs.

3.4. Improvement Phase

Correcting the accuracy problems found in the MRP during the Analyze phase is the goal of the Improvement phase. In order to optimize inventory management and handle issues with carrying costs and potential sales loss, this entails implementing Just In Time (JIT) and Kanban systems. In order to meet the demand in 2021, the strategy shown in Table 4 will be put into action. The outcomes will then be compared with data from the prior years (2018, 2019, 2020) that were looked at in earlier phases. The strategy outlines a number of actions, including improving data accuracy, using the Kanban system to execute Just-In-Time (JIT), and creating Kanban rules to create a production system that is calibrated and responsive to demand. These stages are carried out with defined roles allocated, which guarantees task ownership clarity and promotes coordinated efforts to optimize inventory levels.

Table 4 Improvement Plan

Improvement Plan		
Improvement Task >>>	Inventory Costs Improvement	Responsibility
Actions Required		
Validate Data Accuracy/Integration: Validate the accuracy and timeliness of the data that is used for material planning. Combine data from several sources, including sales, production, and procurement, to create a complete picture of supply and demand.		Planning department
T Implementation - Just-In-Time: This phase introduces the application of the Just-In-Time (JIT) philosophy, emphasizing inventory management with the objectives of waste reduction, cost minimization related to inventory holding, and operational efficiency enhancement. The JIT system operates on a "pull" basis, responding to customer orders or process signals, aligning production with actual demand rather than forecasts. **Improvement Phase:** **Pull Production through Kanban System:** Implementing the JIT system involves employing a Kanban system for pull production. This method ensures production is demand-driven, aligning with customer requirements and minimizing forecast-based discrepancies. **Evaluate and Fine-Tune Results:** After JIT system implementation, a thorough assessment is imperative to gauge the impact of changes. This includes scrutinizing inventory levels and associated costs. Analysing these metrics enables the identification of areas where the JIT system excels and areas requiring further refinement. **Control Phase:** • **Set Kanban Rules:** In order to create effective Just-In-Time (JIT) systems, Kanban rules must be put into place. With the goal of reducing waste and maximizing efficiency, these regulations control the movement of products and materials during the production process. • **Control Improvement Over Time:** Control charts are used to monitor and maintain improvements over time. These charts function as a common process monitoring tool, guaranteeing consistency and stability in the applied enhancements.		Production / Inventory / Planning/ Quality Departments

In the dynamic landscape of manufacturing, efficiency and adaptability play pivotal roles. The Kanban system, a paradigm shifts from the traditional "Push system" to a "Pull system," stands as a revolutionary approach synchronizing inventory levels with consumption rates. The impetus for this transformation stems from the aspiration to mitigate inefficiencies induced by excessive inventory and overproduction, hindering organizational agility and responsiveness. Originating from the word "signal," Kanban is a comprehensive strategy for streamlining production flow and guaranteeing that goods are produced in direct response to real consumer demand. Beyond inventory control, the core principles of Kanban are limiting work-in-process (WIP) items and encouraging a demand-driven production cycle. This process reduces waste and increases industrial flexibility so that it can react quickly to demand changes.

This introduction examines the role of the Kanban system in manufacturing, emphasizing the ways in which it can save expenses and improve customer satisfaction. We look at two types of well-integrated Kanban systems:

1. **Single-Card Kanban System PIK**

The PIK card, which uses a single card to indicate when production is required, directs the start of item production, creating a direct connection between the manufacturing process and current demand.

2. **Two-Card Kanban System**

Two types of cards are utilized in this case:

- **Production Withdrawal Kanban (PWK):** Gives permission to remove components from the previous step so that only necessary parts are put on the production line.
- **PIK:** It offers manufacturing instructions in the upstream process to efficiently control inventory flow when used in conjunction with PWK.

The Kanban system, which starts material flow throughout manufacturing processes via cards or visual cues, allows production to be changed to match demand. Its main benefit is that it lowers inventory levels, which is in line with lean manufacturing principles that view inventory as a possible source of waste that should be removed. Currently, materials are moved from the shops department and go through a number of processes. The demand for cotton 1/30 in 2021 is shown in Table 5, where it is shown that 250 kg will be needed to create 1,000 completed cotton 1/30 T-shirts [10].

