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Reduction of Manufacturing Lead Time by Value Stream Mapping of a Selected RMG Factory in Bangladesh

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***Abstrac*t - Bangladesh is a fast-growing economy powered by the readymade garments (RMG) industry which has promoted the country in the world through the motto 'Made in Bangladesh'. The RMG industry has become the lifeline of the economy of Bangladesh. However, this industry faces several significant obstacles to its continued, sustainable expansion. The trading climate has become very competitive because of the phase-out of the export quota system. Additionally, with today's rapid fashion, consumers want items with short lead times and affordable prices. Adopting the lean methodology across the board in the garment business is essential for long-term sustainability in this cutthroat context. Lean manufacturing is a philosophy to deliver the finest goods on time with minimum endeavor and less price. Lean manufacturing aims to cut lead times and remove wastes that don't impose value on products. The purpose of this research is to identify wastes and to reduce manufacturing lead time by eliminating or reducing the excess tasks that cause higher lead time by implementing lean concepts. But implementing lean philosophy is a difficult task. During the visit to the selected RMG factory, the Short Sleeve T-shirt, one of their products, was selected for conducting this research. All the processes were observed required for the transformation of raw materials into a finished T-shirt. During the observations, the methodology of time study was applied to collect the data. Necessary information was gathered by observing the processes and interacting with the executives. Then, the current state of the value stream mapping was drawn. Wastes, responsible for a longer time, were ranked by taking the help of an 80-20 rules diagram. After this, root cause analysis was performed to find the reasons for the unwanted time consumption. Improvement strategies were introduced to reduce waste. Lean tools like Kanban to reduce WIP, Single Minute Exchange of Die to reduce changeover time, and Total Productive Maintenance to reduce machine breakdown were used to minimize the waste. Based on improvement strategies, The value stream mapping's future state was illustrated, showing the refinement where total manufacturing lead time was reduced by 61.20%. Finally, this research has suggested some recommendations to the management of the selected RMG factory to minimize waste and increase efficiency and reduce waste in the operations. This research illustrates the usual conditions of the RMG industry of Bangladesh by presenting the current state of the value stream. The Bangladeshi clothing sector must completely embrace lean principles and embark on the direction of sustainable growth.**

Keywords: **Lean Philosophy, Lean Tools, Value Stream Mapping, Lead Time, Wastes**

I. INTRODUCTION

Lean manufacturing allows any production or service process to be completed by eliminating needless processes. Value Stream Mapping (VSM) is one of the most successful lean methods for reducing lead time. Simulation helps to identify the value-adding and non-value adding time more efficiently. Reduced lead times foster positive relationships between customers and producers, as well as producers and suppliers [1].

Lean manufacturing is used to remove or reduce waste in any manufacturing or service process that does not add value to the final product or service. It is not simple to adopt lean manufacturing since it takes a significant amount of work as well as extensive knowledge and understanding of the theories and concepts that underpin lean manufacturing. Implementing lean manufacturing may appear difficult at first, but after it is implemented successfully, the efforts put into the process will feel worthwhile. For many years, the fundamental concepts of lean manufacturing have been used in Japan, with regular benefits such as reduced manufacturing time, reduced production lead time, reduced inventory, and increased customer satisfaction. The origins of Lean may be traced back to Toyota, a Japanese corporation. The Massachusetts Institute of Technology's James P. Womack, Daniel T. Jones, and Daniel Roos wrote about lean manufacturing in their book 'The Machine That Changed the World' in 1991 [2].

Many competitive countries outside of the RMG industry are waiting for us to make a mistake. A single blunder might result in the loss of the worldwide market. Lean manufacturing technologies could reduce or eliminate non-production time. This would result in more foreign profits and a big boost to our economy.

A. Objective of this Research

The objective of this research is to reduce manufacturing lead time by identifying and eliminating wastes.

II. LITERATURE REVIEW

Necessary theoretical information is briefly discussed.

