Waste Reduction and Productivity Improvement through Lean Tools

Masudul Haque Talukder[1], Mohammad Ali Afzal[1], MD.Abdur Rahim, Mohd.Rifat Khan

Abstract— In Bangladesh most of our foreign currency comes from garments sector. The phase-out of the export-quota system from the beginning of 2005 has raised the competitiveness issue of the Bangladesh RMG industry as a top priority topic. The most important task for the industry is to reduce the wastes and productivity improvement of garment manufacturing. Hence, this study focuses on identifying and reducing of wastes and improving productivity. Case study methodology has been applied to collect and analyze data by direct observation. Wastes are identified by using value stream mapping. Value Stream Mapping is the simple process of directly observing the flow of information and material as they occur. Pareto analysis is used to rank the wastes identified by VSM. Root cause analysis is developed to identify key causes behind wastes. Then Cellular Manufacturing and Kanban have applied to reduce wastes and improve productivity. Cellular Manufacturing refers to a manufacturing system wherein the equipment and work-stations are arranged in an efficient sequence that allows continuous and smooth movement of inventories and materials to produce from start to finish in a single process flow, while incurring minimal transport or waiting time, or any delay for the matter. In this research raw material kanban has been used. Raw material kanban method is a calculation that determines the optimal amount of raw material goods to be placed in a buffer. It assures there is always just enough material on hand to make what is needed. This research extracts the common scenario of the garments sector of Bangladesh by depicting the existing pictures of the value stream. System simulation has been applied to measure the proposed system's performance. Arena 10 software has been used for system simulation. Again AutoCAD 2004 has been used for layout analysis. Finally, the research work proposes some recommendations for the studied organizations to improve the performance.

Keywords— Kanban, Pareto Analysis, Productivity Improvement, Value Stream Mapping.

1 INTRODUCTION

IN Bangladesh, Ready-made Garments (RMG) sector plays an important role for the economic development of the country. The industry has contributed to export earnings, foreign exchange earnings, employment creation, poverty alleviation and the empowerment of women. The RMG industry is the only multi-billion-dollar manufacturing and export industry in Bangladesh. Currently, there are 4490 manufacturing units. The RMG sector contributes around 75 percent to the total export earnings. In 2007 it earned $9.35 billion. This sector also contributes around 13 percent to the GDP, which was only around 3 percent in 1991. Of the estimated 4.2 million people employed in this sector, about 50 percent of them are women from rural areas. Bangladesh has been exporting RMG successfully over two decades with the lowest labor cost in the region and subcontracting with foreign buyers. But with the abolition of quota and GSP, the trading environment has become fiercely competitive. Bangladesh, whose economy is heavily dependent on this sub-sector, will now have to compete against garments giants like China and India. However to maintain this growth in positive direction it is necessary to ensure proper utilization of every resource. In today's competitive world, the most important driver for success is time; the company that delivers best quality goods with the shorter time required for production and shorter lead time is the market winner. Financial growth of any company also depends upon waste reduction and productivity improvement. So to gain profit from scarce time and to reduce waste it is necessary to use lean tools after identifying waste as well as adopting new manufacturing concepts and technology in every sector of the garments industry and new business initiatives should be taken in this sector in order to stay alive in the new competitive market. Lean principle is widely implemented among various industries all over the world. However in Bangladesh maximum industries runs in a traditional way. Some industries are trying to implement but can't properly. So the goal of this study is to introduce different lean tools such as value stream mapping, cellular manufacturing, kanban, root cause analysis, etc. and simulation to identify, measure and reduce wastes. The major purposes of the use of lean production are to increase productivity, improve product quality and manufacturing cycle time, reduce inventory, reduce lead time and eliminate manufacturing waste. To achieve these, the lean production philosophy uses several concepts such as one-piece flow, kaizen, cellular manufacturing, synchronous manufacturing,

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inventory management, poka-yoke, standardized work, work place organization, and scrap reduction to reduce manufacturing waste (Russell and Taylor, 1999). In lean production systems attempts are made to eliminate waste through continuous improvement of processes of the entire value chain in the organization. Having nurtured a lean manufacturing mindset among the employees, it facilitates achievement of continuous product flow through physical rearrangement and control mechanisms.

2 BACKGROUND OF THE STUDY

Garments industry plays a vital role in economic growth of the country. To fulfill the demand of the customers and to stay in the competitive market, the existing situation of the industry must be improved, its productivity, efficiency must be optimum level. Reducing waste by using lean tools an industry can reduce cost and quality alters, improve productivity, performance rate and efficiency. By using a detailed and through procedure one can eliminate losses in a systematic manner using various lean tool techniques.

At present the success of the garments sector highly depends upon several factors such as production lead time, waiting time, work in process inventory, defects, unnecessary motion etc. To optimize all this factors it is necessary to introduce new concept of manufacturing. In this context the textile industry sector is selected for this research work. The selected textile industry consists of several sections such as cutting, printing, sewing, finishing etc.

3 METHODOLOGY

This research paper is based on case study approach. This case study research has been carried out in a selected garments industry. Several lean tools such as Value Stream Mapping, Cellular Manufacturing and Kanban are used in sewing, cutting and finishing section to identify the existing wastes of the selected garments industry and to reduce them. Value adding time and non value adding time and unavoidable non value adding time in cutting, sewing and finishing section of our studied garments has been identified that are discussed later.

Action plan of the research

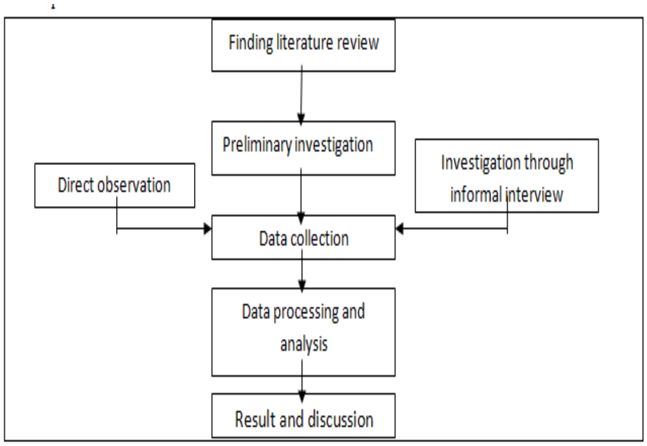

Fig. 1 Flow chart of research study

4 FINDINGS AND ANALYSIS

This chapter presents the findings of the case study. The case study has been conducted in two case organizations Case-A and Case-B. This case study deals with various types of wastes exist in various processes. The information as well as data has been gathered through the observation and interview. The data and information was collected through the observation of the production floor and some past record from the industrial engineering and planning department of the selected industry. Finally all data has been analyzed by using various types of tables, graphs and some tools such as value stream mapping, cause effect diagram, Pareto analysis, cellular manufacturing.