Table 5 Cotton 1/30 for 2021 Data[10]

Quarter	Demand (T-Shirt)	Raw Material	Kanban data	
1st	7762	1781 kg	AVG Demand	19344 unit
2nd	4939	1235 kg		
			Manufacturing Lead time	6 days
3rd	3246	812 kg	Suppliers Lead time	1 day
			Annual Holding cost	$391.84
4th	3387	847 kg	Annual Ordering cost	$4140.384

Table 6 Demand Data of Cotton 1/24 for 2021[10]

\`Period (Quarter)	Demand (No. of T-Shirt)	Amount Needed of Raw Material (Kg)	Kanban data	
1st	2265	518	AVG demand	9480 unit
2nd	1980	495		
			Manufacturing lead time	6 days
3rd	2402	601	Supplier lead time	1 day
			Annual holding Cost	1023.16$
4th	2826	707	\`Annual Ordering cost	2065.10$

Table 6 highlights the expected demand for the cotton 1/24 in 2021, with a specific requirement of 250 kilograms to create one thousand completed units of the cotton 1/24 t-shirt [10].

Right now, inventory accumulates at every stage of the procedure, starting with the 200 rolls (500 kg) of fabric that are kept in storage and going all the way through the manufacturing cycle. The suggested fix for this is to introduce redesigned Kanban cards and switch from a push to a pull mechanism. Equations 1 and 2 of the Toyota Production

System (TPS) serve as the basis for calculating the necessary quantity of Kanban cards [11]. In keeping with the TPS, this method uses a particular computation to figure out the ideal number of Kanbans.

According to Equation 1, PIK is equal to Demand During Production Lead Time×(1+α)/Container Capacity [11]. Equation 2 calculates PWK as Demand During Replenishment Lead Time×(1+α)/Container Capacity [11].

Where:

The quantity of product to be utilized or sold while waiting for more to be produced is the "Demand During Production Lead Time."

The additional buffer percentage known as the Safety Factor (α) protects against unpredictability and uncertainty.

Container Quantity, which often corresponds to one container or batch, is the usual number of objects moved or produced at one time.

Regarding Cotton 1/30:

Based on table 5, the demand (D) is 1612 units per month, or 81 units per day.

According to Table 5, the Production Lead Time (T) is six days.

The expected safety factor (α) to account for any difference in demand between quarters is 10% or 0.1.

Container Size (C)= (Daily demand times lead time plus safety stock.

C = (81 x 1 + 8 units) = 89 units.

By inserting the provided parameters into the PIK formula, we get:

$$\text{PIK} = \frac{81 * 6 * (1 + 0.1)}{89} = 6.006$$

Rounding up to the nearest whole number, as fractions of Kanban cards are not practical, a total of 7 PIK cards will be required.

Production Withdrawal Kanban (PWK)

- The monthly demand (D) is 1612 units, equivalent to 81 units per day (as per table 5).
- The Replenishment Lead Time (T) is 1 day (as per table 5).
- A Safety Factor (α) of 10%, denoted as 0.1, is considered.
- The Container Size (C) is determined to be 89 units.

The number of PIK cards is rounded up to seven in order to guarantee practicality. Table 5 shows that the monthly demand (D) for the Production Withdrawal Kanban (PWK) is 1612 units, or 81 units per day. With a 10% (0.1) Safety Factor (α) and an 89 unit Container Size (C), the replenishment lead time (T) is one day. By using the PIK formula with the supplied parameters:

$$\text{PWK} = \frac{81 * 1 * (1 + 0.1)}{89} = 1.01$$

Rounding this up to the nearest whole number, as fractions of Kanban cards are not practical, a total of 2 PWK cards will be required.

For Cotton 1/24

The monthly demand (D) is 790 units, equivalent to 40 units per day (as per table 6).

The Lead Time (T) is 6 days (as per table 6).

A Safety Factor (α) of 10%, denoted as 0.1, is considered.

The Container Size (C) is determined to be 44 units.

By inserting the provided parameters into the PIK formula for Cotton 1/24:

$$\text{PIK} = \frac{\left(40 * \ 6 \ * \ (1 + 0.1)\right)}{44} = 6$$

6 PIK card will be required

The monthly demand (D) is 790 units, equivalent to 40 units per day (as per table 6).

The Replenishment Lead Time (T) is 1 day (as per table 6).

A Safety Factor (α) of 10%, denoted as 0.1, is considered.

The Container Size (C) is determined to be 44 units.

By inserting the provided parameters into the PIK formula for Cotton 1/24:

$$\text{PWK} = \frac{40 \text{ x } 1 \ \text{ x } (1 + 0.1)}{44} = 1.01$$

Rounding off to the nearest whole number, as fractions of Kanban cards are not practical, a total of 2 PWK cards will be required.