A. Lean Manufacturing

Lean manufacturing is a manufacturing philosophy that helps reduce lead times by optimizing non-value-added activities across the supply chain [3]. One of the major developments in management practice over the last two decades has been the introduction of lean, lean manufacturing, and lean concepts [4]. Seven types of lean wastes are identified by Ohno, and they are,

1. Excess Production: It happens when tasks keep going when they must be stopped. Increased inventory is the result of excess production.

2. Excess Queues: This is also called a waiting line, and it happens when a successive operation fails to complete the task within the actual time.

3. Over Transportation: Over transportation of semi-finished goods, like WIP being moved from one location to another must be avoided at all costs as it prolongs lead times and adds no value. Additionally, degradation might happen while being transported.

4. Over Processing: Because of defects, overproduction, or excess inventory, additional tasks including repairing, transferring, or spaces are required.

5. Excess Inventory: All inventories that are not required to meet consumer orders are thrown away. Stocked goods necessitate additional movement as well as storage.

6. Unnecessary Motion: Additional measures are attempted for compensating unfavorable floor design, flaws, reworking, surplus output, or too much stock.

7. Rejects and Flaws: Products that can't meet customer expectations or specifications, resulting in dissatisfaction.

B. Value Stream Mapping

Toyota created the Value Stream Mapping (VSM) approach. In the process of designing lean, the VSM approach is utilized to visually portray the existing and future states. The value stream map represents the flow of goods and data of production. Each activity is it value adding or non-value adding is considered in VSM.

Any operation that meets the customer's expectation is considered a value-added activity. An exception of this is referred to as a non-value-added activity [5]. Some specific data are used as an intrinsic part of the value production process in value stream mapping. They are as follows:

1. Cycle Time (C\T): The time it takes to complete one cycle of an operation, or function, job, or work from beginning to end. The term "cycle time" is used to distinguish between the entire duration of a process and its run time.

2. Takt Time: Takt time is derived from the German term 'Taktzeit,' which means 'cycle time.' To meet client demand, it is the maximum permissible time for producing one product. It's the speed at which we must operate in order to meet client demand [6].

3. Changeover Time: The time spent converting a configuration for one product line to a setup for another product line that does not add any value.

4. Available Time: The amount of time a production line is available for use. The availability time is measured in seconds and excludes scheduled downtime such as lunch and breaks.

5. Uptime: Uptime is the ratio of a machine's actual production time to its availability time. Uptime is computed as a percentage by dividing actual production time by availability time.

The steps of VSM are divided as follows,

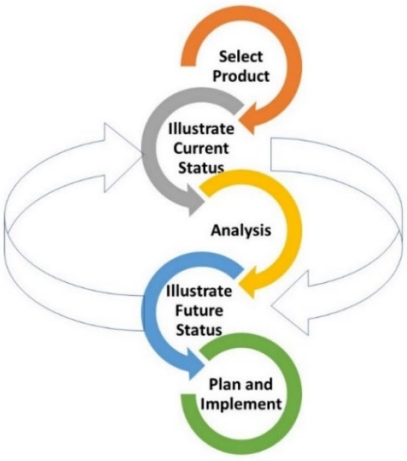


Fig. 1 Process of developing VSM [7]

C. Single Minute Exchange of Dies (SMED)

Shingo created the one-minute exchange of dies hypothesis in the mid-20th century to allow for rapid changeovers between operations while staying under a one-minute time limit. The term "single minute" does not imply that all changeovers and setups should be completed in one minute, but rather that they should take less than ten minutes [8].

D. Kanban

Kanban is a strategy used in lean manufacturing philosophy to keep inventory under check. Kanban is a Japanese word that means "card signal." Kanban procedures were first established by Toyota. The card was used to control material flow on the assembly line in the Toyota factory. The fundamental idea behind adopting Kanban is to properly coordinate suppliers and manufacturers so that suppliers can provide the correct and needed number of parts or components at the right time. The manufacturer does not need to have parts in inventory to accomplish this [9].