4.1 Demography of Case Organization for Case-A

This organization was established in 1982. It produces mainly Textile Product. The no. of production centers are: 13 and Sub-Centers are: 630. It has 36000 artisans (almost all are women). The no. of regular employees is 684 and part time employees are 630. The market of this organization can be segmented into two categories. These are Case- A's outlets and export. There are 10 self-owned outlets (6 in Dhaka, 2 in Chittagong, 1 in Sylhet and 1 in Khulna) and 1 franchised(London, U.K). Except these the product of Case- A also exported in Italy, U.K, Netherlands, Spain, France, Canada, Japan, Korea, and Australia. This organization is the most established local retail brand in Bangladesh. It is the pioneer in developing a market for Bangladeshi craft and trendsetter in local fashion industry. The sources of Case- A products mainly divided into three types. These are Case- A Production Centre- 1, Case- A Production Centre- 2, and Independent Producers. This organization is recognized and awarded several times such as Best Outdoor Communication, 2008 by Brand Forum; The Best Fashion & Lifestyle Brand Award, 2009 by Brand Forum; a 'Super brand' award 2009/ 2011; etc. The key product lines of Case- A are Men's wear (Panjabi, Pajama, Shirt, Fatua, and Short Kurta), Women's wear (Salowar, Kamiz, Dopatta, Taaga, Saree), Children wear (Panjabi, Pajama, Fatua, Nima, Panty), Household(Bed Cover, Cushion Cover, Pillow Cover, Table Cloth), Jewellary (Gold, Diamond, Silver, Pearl, Beads, Clay & Jute), Leather (Bag, Sandal), Others(Metal, Clay, Jute, Cane & Bamboo etc.). Among them AAF supplies Panjabi, Saree, Fatua, SKD, Tagaa, Household, Others.

For Case-B

This organization was established in 1990. The no. of employees is 700. It is vertically integrated with Knitting, Dyeing, Spinning - Lean based 100% compliant Ready Made Garments Industry. The main valuable customers are Tesco(USA), Carrefore(USA), Auchan (UK), Gemo(USA), Azda(USA), George (USA). It produces all types of Knit items including T-Shirt- long sleeve & short sleeve, Tank top, Pajama, Hooded Jacket, Polo Shirt, Shorts, All types of Kids Items, Jogging Sets, Woman's Night Gown etc.

In this organization all lines are modular system and all operators are multi skilled. The accurate SMV is evaluated by Industrial Engineering Department using SSDM method. Correct method is shown to operator by IE Department. Target & Efficiency is measuring by this SMV. Incentive system is used to motivate the operators for increasing productivity. Lean tools that are trying to use in this factory are – 5S, TPM, Value Stream Mapping, Kanban, Just In Time, Kaizen – which will help to drive away all the unnecessary waste as well as increasing productivity and reducing lead time. Strong Quality Department is working not only for ensuring Quality pass but also taking preventive maintenance. Quality tools that used are Traffic Light System, Root Cause, Check Sheet, Control Chart and All Seven Quality Tools.

4.2 Findings

Our predetermined destination is to find out the current scenario of traditional system to reduce wastes. Then apply lean tools for reducing the wastes.

Current Scenario of Existing System:

After visiting the Case-A and Case-B several wastes are identified and these influenced the overall production process of the organization. These major wastes for both industries are as follows:

1. Unnecessary inventory
2. Over transportation
3. Defects
4. Over production
5. Waiting

These wastes are identified through current state value stream mapping. Again, we also found most of the time operator passing their time by gossiping. Although having capability they never meeting the target according to SMV, because of lack of supervision.

The current state value stream mapping (Figure 2 of Case-A & Figure 3 of Case- B), which is used to identify wastes is given bellow:

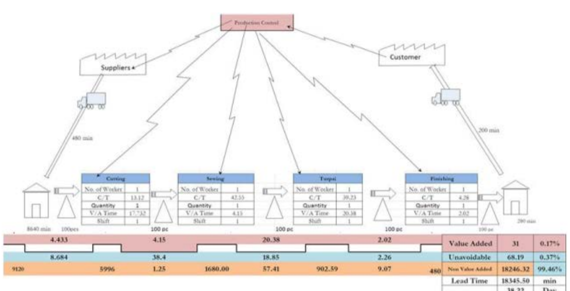

Fig. 2 Vaule stream mapping of case-A

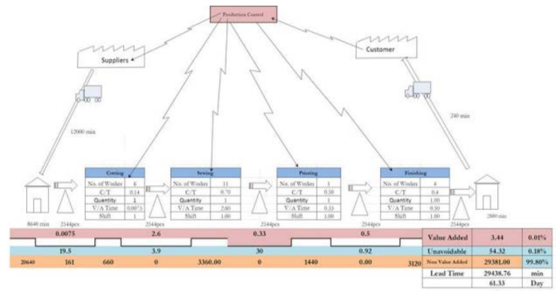

Fig. 3 Vaule stream mapping of case-B

4.3 Pareto Analysis to Rank Wastes in Terms of Time

By using Value Stream Mapping at two case organizations we found 5 types of non- value adding time. Then we use Pareto analysis to rank wastes in terms of time.

At Case-A:

Total wastes (Non- value adding time): 18246.32 min

The factors and their percentages contributing this non value adding time are given bellow:

1. Queuing time (Queuing by inventory): 16605.73min (91.01%)
   a) Queuing by raw material: 8640min (47.35%)
   b) Queuing by WIP inventory: 7685.73min (42.12%)
   c) Queuing by finished goods: 280min (1.54%)
   d) Waiting time by Operators: 59.25min (0.32%)
2. Rework time (time required to rework): 504 min (2.76%)
3. Carrying time (time required for over transportation): 775min (4.25%)
4. Over production time (time required for over production): 302.34min (1.66%)

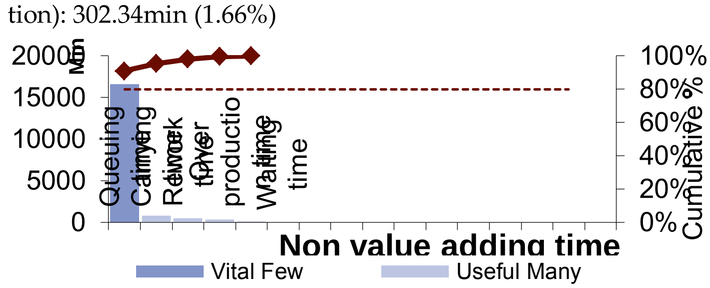

Fig. 4 Pareto analysis for Case- A

From this analysis we found that, the maximum non-value adding time of Case-A is queuing time and its percentage is 91.01%, then carrying time and its percentage is 4.25%.

