



Increasing the Process Cycle Efficiency of Men's Trousers Assembly Line

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ABSTRACT

Value is known as the price, which the customer is ready to pay for and the ultimate customer defines the value. Eliminating the waste is important for reduction of costs and meeting the demands of customers in short delivery times. Process Cycle Efficiency (PCE) is defined as the measurement of the amount of value-added time in a process. In this study, the PCE of men's trousers assembly line was tried to be increased. To achieve this aim, the value stream map of the line was examined. Overall equipment efficiency (OEE) values of the operations were calculated, the operations with OEE values under 85% were selected, and improvement activities were defined. At the end of these activities, total process lead time and work in process (WIP) stocks decreased and PCE increased from 0.9% to 1.5%.

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KEYWORDS

Value stream mapping, lean, process cycle efficiency, overall equipment efficiency, process lead time, work in process, assembly line

1. INTRODUCTION

The apparel industry has a volatile structure with a high variation in product mix, small order quantities and short delivery times. In order to be competitive and to fulfil the orders on time, the companies have to be flexible to produce a high variety of models [1]. To be competitive, many apparel companies have to improve their manufacturing processes, constantly revise themselves according to the needs and expectations of their customers. Manufacturing processes have to be analyzed accurately to minimize the costs. Waste consumes resources but does not add any value to the product [2]. Toyota production system accepted the waste types as overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion, defects [3].

Lean thinking is doing more with less and it starts with value [4]. Value is known as the price which is the customer is

ready to pay for and the ultimate customer defines the value. A value stream can be described as any value-adding and non-value-adding activities, which are done to make a product. Value stream mapping (VSM) is one of the most important tools for lean strategy with its visualization the non-value adding activities in the material and information flow of product. Wastes should be visualized and VSM is a very useful tool as it underlines kaizen activities for waste reduction. The first step in VSM is to choose a product family as the target for improvement [5]. The second step is to identify the wastes by drawing current value stream map. Unlike most process mapping techniques that often only document the basic product flow, VSM also documents the flow of information within the system. Where the materials are stored (raw materials and WIP) and what triggers the movement of material from one process to the next are key pieces of information [1]. The final stage in VSM is to create the future state map. The future state map highlights the lean

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tools, which are needed to eliminate the waste in the product value stream [6].

OEE is one of basic tools in lean manufacturing and it is an indicator, which defines the waste points in VSM. OEE is the measure of efficient usage of time for producing quality product. While the OEE is calculated, the time, which the machine is producing, is taking into account, not the amount of the output [7]. The waste hinders the capacity and performance. Machine breakdowns, setup and adjustments, reduced speed, minor stoppages, quality losses are the causes of low OEE. By removing waste in the manufacturing processes, the companies can manage to meet the demands with shorter lead time, high quality and they can get a competitive advantage over the other companies in recent volatile conditions by having flexibility to change schedules and giving priorities more quickly [8]. The studies in the literature, some of which are given below, show that lean principles can be applied to apparel companies.

Kumar and Thavaraj identified the target areas of improvement to eliminate the process wastages in current state. They fixed the problem of low flexibility by cellular layout, kaizen and 5s tools [6].

Kumari *et al.* applied lean tools in an apparel company in order to reduce the WIP and the number of workers by removing checking operations [9].

Akcagun *et al.* outlined a case study in an outerwear company. They decreased the total process of outwear from 27-33 weeks to 9-14 weeks by using value stream mapping [10].

Yıldız and Guner analyzed the manufacturing processes from incoming quality control to shipping to eliminate the wastes in a jean producing company [11].

Silva revealed that VSM can be applied to mass production in apparel industries in order to derive positive results such as reducing wastes in inventory and defects. Current and future state VSM was drawn for analyzing the raw material, cutting, sewing and finish goods departments' processes [12].

Kumar used VSM as a key lean tool to analyze machine cycle time, inventory, setup time and information flow on men's trouser production layout. Sewing room was revised by VSM analysis. [13].