E. Total Productive Maintenance

TPM stands for Total Productive Maintenance, which aims to increase production by making processes more dependable and less wasteful. TPM's goal is to keep the plant or equipment in good working order without interfering with regular operations. It was developed in Japan in 1971 as a method for increasing machine availability by maximizing the use of maintenance and production resources.

III. METHODOLOGY

As this is a case study we have followed a quantitivive approach to get the desired data and output. The following flow chart shows the steps we followed to conduct this study.

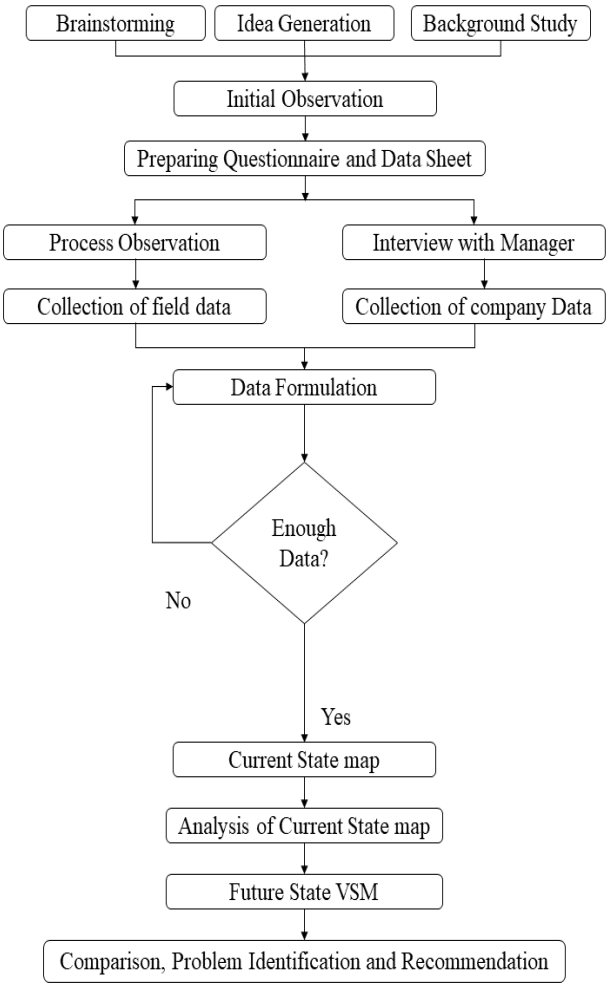


Fig. 2 Research Methodology

IV. DATA COLLECTION AND ANALYSIS

Data were collected from an RMG factory in Bangladesh and analyzed to eliminate waste.

A. Available Time

Available Time = Net Operating Time per shift × No. of Shift

Net Operating Time = $(540 - 60 - 8) = 472\ min$

Available Time= $472 \times 1 = 472\ min$

B. Takt Time [10]

$$Takt\ Time = \frac{Net\ Available\ Time}{Customer\ Demand\ Per\ Day}$$

Net Available Time = $472\ min = 28320\ sec$

Customer Demand= $825\ pcs/day$

No. of Production Line= 2

Production Per line= $\frac{825}{2} = 412.5 \approx 413\ pcs$/day

Production Per Hour= $\frac{413}{8} = 51.625 \approx 52\ pcs/hour$

Takt Time= $\frac{3600}{52} = 69.23\ sec$/per piece

C. Current State Summary

Table I, derived from field data, displays the present situation of three production line segments in terms of value addition, non-value addition, and unavoidable non-value addition time. These three categories were the focus of our analysis.