At Case- B:

Total wastes (Non- value adding time): 29381.00 min

The factors and their percentages contributing this non value adding time are given bellow:

1. Queuing time (Queuing by inventory): 16192.5min (55.11%)
   a. Queuing by raw material: 8640min (29.41%)
   b. Queuing by WIP inventory: 4672.5min (15.90%)

c. Queuing by finished goods: 2880min (9.80%)

2. Waiting time: 12000 min (40.84%)
a. Waiting time by Operators: 480 min (1.63%)
b. Inbound waiting time (Waiting time by raw materials): 11520 min (39.21%)
3. Rework time (time required to rework): 8.2 min (0.02%)
4. Carrying time (time required for over transportation): 862 min (2.93%)
5. Over production time (time required for over production): 318.3min (1.08%)

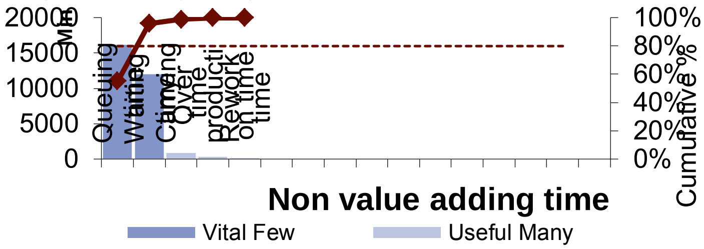

Figure 5. Pareto analysis for Case- B

From this analysis we found that, the maximum non-value adding time of Case-B is queuing time and its percentage is 55.11%, then waiting time and its percentage is 40.84%.

Then we compare different types of non-value adding time between Case- A and Case- B. The comparison of different types of non- value adding time between two case organizations at Figure 6.

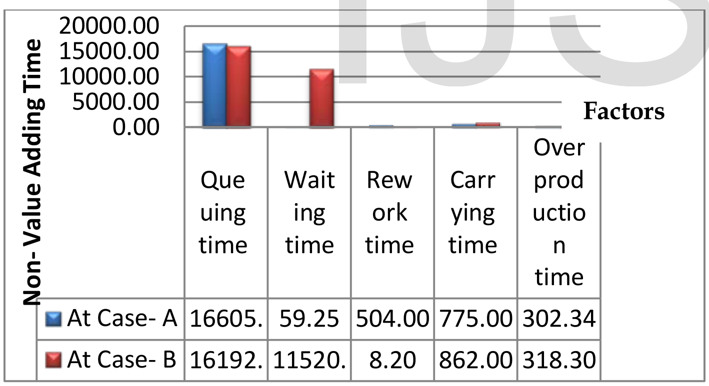

Figure 6. Comparison of different types of non- value adding time between two case organizations with respect to time.

From this comparison we can see that the difference in queuing time, rework time, carrying time and overproduction time is same between two organizations is very low. But the difference in waiting time is high.

Though there are different types of queuing time, we also compare them between Case- A and Case- B. The comparison of different types of queuing time between two organizations is given bellow at Figure 7.

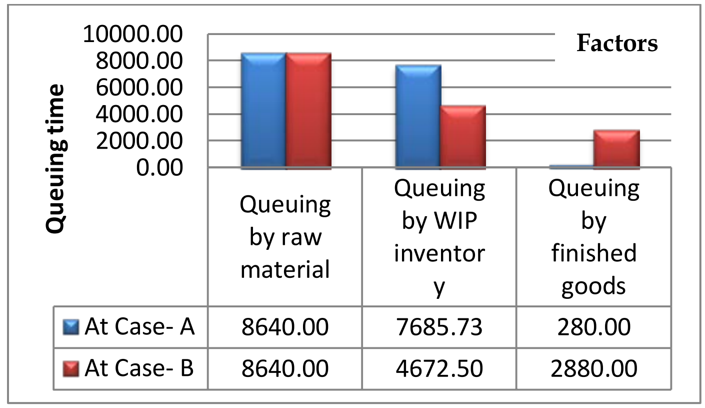

Fig. 7 Comparison of different types queuing time between two case organizations

From this comparison we can see that there is no difference in queuing time by raw material between two organizations. The queuing time by WIP inventory is higher in Case- A than Case- B and queuing time by finished goods is higher in Case- B than Case- A.

4.3.1 5Why Analysis for Case-A: To Identify Root Causes for Various Wastes

After identifying 5 types of waste using value stream mapping, we ranked this wastes by using Pareto analysis. Then we found root causes of these wastes by applying 5 why analysis. We found the root causes of unnecessary inventory are no formal set of procedures to handle inventory, company policy, lack of training & motivation and their recurrence preventions are respectively Kanban, cellular manufacturing, cellular manufacturing. The root causes of waiting are no formal set of procedures to handle inventory, lack of maintenance and their recurrence preventions are Kanban, TPM. The root causes of defect and rework are information gap, lack of training & motivation and their recurrence preventions are respectively cellular manufacturing, training, motivation & instruction for workers properly. The root cause of over transportation is

Wastes	Why 1	Why 2	Why 3	Why 4	Root cause	Solution
Unnecessary Inventory	Unnecessary raw material inventory	Improper inventory management	No formal set of procedures to handle inventory		No formal set of procedures to handle inventory	Kanban
	Unnecessary WIP Inventory	Large batch size	Company policy		Company policy	Cellular manufacturing
		Low efficiency	Lack of expert worker	Lack of training	Lack of training & motivation	Training & motivation for workers
			Lack of sincerity	Lack of motivation		
Waiting	Raw materials shortage	Do not get right information	Improper inventory management	No formal set of procedures to handle inventory	No formal set of procedures to handle inventory	Kanban
	Machine breakdown	Lack of maintenance			Lack of maintenance	TPM
Defect and Rework	Find fault lately	Information gap			Information gap	Cellular Manufacturing
	Lack of expert worker	Lack of training & motivation			Lack of training & motivation	Training , motivation & instruction for workers properly
Over transportation	Poor line balancing	Lack of space	Space are not utilized properly	Poor layout	Poor layout	Cellular Manufacturing
Over production	Produce extra where rate of rejection is very low	To make sure customer order is satisfied			To make sure customer order is satisfied	Reduce rate of over production