For Cotton 1/30 and Cotton 1/24, the computed number of Production Instruction Kanban (PIK) cards is seven and six, respectively. This suggests that a reliable signalling system is required during the production process. Interestingly, this number exceeds the Production Withdrawal Kanban (PWK) card count that has been computed, which is two for Cotton 1/30 and Cotton 1/24. There are intrinsic differences in the nature of the replenishment and production processes, which accounts for the discrepancy in numbers. The increased number of PIK cards suggests a longer production process that includes internal material movement, processing stage durations, and the addition of a safety buffer to minimize any disruptions in addition to the actual T-shirt fabrication. This buffer is essential for allowing for unanticipated delays or variations in manufacturing capacity, guaranteeing uninterrupted and seamless operations. Conversely, the shorter lead times of the replenishment cycle—typically one day—are reflected in the lower number of PWK cards. Resupply is a faster process that requires fewer signals to maintain efficiency because it mostly entails obtaining materials or refilling from internal buffers. Figure 8 shows the suggested fabric flow utilizing Production Order Kanban and Withdrawal Kanban, while Figure 9 shows a Kanban sample. Kanban cards typically use color to help identify particular information, including the type of material and the department or individual in charge of the assignment.

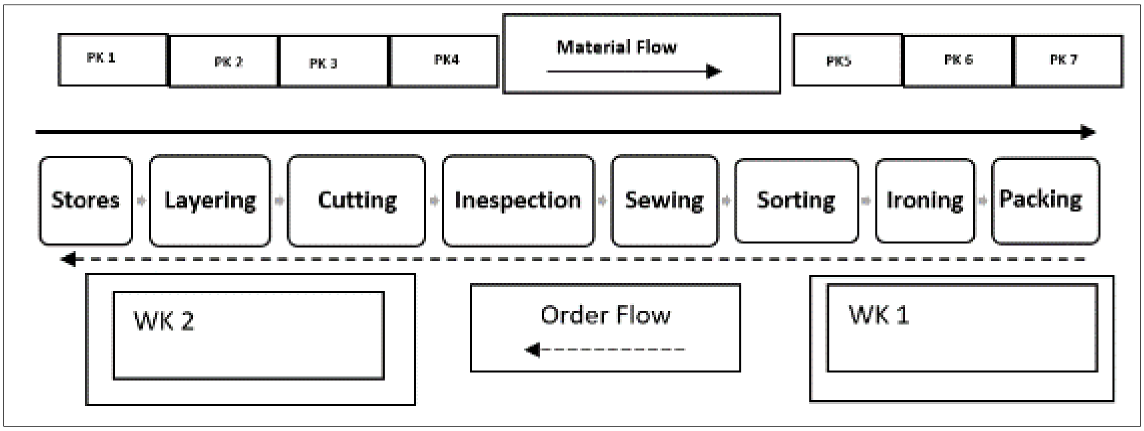

Figure 7 Order and Production Flow through the Kanban

Kanban Card (Front)
Item Nam : T-shirts Cotton :1/24
Container Capacity : 44 units
Location : Storage area C
Reorder point : When the container is empty
Supplier information: Company X .Tel : XXX Website :XXX
Kanban Card (Back)
Withdrawal order : Withdraw 44
Date Issued: When the card is issued
Due Date : Container Capacity
Authorized by: Name or signature of the person who authorized the withdrawal

Figure 8 Kanban Card

A methodical approach to inventory level monitoring and material flow control is demonstrated by the use of the Kanban system for Cotton 1/30 and Cotton 1/24 inventory, which comprises adjusted container sizes of 89 units for Cotton 1/30 and 44 units for Cotton 1/24. A reliable assessment of the current inventory can be obtained by counting the number of Kanban cards in use and the matching container sizes.

Cotton 1/30's seven Production Instruction Kanban (PIK) cards indicate that seven containers are used during the manufacturing process. Additionally, the supplier appears to be replenishing two containers of Cotton 1/30 based on two Production Withdrawal Kanban (PWK) cards. For PWK, the total inventory level is equal to 178 units by multiplying two cards by 89 units each container; for PIK, it is equal to 623 units by multiplying seven cards by 89 units per container. As a result, 801 units make up the total inventory level for Cotton 1/30. In reference to Cotton 1/24, the presence of six PIK cards denotes the use of six containers in the production process. Additionally, two PWK cards are used for restocking. In this instance, 264 units make up the total inventory level for PIK (6 cards multiplied by 44 units each container). It comes to 88 units for PWK (2 cards times 44 units each container). Consequently, the total number of units in the combined inventory is 352.