TABLE I CURRENT STATE ANALYSIS

Process Name	Cutting	Sewing	Finishing
Processing Time (min)	32.52	14.58	95.47
WIP Inventory (min)	-	30	5
Changeover Time (min)	12	417	0
Available Time (min)	472	472	472
Uptime (%)	97.46	97.94	100
Waiting Time (min)	0.5	4.57	2.11
VA Time (min)	4.52	1.89	3.77
NVA Time (min)	7.75	37.5	15.75
UNVA Time (min)	28	12.69	91.7

D. Current State Map

From the collected data including raw material inventory time and finished goods inventory time, the present scenario is illustrated below,

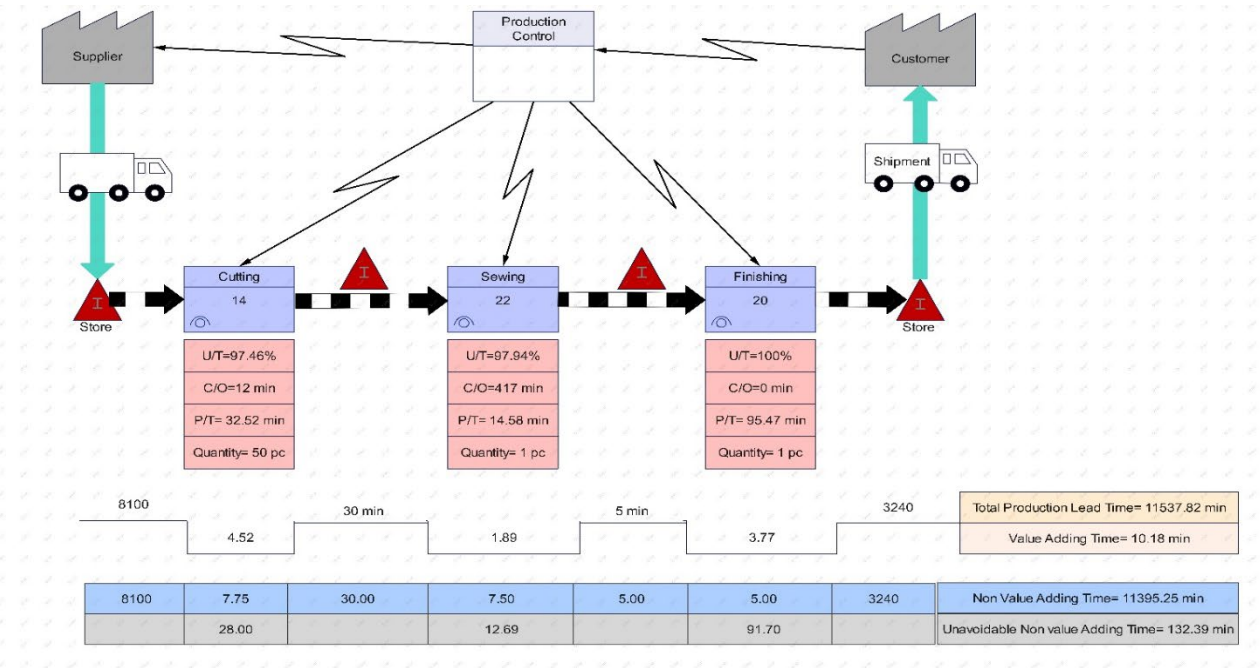


Fig. 3 Present Scenario

The contribution of value-adding, non-value-adding, and unavoidable time in the total production process and the Pareto analysis of those times have been presented in figure 04 and figure 05 respectively.