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poor layout and its recurrence prevention is cellular manufacturing. The 5why analysis for Case-A is given bellow at table 1

Table 1. 5why analysis for Case- A: to identify root causes for various wastes

4.3.2 5Why Analysis For Case- B: To Identify Root Causes For Various Wastes

Using 5 why analysis at Toyo we found the root causes of unnecessary inventory are no formal set of procedures to handle inventory, company policy, lack of training & motivation and their recurrence preventions are respectively Kanban, cellular manufacturing, cellular manufacturing. The root causes of waiting are no formal set of procedures to handle inventory and its recurrence preventions is Kanban. The root causes of overproduction is to make sure customer order is satisfied and its recurrence prevention is Reduce 3% extra production. The root causes of defect and rework are information gap, lack of experience or training and their recurrence preventions are respectively cellular manufacturing, training for workers properly. The root cause of over transportation is poor layout and its recurrence prevention is cellular manufacturing. The 5why analysis for Case- B is given bellow at table 2.

Table 2. 5why analysis for Case- B: to identify root causes for various wastes

Wastes	Why 1	Why 2	Why 3	Why 4	Root cause	Solution
Unnecessary Inventory	Excessive WIP Inventory	Large batch size	Company Policy		Company Policy	Cellular manufacturing
		Different efficiency	Lack of training	Lack of training	Lack of training	Training and Motivation for workers
			Lack of sincerity	Lack of motivation	Lack of motivation	
	Excessive raw material inventory	Do not get right information	Improper inventory management	No formal set of procedures to handle inventory	No formal set of procedures to handle inventory	Kanban
Waiting	Raw materials shortage	Ordered lately	Store already loaded	No formal set of procedures to handle inventory	No formal set of procedures to handle inventory	Kanban
			Trying to use investment cost in other sector	No formal set of procedures to handle inventory	No formal set of procedures to handle inventory	
	Late approval	Sent sample lately	Busy with other paper work.		Busy with other paper work.	Reduce paper work by combining merchandising and supply chain departments
	Machine breakdown	Lack of maintenance			Lack of maintenance	TPM
Over Production	Produce 6% extra where reject is 0.15%.	To make sure customer order is satisfied			To make sure customer order is satisfied	Reduce 3% extra production
Defect and Rework	Lack of experience or training				Lack of experience or training	Training for worker
	Large batch size	Company Policy			Company Policy	Cellular manufacturing
Over transportation	Printing done outside or another floor	Lack of space	Space is not utilized properly	Improper layout	Improper layout	Cellular manufacturing

Cause- effect diagram

After 5why analysis we found that the key causes behind the existing wastes which were identified by using value stream mapping. Cause- effect diagram can be used to present the effect and its key causes visually. The cause- effect diagram of Case- A and Case- B are shown in figure 6 and figure 7 respectively.

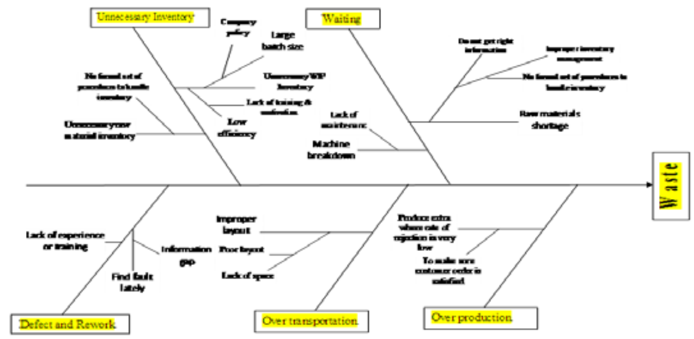

Figure 8. Cause –effect diagram of Case- A

After root cause analysis (5why and cause effect diagram) layout and various performances have been analyzed to measure and improve the condition of the existing system.

4.4 Layout Analysis

For supply chain consideration, the design of the layout is important as a poorly organized facility can delay the flow of the material and information, thus causing increasing non value adding time and subsequently impact timely delivery of the goods. All firms contains flow stream of material, people, equipments, information. The global objective of any facility layout is efficiency such that it:

- Uses a flow pattern that is the most cost effective
- Optimizes utilization of spaces
- Facilitative the installation of an information system network.
- Conforms to health regulations.

4.4.1The Existing Layout of Case- A

The existing layout of Case-A is a functional layout in which the required time to flow material and distance for that position is high. In this layout the WIP inventory is also high. The direction of material flow of existing layout is shown in figure 9

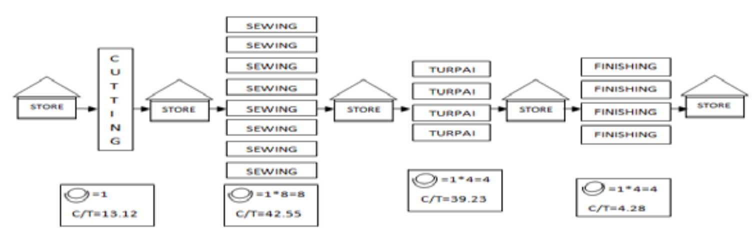

Figure 9. The direction of material flow of existing layout of Case- A

The average time required to finish a batch of product is given bellow in table 3**.** The time is measured from center to center of machines.

Table 3. Time & distance required to move one department to another of existing layout of Case- A

Material movement	Distance (ft)	Average time (min)
Raw material store to cutting	86	20
Cutting to sewing	20	5

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Sewing to turpai	60	15
Turpai to ironing	68	15
Ironing to QC & packaging	104	25
QC & packaging to finished goods store	55	15
Total	393	95

Time taken to move one feet= 95/33=0.2417 min

4.4.2 Reforming the Proposed Layout of Case- A

The proposed layout is cellular in which the department those are required for the production of Panjabi, are arranged in such a way that the distance between the cells are less than the previous one. In this proposed layout the equipment and workstations are arranged in an efficient sequence that allows continuous and smooth movement of inventories and materials to produce from start to finish in a single process flow, while incurring minimal transport or waiting time, or any delay for the matter. The direction of material flow of proposed layout is given at figure 10.