Inventory levels have significantly decreased with the use of the Kanban system as compared to the prior inventory management strategy. Using the Kanban method to implement a just-in-time (JIT) inventory plan is a notable strategic move that will improve operational efficiency and sound financial management. Tables 2 and 3 illustrate historical average inventory levels prior to the Kanban system's installation. These tables were examined throughout the measurement phase. It is anticipated that, after the JIT system is implemented, inventory levels will drop significantly, signifying a change from traditional stock management to a JIT inventory system.

Evaluating the reduction in holding costs for Cotton 1/30 and Cotton 1/24 stocks was the primary goal in determining how much the Kanban Just-in-Time (JIT) system saved on costs. The evaluation compared the annual holding costs per unit before and after JIT deployment, as seen in figure 10.

For Cotton 1/30, the annual holding cost per unit was $1.56, whereas for Cotton 1/24, it was $1.48.

The following calculations were used to calculate the holding cost savings using the rates:

Initial Holding before JIT = Annual Holding Cost per Unit as a product of Average Inventory Before JIT per Unit.

The Holding Cost after JIT= Annual Holding Cost per Unit as a product of the Average Inventory after JIT per Unit.

Total Holding Cost Before JIT is given by:

Cotton 1/30 = 1500 * 1.56 = 2340 $

Cotton 1/24 = 1000 * 1.48 = 1480$

Total Holding Cost After JIT is given by the following:

Multiplying the average of post-JIT inventory levels by annual holding cost for each unit under each cotton type:

Cotton 1/30 = 801 * 1.56 = 1249.56 $

Cotton 1/24 = 352 * 1.48 = 520.96 $

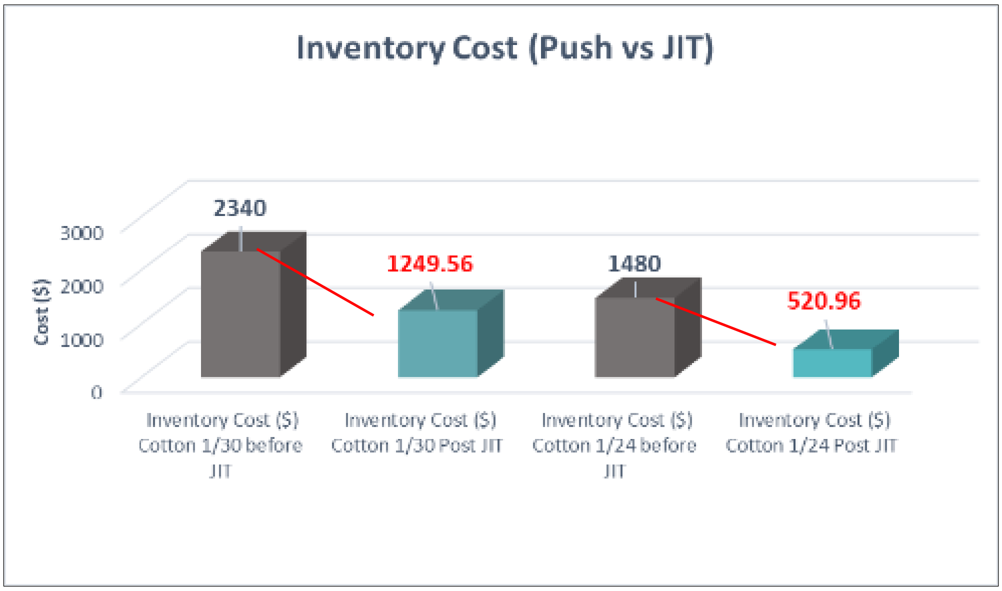

Figure 9 Push vs JIT Inventory cost

Because ordering costs are frequently less substantial than changes in holding costs, it was decided to exclude ordering costs from this research. JIT systems are primarily intended to lower holding costs by reducing inventory levels. Moreover, speculative cost estimates are required due to the lack of precise data on post-JIT ordering frequencies and volumes. In spite of this, considerable inventory savings were achieved by using the Kanban Just-in-Time system. Maintaining these levels is essential to reaping the long-term benefits of the Six Sigma framework, as the core objective of the Kanban system is to continuously maintain these ideal inventory levels throughout time. The Control phase will be largely concerned with maintaining and monitoring these changes, as well as developing tactics for detecting deviations and implementing remedial steps as quickly as possible.