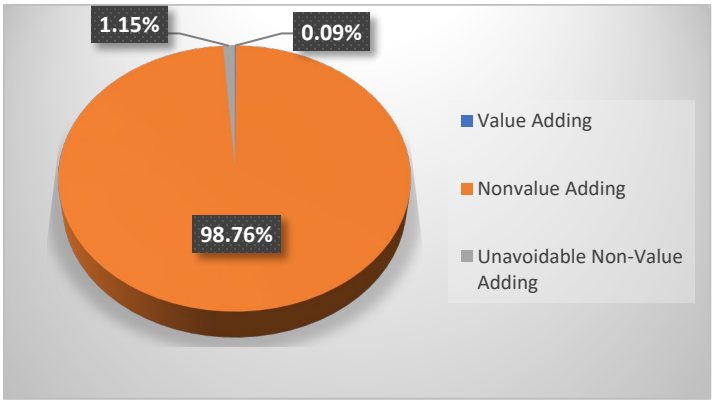


Fig. 4 Percentage of Times

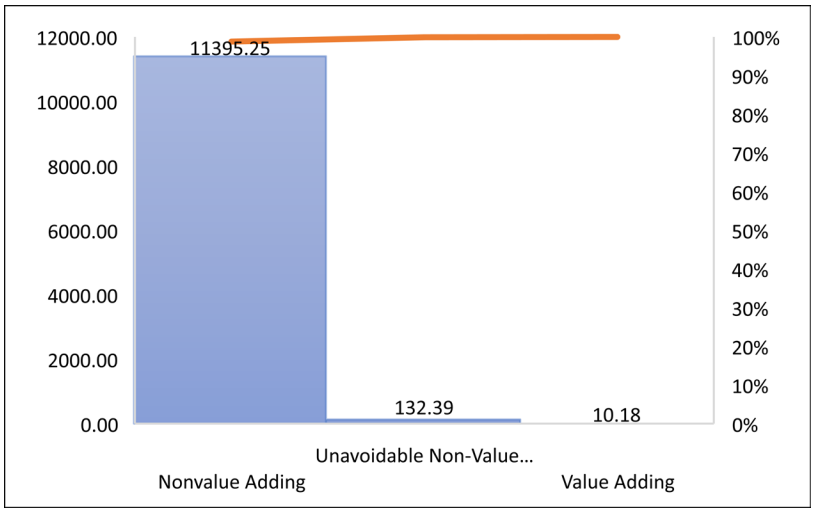


Fig. 5 Pareto Analysis of Manufacturing Time

A table has been generated based on collected data showing the wastes that come from excess inventories.

TABLE II LIST OF EXCESS INVENTORIES

Waste Type	Time (min)	Total Time (min)	Contribution (%)	Reason
Raw Material Inventory	8100	11375	71.21%	1. Lack of Supplier reliability.
				2. Information gap.
				3. Lengthy planning time.
WIP Inventory	35		0.31%	1. Unskilled worker
				2. Information gap.
Finished Goods Inventory	3240		28.48%	1. Waiting for economic scale
				2. Transportation cost
				3. Dependency on parent organization for shipment

V. STRATEGIES TO IMPROVE

Following strategies have been followed to improve the scenario,

1. Minimizing Raw Material Inventory Time.
2. Minimizing Finished Goods Inventory Time.
3. Minimizing Non-Value Adding Times.
4. Minimizing Processing Times.
5. Minimizing Changeover Time.

A. Minimizing Raw Material Inventory Time

Raw material inventory time accounts for 71.21% of total wasted time. According to information obtained from a conversation with the merchandiser department, the management of the firm under study frequently stores raw materials up to 15 days before manufacturing begins.

It takes six days to complete the fabric relaxing, fabric inspection, product sample, and buyer confirmation. The lead time has greatly risen throughout this period. So, it is recommended to reduce this time length by,