So this layout will help to reduce many types of wastes that occur in existing layout.

Calculation of no. of required section for Case- A

No. of section required= cycle time of this section* output produced after 1 cutting operation/cycle time of cutting.

No. of cutting section required=1

No. of sewing section required=42.55*4/52.48=3.24≈4

No. of turpai section required=39.23*4/52.48=2.99≈3

No. of finishing section required=4.28*4/52.48=0.33≈1

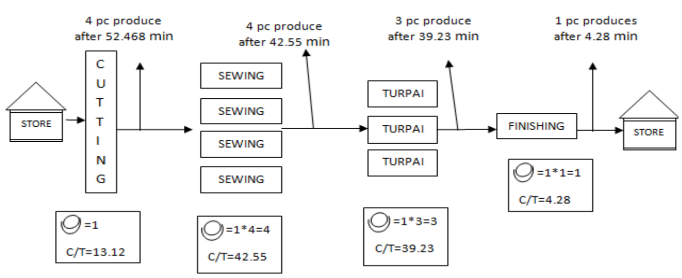


Figure 10.The direction of material flow of proposed layout of Case- A.

The distance between the departments of the proposed layout after reforming is given bellow in Table 4. The time is measured from center to center of machines.

Table 4. Time & distance required to move one department to another of proposed layout of Case- A

Material movement	Distance (ft)
Raw store to cutting	83.5
Cutting to sewing	10.5
Sewing to turpai	3
Turpai to finishing(Ironing, QC, Packaging)	4.5
Finishing to finished goods store	77
Total	178.5

Time taken to move 178.5 feet = 178.5* time taken to move one feet =178.5*0.2417 =43.15 min

Reduction of time = (95-43.14)*100/95 = 54.59%

4.4.3 The Existing Layout of Case- B

The existing layout of Toyo is also a functional layout in which the required time and distance for that position is high. In this layout the WIP inventory is also high. The direction of material flow of existing layout is shown in figure 11.

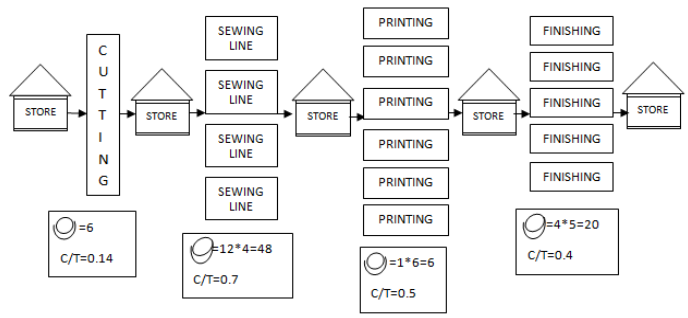


Figure 11. The direction of material flow of existing layout of Case- B.

The average time required to finish a batch of product is given bellow in table 5. The time is measured from center to center of machines.

Table 5. Time & distance required to move one department to another of existing layout of Case-B

Material movement	Distance (ft)	Average time (min)
Raw- material store to cutting	235	60
Cutting to sewing	59	12
Sewing to printing	148	30
Printing to iron	106	30
Iron to finishing	2	1
Finishing to finished goods store	35	9
Total	585	142

Time taken to move one feet = 142/585=0.2427 min

4.4.4 Reforming the Proposed Layout of Case- B

The proposed layout is cellular in which the equipment and workstations are arranged in an efficient sequence that allows continuous and smooth movement of inventories and materials to produce from start to finish in a single process flow, while incurring minimal transport or waiting time, or any delay for the matter. The direction of material flow of proposed layout is given at figure 12.

So this layout will help to reduce many types of wastes that occur in existing layout.

Calculation of no. of required section for Case- B

No of section required=cycle time of this section*output produced after 1 cutting operation/cycle time of cutting

No. of cutting section required=1

No. of sewing section required=0.7*1272/178.08=5

No. of printing section required=0.5*1272/178.08=3.57≈4

No. of finishing section required=0.4*1272/178.08=2.89≈3

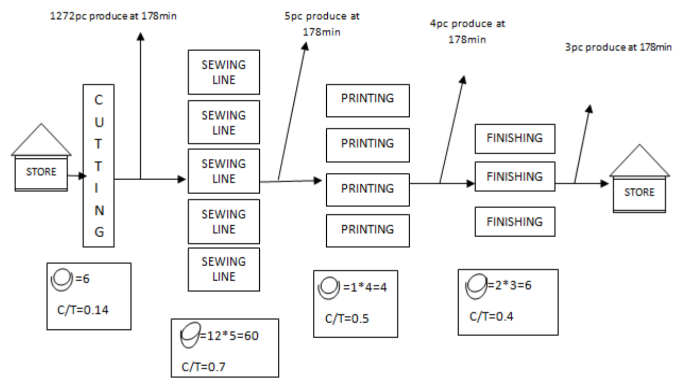


Figure 12.The direction of material flow of proposed layout of Case- B.

The distance between the departments of the proposed layout after reforming is given bellow in table 6.

Table 6. Time required to move one department to another of proposed layout of Case- B.

Material movement	Distance (ft)
Raw store to cutting	235
Cutting to sewing	59
Sewing to printing	33
Printing to iron	6
Iron to finishing	3
Finishing to finished goods store	21
Total	357

Time taken to move 357 feet = 357* time taken to move one feet=357*0.2427 =86.64 min

Reduction of time = (142-86.64)*100/142= 38.98%

4.5 Kanban Analysis

In traditional system there is not any systematic way to identify what amount of raw materials required. Again there is not any formal procedure to determine when and how much should be ordered. KANBAN can reduce inventory. Again it can minimize raw material shortage by controlling amount of inventory.

After applying cellular manufacturing and stabilizing the production raw material KANBAN should be applied because there is excessive raw material inventory and sometimes for raw material shortage operators are waiting.

To identify the proper amount of fabric we can use fabric consumption formula.

Fabric required in kg per pc: {(Body length in cm*body width in cm+ sleeve length in cm*sleeve width in cm)*2}*GSM/(1000*10000) + 15% allowance kg

GSM= Gram per Square Meter

KANBAN size, K= (DL+ SS)/ CS

Where, K = Kanban size, DL = Average Demand during Lead time, **SS** = Safety Stock, CS = Container Size

Safety stock, SS= z*σ_L

Where, z = Number of standard deviations for a specified service level, σ_L = standard deviation of usage during lead time.