3.5. Control Phase

The primary goal of the Control phase of Six Sigma is continuous monitoring and oversight of the improvements, which is made possible by Cotton 1/30 and Cotton 1/24's utilization of the Kanban Just-in-Time system. The completion of this step is essential to ensuring ongoing inventory level optimization. The application of two tools has aided in efficient management. These consist of control charts and Kanban rules. When adhered to strictly, the Kanban principles can stop the flow of defective materials during the manufacturing and transportation process, guarantee that parts move between processes without interruption, balance production and withdrawal quantities, label actual parts with Kanban labels, and confirm that the number on the Kanban corresponds to the actual count of parts. An extensive framework for inventory management is provided by these regulations. These rules help to prevent overproduction, reduce waste, and maintain the flow of commodities. Control charts are a useful supplement to these rules because they show inventory levels. By comparing the inventory system's performance over time to pre-set thresholds, control charts are mainly used to monitor system performance. To identify any differences in inventory levels that may require corrective action, it is imperative that these charts be reviewed often. The identification of possible supply chain concerns is made easier by the visual portrayal of trends and abnormalities in control charts.

3.5.1. Kanban's Operational Rules

When it comes to making a production system more agile and responsive, the operational concepts of Kanban are essential. In addition to offering direction, these principles are the basis for determining the rhythm of production, controlling material flow, and guaranteeing process alignment. They establish an atmosphere that encourages accountability, transparency, and improvement—all factors critical to the success of lean techniques. When using Kanban, there are six operational guidelines to follow:

- **Strict Quality Control when it comes to Material Handling**: Each item utilized in the production process must adhere to quality standards. Prompt rejection of defective materials is imperative to prevent the wastage of labour and resources, ensuring a seamless production flow.
- **Demand-Driven Material Withdrawal:** Fundamentally, a pull system works on demand, whereas a push system depends on projections. Instead than depending on anticipated demand, each production stage in a pull system starts production in response to the demand from the step after it.
- **Balance in Production-Consumption:** Ensuring that the number of things produced exactly corresponds with the required quantity is vital. In order to effectively control inventory levels and avoid overproduction, strict adherence to Kanban standards is required. Kanban cards are used to make it easier to fabricate and transfer materials as needed.
- **Kanban as the Primary Tool for Production Guidance**: Material movement and production do not happen until a Kanban card is present. This rule establishes Kanban as the main steering mechanism. It therefore prevents excess inventory and unlawful manufacture. There can be no production without a matching Kanban.
- **Visible and Accurate Kanban Information**: Affixing Kanban cards to materials is essential. This procedure makes information easier to grasp and verify while monitoring inventory levels during the manufacturing process.
- **Consistency in Kanban Information**: It is essential to make sure that the quantity indicated on the Kanban card appropriately represents the resources that are available. Any differences between the information on the Kanban card and the supplies should be addressed right away in order to keep the production process running smoothly.

3.5.2. Control Charts

Control charts are essential tools for monitoring process stability and indicating when corrective action is required in statistical process control and Six Sigma techniques. Attribute and variable control charts constitutes the two major categories of control charts. Variable control charts work well for operations that need to be precise and take variances into account. They can be used for data types including weight, time, or temperature. In contrast, categorical data such as defect counts or nonconformities are represented using attribute control charts.

Variable control charts are useful when it comes to data management and production processes. One such chart is the Individual Moving Range (I MR) chart. The I MR chart works well for tracking data points, especially in systems where it's important for each measurement to be independent of the others and for there to be variances between points. It is useful for monitoring stock levels in a Kanban system, helping to keep things moving smoothly and effectively.

The middle line in the diagram is the average of all measurements; it is used as a standard to assess inventory levels at every observation. Control limits specify the expected range of variation during operations and are usually set at three deviations from the mean (μ ± 3σ). This is enhanced by the MR chart, which emphasizes the movement or variation between data points. The average of these variations is shown by its middle line, which provides information about how consistently inventory changes occur. Control limits on the MR chart are often calculated at three times the moving range from the line in order to highlight any notable data deviations. Figure 11 displays the I MR plots for Cotton 1/30 and Cotton 1/24, which highlight the effectiveness of the monitoring.