1. Improving the reliability of the supplier
2. Ordering more frequently
3. Forecasting more accurately

TABLE III IMPROVEMENT OF CHANGEOVER TIME

Time	Activity	Scenario Before Implementation	Expected Change after Implementation
Planning Time	Layout Planning	Internal	External
	M/C Planning	Internal	External
	Style Analysis	Internal	External
Machine Setting Time	Machine unavailability	Not checked	External
	Work Aids	Decided by hit and trial method	External
	Machine Setting on Actual Fabric	Internal	Make external as much as possible
	Machine Movement	Internal	Make external as much as possible
Operator Demonstration & Idle Time	Pilot Demonstration	Demonstration for the new operation to the given operator idle from the previous style and not according to the skill level	Operator planning: external; parallel demonstration
	Operator Change, Re-Demonstration	Incompetent operators changed after the pilot run	Minimize
	Idle Time	Multiple operators idle at any given time during line setup	Minimize
Pattern and Quality Issue	Marking	Internal	External
	Template making	Internal	External
	Quality Standards	Internal	External
Cutting and Fusing Time	Cutting Accuracy	Internal	Make external as much as possible
	Fusing, Folding, and Pairing	Internal	Fusing, folding, external

B. Minimizing Finished Goods Inventory Time

Finished goods inventory contributes 28.48% of the excess inventory time. The firm under study typically delivered its final goods to the customer 6 days later. Dependence on the parent organization for transportation and expense also played a big part in this.

However, more inventories came at a cost, which is a waste. Cost is not considered in this study, although it is recommended that transportation be done over 2 days in order to balance this occurrence.

C. Minimizing Non-Value Adding Times

The total 35 minutes of WIP has been reduced to 18 minutes by modifying the layout. 7.18 minutes waiting times in different sections have been reduced to 4.64 minutes by implementing TPM, 5S, and enhancing operators' skills.

D. Minimizing Processing Times

Processing times in the Cutting and Sewing sections have been reduced to 22.52 minutes and 9.58 minutes from 32.52 minutes and 14.58 minutes respectively by reducing machine breakdown time by 40% [11].

E. Minimizing Changeover Time

The Changeover time sewing section was 417 minutes. This time has been reduced to 160 minutes by implementing SMED [12]. After improvement, the total changeover time in the cutting and sewing section is 172 minutes. The following table shows the improvement.

F. Future State Map

Using value stream mapping, lean wastes were found. Then, via the use of Kanban, TPM, and SMED, they were either removed or decreased. The suggested future state map is displayed in Figure 6.