For Case- A: GSM= 110

Fabric required per pc Panjabi = {(Body length in cm*body width in cm+ sleeve length in cm*sleeve width in cm)*2}*GSM/(1000*10000) + 15% allowance kg

= [{(90 cm*64 cm+ 54 cm*20 cm)*2}*90/ (1000*10000) + 15% allowance] kg

= [0.12312+ 0.018468] kg =0.141588 kg ≈ 0.14 kg

Lead time= 480 min [from Current State Value Stream Mapping]

Demand of Panjabi over the lead time= 42.19 pc

For service level 80.2%

Number of standard deviations for a specified service level, z= 0.5

Safety stock, SS= 0.5*171.69= 85.845 pc = 85.845* 0.14= 12.02 kg

So, fabric required= 42.19* 0.14 kg = 5.91kg

And container size= 5 kg

Then KANBAN size, K= (5.91+12.02) / 5= 3.585≈ 4

When 4 containers remain then order should be placed to supplier.

For Case- B: GSM= 180

Fabric required per pc Panjabi = [{(Body length in cm*body width in cm+ sleeve length in cm*sleeve width in cm)*2}*GSM/(1000*10000) + 15% allowance] kg

= [{(66 cm* 45 cm+ 20 cm* 20 cm)*2}*180/ (1000000) + 15% allowance] kg=[0.12132+0.018198] kg=0.14 kg

Lead time= 12000 min [from Current State Value Stream Mapping]

Demand of basic t- shirt over the lead time= 45272.33 pc

So, fabric required= 45272.33* 0.14 kg= 6338.13 kg

For service level 80.2%

Number of standard deviations for a specified service level, z= 0.5

Safety stock, SS= 0.5* 79920.68= 39960.34 pc =39960.34 * 0.14kg = 5594.45 kg

And container size= 5 kg

Then KANBAN size, K= (6338.13 + 5594.45) / 5= 2386.52≈ 2387

When 2387 containers remain then order should be placed to supplier.

4.6 Future State Value Stream Mapping for Case-A

Over transportation time for proposed system can be found from Table 5.4 and that is 43.15 min. Raw material kanban has been applied in the proposed system. So the delay for raw material and waiting for raw material shortage is zero. WIP queuing time has been determined by simulation using Arena 10 software. And the WIP queuing time for proposed system is 112.12 min from. So the non value adding time for the process of cell is 273.15min. The total non- value adding time is 753.15 min. Finally, lead time for proposed system has been measured and that is 852.34 min. So, the value added time is 4%, non value adding (unavoidable) is 8%, non value adding time (wastes) is 88 % shown in figure 12. Future state value stream mapping shows the available improvement which can be made possible near future.

For Case- B

Over transportation time for proposed system can be found from Table 5.6 and that is 86.67 min. Raw material Kanban has been applied in the proposed system. So the delay for raw material and waiting for raw material shortage is zero. WIP queuing time has been determined by simulation using Arena 10 software. And the WIP queuing time for proposed system is 82.974 min. So the non value adding time for the process of cell is 419.77 min. The total non- value adding time is 899.77 min. Finally, lead time for proposed system has been measured and that is 957.53 min. So, the value added time is 0 .36%, non value adding (unavoidable) is 5.67%, non value adding time (wastes) is 93.97 % shown in figure 12. Future state value stream mapping shows the available improvement which can be made possible near future.

4.7 Workforce Allocation for Case- A

Existing:

Table 7. Existing workers in different departments

Process	No. of worker
Cutting	4
Sewing	32
Turpai	16
Finishing	16
Total	68

Proposed: No. of workers for our proposed cellular layout is given bellow at table 8.

Table 8. Proposed workers in different departments

Process	No. of worker
Cutting	4
Sewing	16
Turpai	12
Finishing	4
Total	36

Reduction of workers= 68-36 = 32

For Case- B: Existing:

Table 9. Existing workers in different departments

Process	No. of worker
Cutting	6
Sewing	48
Printing	6
Finishing	20
Total	80

Proposed: No. of workers for our proposed cellular layout is given bellow at table 10.

Table 10. Proposed workers in different departments

Process	No. of worker
Cutting	6
Sewing	60
Printing	4
Finishing	6
Total	76

Reduction of workers= 80-76 = 4

The graphical representation of workforce status of two case organizations is given bellow:

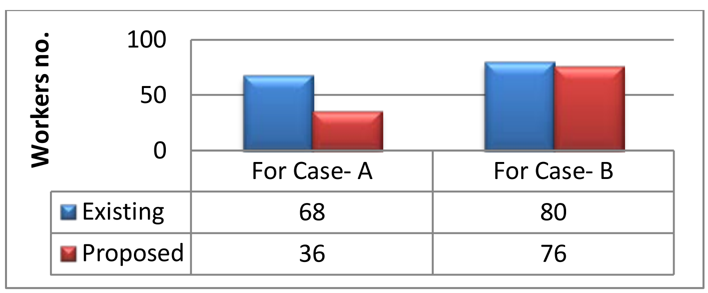


Figure 13. Workforce status of two case organizations

4.8 Space Status for Case- A

Existing space: 2861in^2

Proposed space: 1051 in^2

Space reduction: (2861-1051) in^2=1810 in^2

Space utilization: (1810/2861)*100% = 63.26%

For Case-B

Existing space: 14104.51in^2

Proposed space: 7822.22 in^2

Space reduction: (14104.51-7822.22) in^2=6282.29 in^2

Space utilization: (6282.29/14104.51)*100% = 44.54%

The graphical representation of required space of two case organizations is given bellow:

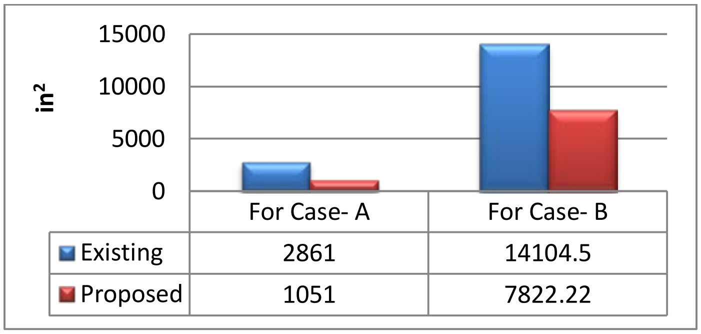


Figure 14. Required space status of two case organizations.