Most of these studies try to decrease the total process lead time of a product from supplying process to shipment by using lean production principles and methods. In these studies, value stream mapping, kaizen, 5S and SMED applications were explained in detail with case studies. However, OEE and PCE were not the main topic of these studies. In this research, it was tried to determine and decrease the non-value-added time and eventually, to improve the rate of process cycle efficiency in the men's trousers production line by the help of lean principles. As

defined before, OEE is an indicator, which defines the waste points in VSM. This research was conducted with the aim of emphasizing the importance of OEE and showing its application in an apparel company in detail as an example for other apparel companies.

Value Stream Mapping, Process Cycle Efficiency and Overall Equipment Efficiency

When creating a flowchart of a garment, the cycle times of all the operations in a line are summed and the line with the longest duration is determined as the mainline. Lines which have shorter durations are segment lines and they are located outside of the mainline and they join the mainline at the related matching points. The difference between the duration of the segment and mainline is also important in the management of work in processes (WIP). The sewing process starts in the segments and the mainline at the same time and the segments create overstock at the points where they join the mainline. In order to determine the optimum WIP in a segment, the duration of the segment and the duration in the mainline from the first operation to the last operation, where the segment joined the mainline, should be compared. The difference between these two durations causes WIP inventory. WIP stock is very important for making improvements and reducing waste time.

Cycle time (CT) is the time, which takes to complete the production of one unit from start to finish. Cycle time is consisting of value-added and non-value-added times. Value-added time is the process time part of cycle time, which elapses during making the activities, which are defined as value by the customer. Cycle time equals the process time of the task in the garment assembly line. The cycle time of the operation is the ideal time for finishing that operation, however, in real life, the production conditions, which are measured by OEE, can deviate this balance.

Overall Equipment Effectiveness (OEE) is a simple metric, which shows how much right-first-time product is produced at a single equipment in the given time. In other words, it measures how effectively the time is used to produce a quality product at that equipment. OEE can be calculated with equation (1) and the following sub-equations (2), (3), (4).

$$OEE = Performance \times Availability \times Quality \quad (1)$$

$$Performance = \frac{Actual\ output \times Cycle\ time}{Daily\ working\ time \times Workload} \times 100 \quad (2)$$

$$Availability = \frac{(Daily\ working\ hours - Breakdown\ and\ adjustment\ times)}{Daily\ working\ time \times Workload} \times 100 \quad (3)$$

$$Quality = \left(1 - \frac{Daily\ repairing\ time}{Daily\ working\ time \times Workload}\right) * 100 \quad (4)$$

OEE value of 100% is the sign of perfect production, which means manufacturing right-first-quality product without time loss. Adversely, OEE value of under 100% is accepted

as loss factor and OEE percentages should be used to define the actual cycle time (ACT) as in equation (5).

$$ACT = \frac{CT}{OEE} \quad (5)$$

The actual cycle time will cause longer process lead time (PLT). Process lead time is the total time for a unit product to go its way through the operation from starting with the raw material's arrival to receiving money and can be calculated with equation (6). Process lead time is consisting of waiting time before the process, setup time, process time, waiting time after the process and transfer time between processes. The lead time of an operation should not be much higher than the cycle time of that operation, otherwise, there will be an overstock of WIP and this will decrease the process cycle efficiency of the line. Total process lead time is the sum of process lead times of all operations in the line.

$$PLT = ACT \times WIP \quad (6)$$

Process cycle efficiency (PCE) means that the duration of one job from the beginning of production to the arrival of the warehouse is completed in the shortest time.

PCE is improved by reducing non-value adding activities, and minimizing the necessary but non-value adding activities. In reality, the PCE is typically in the 5% to 10% range. While the PCE is the efficiency of the whole assembly line, OEE is valid only for one operation. PCE can be calculated with equation (7).

$$PCE = \frac{\text{Total cycle time (total value-added time)}}{\text{Total Process lead time}} \quad (7)$$

VSM shows the current situation in the line and it is easy to detect OEE values less than 85% and high WIP inventories. These are the key places, which have to be improved.