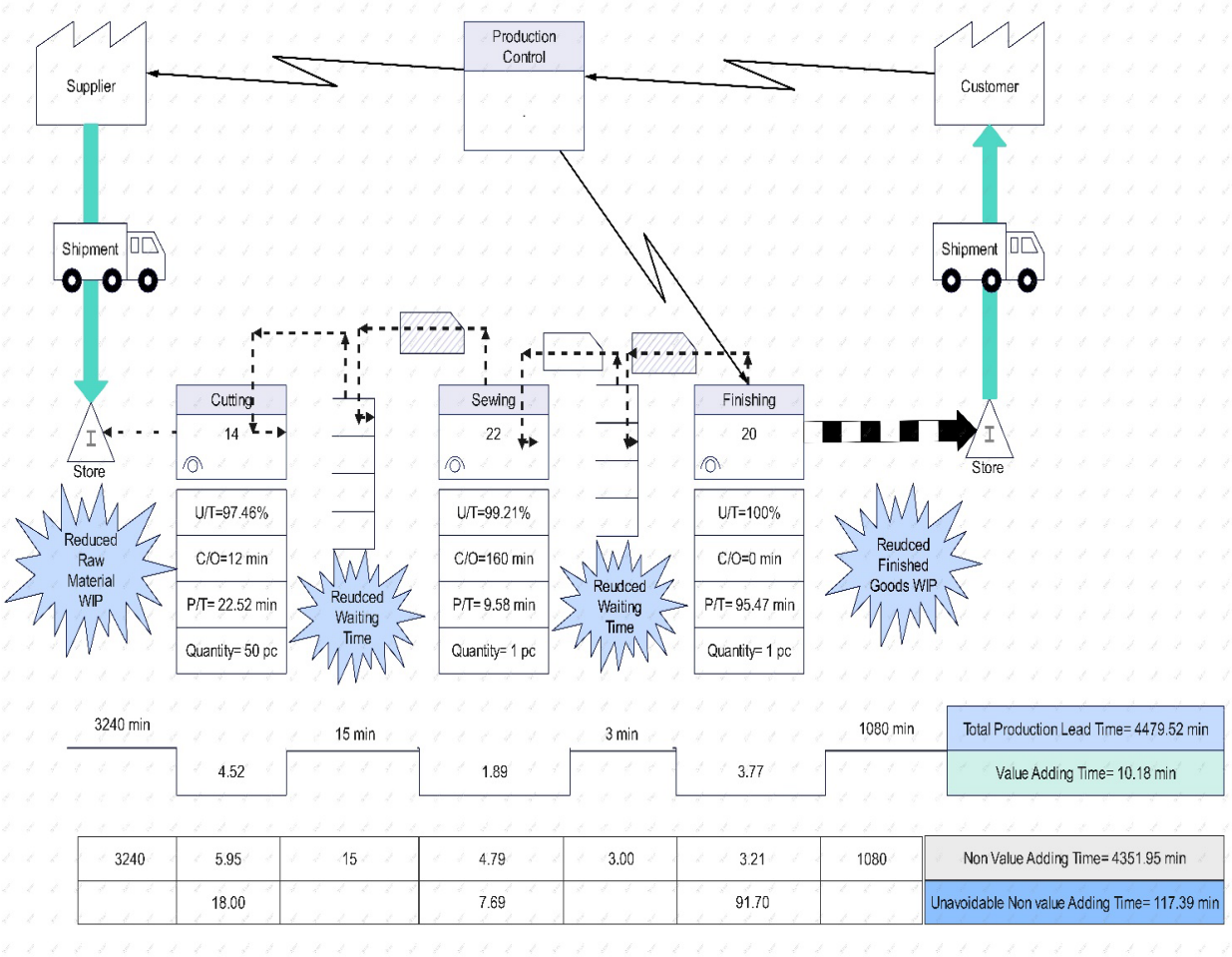


Fig. 6 Future State Map

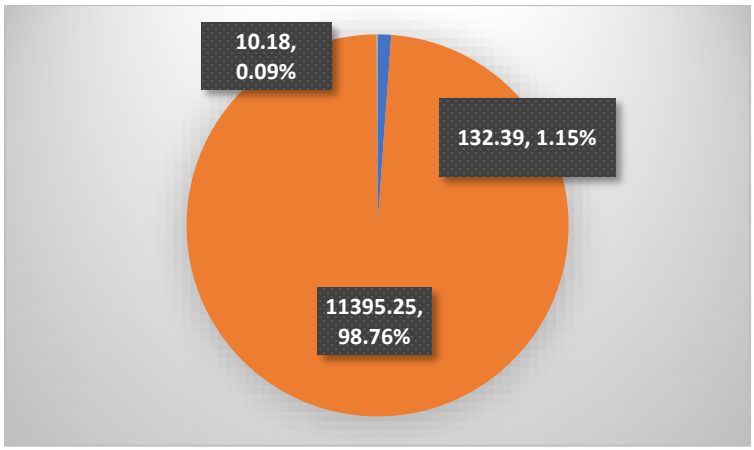
VI. RESULTS OF THE STUDY

The implementation of lean tools with the help of simulation outcomes is a remarkable result that is shown in Table II. Excess inventory has been reduced by a significant figure.