4.9 Lead Time Status for Case- A

Existing lead time for 100pc= 18345.50 min [From Current State Value Stream Mapping]

Proposed lead time for 100pc= 852.34 min [From Future State Value Stream Mapping]

Reduction of lead time= (18345.5-852.34) min= 17493.16 min = 36.44 day

For Case- B

Existing lead time for 2544pc= 29478.76 min [From Current State Value Stream Mapping]

Proposed lead time for 2544pc= 957.53 min [From Future State Value Stream Mapping]

Reduction of lead time= (29478.76-957.53) min = 28521.23 min = 59.42 day

The graphical representation of lead time status of two case organizations is given bellow:

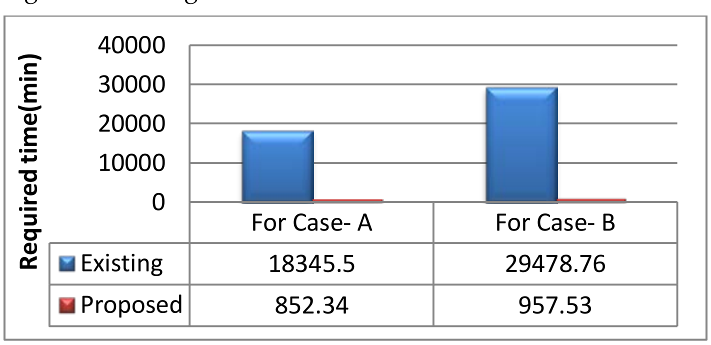


Figure 15. Lead time status of two case organizations

4.10 Inventory Status for Case- A

Existing inventory (in terms of queuing time): 16605.73min

a. Raw material related: 8640min
b. WIP inventory related:
Manually calculated: 7685.73min
From simulation: 7671.48 min
c. Finished goods: 280min

Proposed inventory (in terms of queuing time): 392.12 min

a. Raw material related: 0 min
b. WIP inventory related: 112.12min
c. Finished goods: 280min

Reduction of inventory (in terms of queuing time) = (16605.73-392.12) min = 16213.61 min = 33.78 day

For Case- B

Existing inventory (in terms of queuing time): 16192.5min

a. Raw material related: 8640min

b. WIP inventory related:

Manually calculated: 4672.5 min
From simulation: 4689.828 min

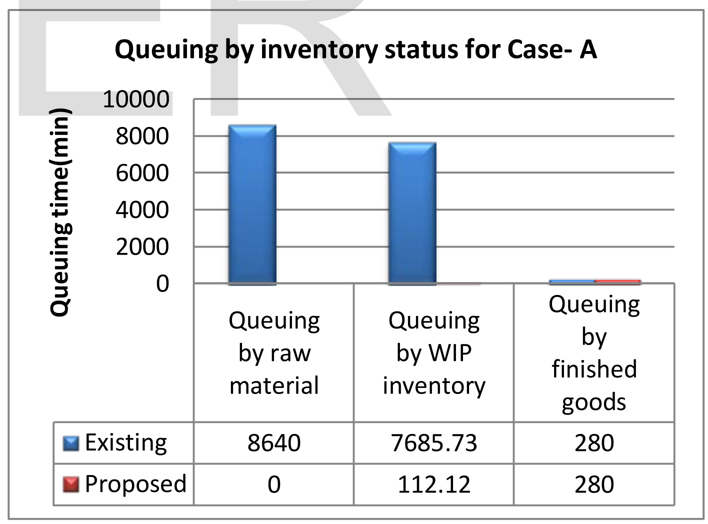
c. Finished goods: 2880min

Proposed inventory (in terms of queuing time): 362.974 min

d. Raw material related: 0 min
e. WIP inventory related: 82.974 min
f. Finished goods: 280min

Reduction of inventory (in terms of queuing time) = (16192.5-362.974) min = 15829.53 min = 32.98 day

The graphical representation queuing time by WIP inventory status & queuing time by inventory status of two case organizations is given bellow:



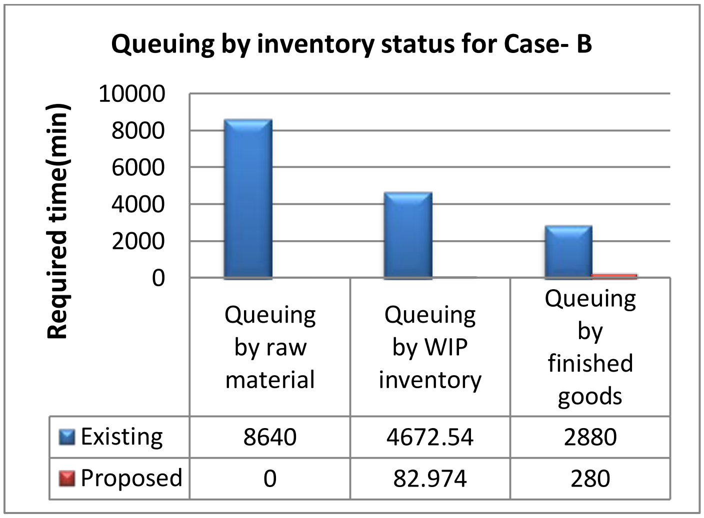


Figure 16. Queuing time by WIP inventory status of two case organizations

Figure 17. Queuing time by inventory status of two case organizations

4.11 Efficiency Status

Efficiency = (Total minutes produced / Total minutes Attended) x 100

Total minutes produced = No. of produced pieces X SMV of that activity

Total minutes Attended = Daily working hours * No. of workers

For Case- A:

Existing: No. of worker= 68

SMV for a Panjabi= 114.04

No. of produced Panjabi= 103.52 per day

Total minutes produced = 103.52* 114.04= 11805.42 min

Total minutes Attended = 480* 68= 32640 min

Efficiency= (11805.42/ 32640) * 100% = 36.17%

Proposed: No. of worker= 36

SMV for a Panjabi= 114.04

No. of produced Panjabi= 144 per day

Total minutes produced = 144* 114.04= 16421.74 min

Total minutes Attended = 480* 36= 17280 min

Efficiency= (16421.74/ 17280) * 100% = 95.03%

Efficiency improvement= (95.03- 36.17) %= 58.86%

For Case- B:

Existing: No. of worker= 80

SMV for a basic t- shirt= 7.81

No. of produced basic t- shirt= 2753 per day

Total minutes produced = 2753* 7.81= 21500.93 min

Total minutes Attended = 480* 80= 38400 min

Efficiency= (21500.93/ 38400) * 100% = 55.99%

Proposed: No. of worker= 76

SMV for a basic t- shirt= 7.81

No. of produced basic t- shirt= 3229 per day

Earned minutes= 3229* 7.81= 25218.49 min

Available minutes= 480* 76= 36480 min

Efficiency= (25218.49/ 36480) * 100% = 69.13%

Efficiency improvement= (69.13- 55.99) %= 13.31%

The graphical representation of efficiency status of Case- A and Case- B is given bellow:

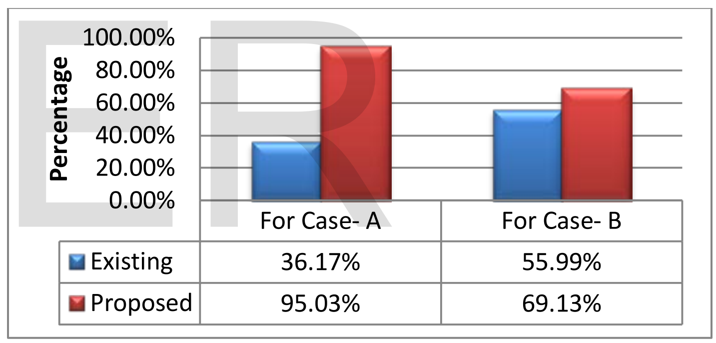


Figure 18. Efficiency status of two case organizations

4.12 Productivity Status

Labor productivity= (output/ input)

Productivity Status for Case- A:

Existing:

Labor productivity per day= output per day/ no. of worker = 103.52/ 68 pcs per worker = 1.52 psc per worker

Proposed:

Labor productivity per day= output per day/ no. of worker = 144/ 36 pcs per worker = 4 pcs per worker

Productivity Status for Case- B:

Existing:

Labor productivity per day= output per day/ no. of worker = 2753/ 80 pcs per worker = 34.41 pcs per worker

Proposed:

Labor productivity per day= output per day/ no. of worker = 3229/ 76 pcs per worker = 42.49 pcs per worker

The graphical representation of labor productivity status of two organizations is given bellow:

Figure 19. labor productivity status of two organizations

4.13 Overall Comparison between Existing and Proposed System

Comparing the overall performance and wastes of existing system and proposed system we find that there is huge scope to improve as shown in figure 20.

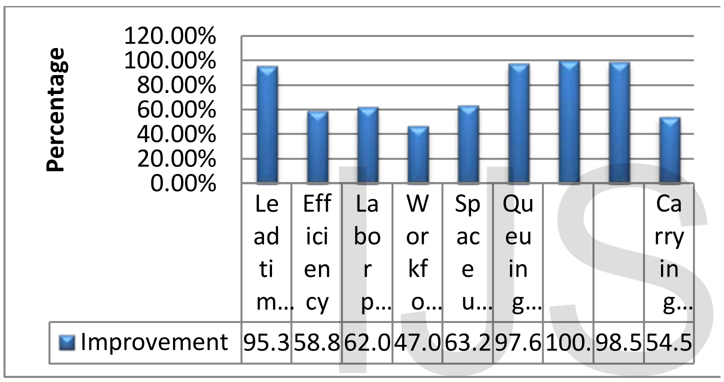


Figure 20. Overall improvements at Case- A

From the above discussion we see that for Case- A, workforce is reduced 47.05%. Required space is reduced 63.26 %. Over transportation is reduced 54.58 %. Inventory is reduced 97.64 %. In which raw material inventory is reduced 100 % and WIP is reduced 98.54 %. Lead time is reduced 95.35 %. Efficiency is improved 58.86 %. Labor productivity is improved 62 %.

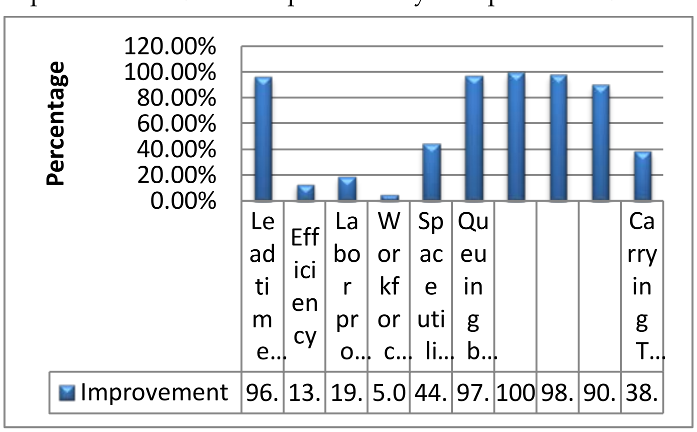


Figure 21. Overall improvements at Case- B.

From the above discussion we see that for Case- B, workforce is reduced 47.05%. Required space is reduced 63.26 %. Over transportation is reduced 38.97 %. Inventory is reduced 97.64 %. In which raw material inventory is reduced 1000 % and WIP is reduced 98.54 %. Lead time is reduced 95.35%. Efficiency is improved 58.86 %. Labor productivity is improved 62 %.

5 CONCLUSION

This empirical study has extracted an overall scenario of the cutting, sewing and finishing section of the selected garments factories in the context of identifying and reducing wastes and improving productivity. The study found that for Case- A, the value added time is only 31min while non- value added and unavoidable non value added time is 18314.5 min and for Case- B, the value added time is only 3.44 min while non- value added and unavoidable non value added time is 29435.32 min. This non value added time is the scope of improvement for the companies. If the company can reduce the wastes and non value added time the lead time and cost will be reduced simultaneously. By using value stream mapping, wastes such as- unnecessary inventory, defects, over transportation, waiting, over production, unnecessary workers etc. has found which exist case organizations. Using Pareto analysis various wastes has been ranked in terms of time. Key causes behind various wastes have been identified by applying 5why and cause-effect diagram. Unnecessary workers, WIP and over transportation have been reduced by using cellular manufacturing. KANBAN has also been used to reduce excess raw material inventory and waiting. After proposing new method, we found the total value added and unavoidable non value added time is only 821.34 min and 954.09 min for Case- A and Case- B respectively. Finally proposed system was analyzed through simulation model and found satisfactory result.

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