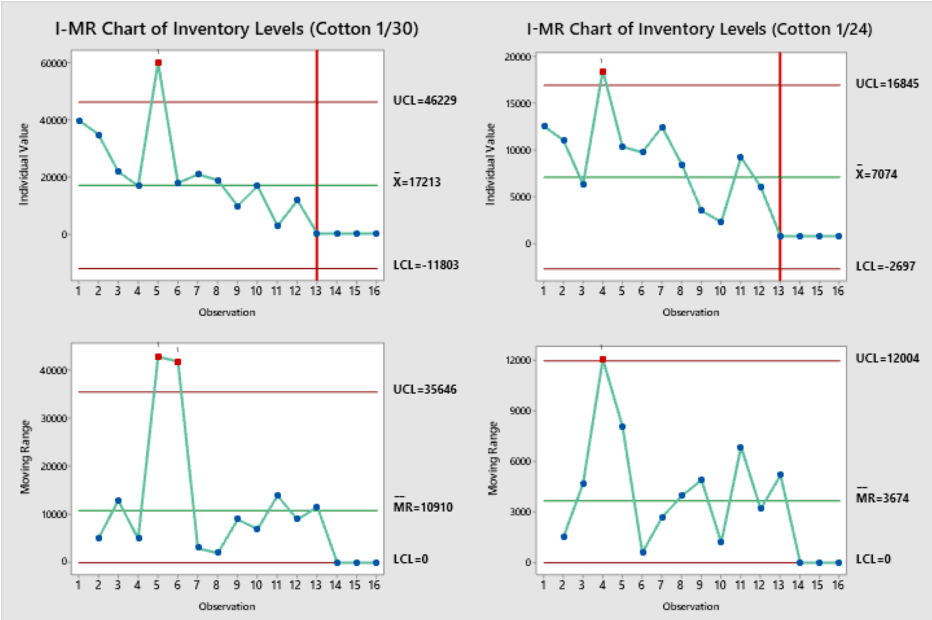

Figure 7 I MR Control Chart for Push vs. JIT Inventory Levels

After the implementation of JIT, there were changes in the way inventory was maintained, as shown by an analysis of the I MR charts for the Cotton 1/30 as well as for Cotton 1/24. During the pre-JIT period (observations 1–12), the charts depict fluctuations. Cotton 1/30 inventory levels are higher than the upper control limit in some instances, suggesting that overstock may be a problem. In Cotton 1/24, there seems to be a tendency to maintain inventory levels higher than necessary, even while it doesn't go above the control limitations. Inventory levels are expected to stabilize after the JIT deployment (observations 13–16), falling within control limits. This provides an example of how JIT principles are applied, with a focus on inventory reduction and demand alignment. To identify any new cycles, trends, mixtures, or patterns, it is imperative that you keep a close eye on these charts. By being proactive, you may stay in control and follow JIT guidelines while responding quickly to any deviations.

4. Conclusion

Using the Lean Six Sigma technique to manage Cotton 1/30 and Cotton 1/24 inventory in the textile sector has shown to be a methodical and efficient way to deal with the issues brought on by high inventory prices. The structured Lean Six Sigma process, which consists of five steps, provided a framework for finding, evaluating, and putting into practice solutions to improve inventory management procedures including defining, measuring, analysing, improving, and controlling. In the Definition phase, the project goals and objectives were clearly established through the development of a project charter. This phase laid the groundwork for a focused and well-defined initiative aimed at optimizing inventory costs. The Measure phase involved identifying and developing metrics to assess the current state of inventory management, setting the stage for data-driven analysis and improvement. During the Analyse and Improve phases, proposed solutions were evaluated and prioritized based on their potential impact on inventory costs. The Control phase then facilitated the implementation of approved solutions, ensuring that the organization had the necessary tools and strategies in place to sustain improvements over time. Cotton 1/24 and Cotton 1/30 experienced a significant reduction in average inventory levels as a consequence of the effective use of Lean Six Sigma. The adoption of a just-in-time (JIT) inventory system in lieu of traditional stock management resulted in a noteworthy reduction of holding costs by 46% and 65%, respectively exceeding the 35 % stated in the projected charter. These tangible outcomes highlight the efficacy of Lean Six Sigma in achieving the project's objectives and delivering substantial cost savings. Moreover, it is noteworthy that the project theoretically exceeded the initial target, considering the work was based on secondary data and not direct implementation. This theoretical success emphasizes the adaptability and potency of Lean Six Sigma in addressing challenges and optimizing processes even in an analytical context. The methodology's ability to deliver positive outcomes through comprehensive analysis and strategic planning showcases its versatility and value in achieving organizational goals.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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