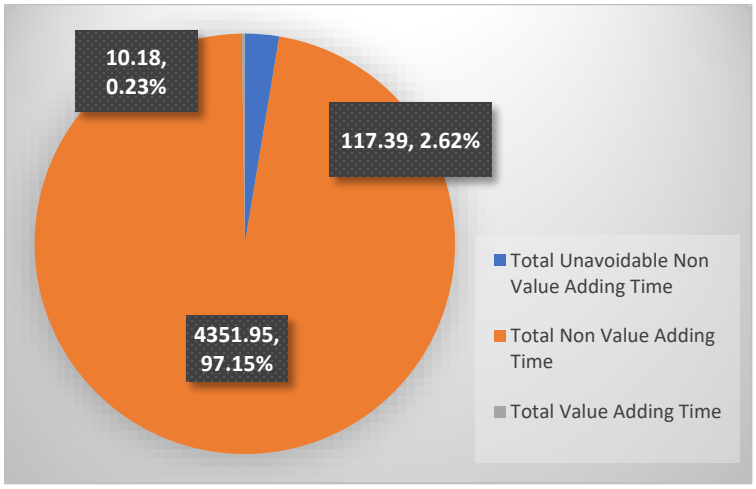
TABLE IV COMPARISON AFTER IMPROVEMENT

Factors	Current State Map	Improvement Techniques	Future State Map
Extra Inventory (min)	11375	Kanbans, Modified Floor Design	4338
Waiting Time (min)	7.18	TPM	4.64
Material Flow System	Push	Kanban	Pull
Changeover Time (min)	429	SMED	172
Total Value-Adding Time (min)	10.18		10.18
Total Non-Value Adding Time (min)	11395.25	Improved Information Flow	4351.95
Total Unavoidable Non-Value Adding Time (min)	132.39	Both sides Automatic Fabric Spreading Machine	117.39
Total Lead Time	11537.82		4479.52

The following figures show the changes in times after implementing lean tools.



(a)



(b)

Fig. 7 Pie Chart for percentage of times: a) Current State, b) Future State

VII. SUGGESTIONS

The following suggestions are to be made for the chosen clothing company's betterment.

1. VSM must be used to determine the existing situation as well as to categorize various waste categories.
2. Kanban Supermarket should take the place of the conventional push system. Reduce waiting times and WIP with a pull mechanism.
3. To make the most of the manufacturing line, the bottleneck point should be located.
4. Other lean methods, like no flaws, line balance, 5S, Poka-Yoke, JIT, etc., should be used to reduce other wastes.

5. When it is exceedingly difficult to reduce waste from a process one step at a time, continuous improvement techniques such as Kaizen should be used.
6. Sessions for employee training and motivation should be vigorously promoted.

VIII. CONCLUSION

Short lead times offer an edge in the present competitive market to stay in the market by adjusting to the changing environment. It is crucial to recognize non-value-added tasks and remove them in order to decrease lead time. Value stream mapping is an unfailing method to assess the present situation in this case. This research's major objective was to determine the extent of the use of the VSM approach in a particular clothing manufacturer. To do this, a product family (in this case, T-shirts) was chosen. The buildup of WIP inventory served as a dividing line between processes. A time study was used to gather the data needed for value stream mapping. The value stream's current status was then shown. The current state value stream map has identified the value-added time as 10.18 min which is 0.09% of the total lead time. On the other hand, the non-value-adding time is 11395.25 min which is 98.76% of the total lead time. Then, it was determined how much time was wasted during the various operations (cutting, sewing, and finishing). Then, the most accountable wastages were identified using the Pareto analysis and this shows that raw materials inventory and finished goods inventory are the major waste of this production process. The causes of those effects were then identified using a root cause and effect diagram. It has been suggested to use an improvement strategy to address those issues. Time waste has been targeted for reduction using a variety of lean tools and strategies. The kanban supermarket has been proposed for implementation in place of the conventional push system material flow. Value stream maps are constructed in their future states to show how the process will improve. In the proposed future state, the non-value time is reduced to 4351.95 minutes. Thus, the total lead time is reduced to 4479.52 minutes which is reduced by 61.20% of the current lead time. This research used a value stream mapping tool to decrease the time that is responsible for large lead times. Therefore, the non-value-added time at the process level is a major focus of this study. If process-level research is conducted, it will be possible to cut back on non-value-added process-level time even further. VSM depicts the process's present scenario. Therefore, VSM should be used to continually verify the process.

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