2. MATERIAL AND METHOD

In this study, the OEE values of the operations were used in order to make improvements and increase the process cycle efficiency in the apparel company. Daily work time is 540 minutes and daily customer demand is 450 pieces. Men's trousers line was chosen as the product family. Men's trousers are made of belt and pocket preparation, front and back pants mounting sections. The cycle time of each operation is measured with the help of a stopwatch. WIP stock of each operation was counted three times a day for both current and future states. The average value of these three WIP stocks were used as WIP quantities in each operation. OEE values of each operation were calculated by using collected performance, machine availability and quality data. After WIP stock and cycle time of each operation are determined, actual cycle times of operations were calculated by using OEE values. Process lead times of operations were found by using the actual cycle times and WIP levels of operations. VSM of the men's trousers assembly line was generated, by sequencing the unit cell of each operation. Figure 1 shows a unit cell of this VSM. After defining the current cycle time (process time), WIP, OEE, process lead time data, current process cycle efficiency of men's trousers production line was calculated.

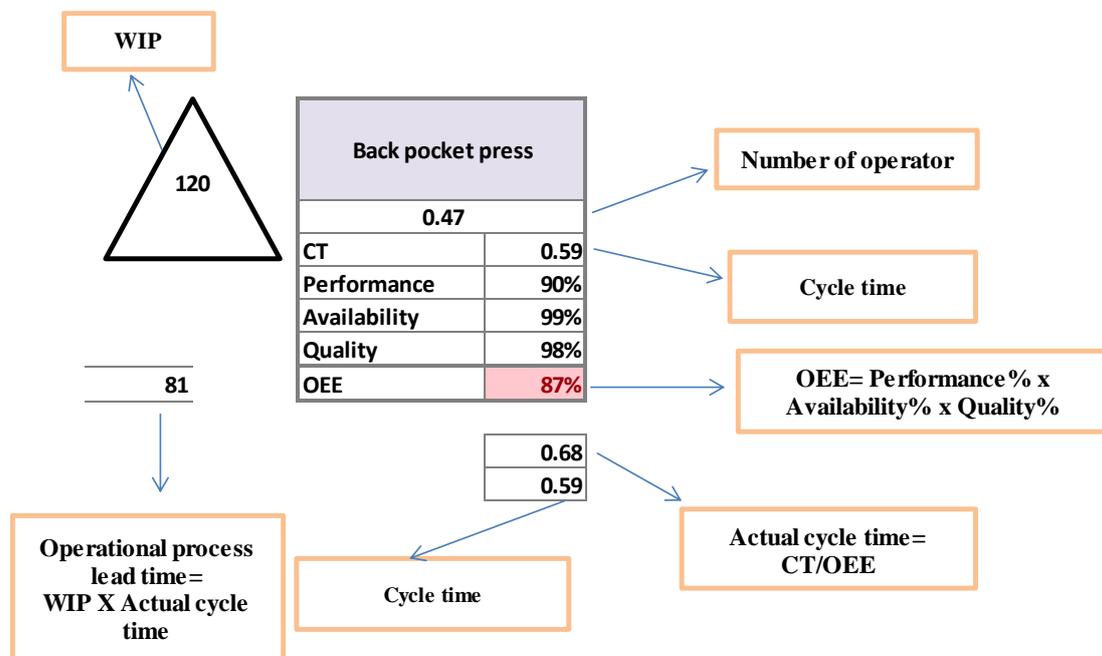


Figure 1. A unit cell of a value stream

Calculations of above operation were given in the following lines as an example. The daily target was 450 pieces and the daily working time is 540 minutes. Cycle time (CT) is 0,59 minutes. The operator produced 404 piece/day. The counted average WIP stock for this operation is 120 pieces. Machine breakdown is 278 minutes and repairing time is 5 minutes.

The related calculations were made for all operations in the line. All of these values were written on the VSM in Figure 2.

OEE values were examined in VSM and the operations, which have OEE values under 85% were determined for improvement. After doing the planned activities, before and after values of PCE were compared.

3. RESULTS AND DISCUSSION

The value stream of material and information flow of the current situation in the men's trousers line is as in Figure 2.

$$\text{Workload} = \left(\frac{\text{Daily target} \times \text{Cycle time}}{\text{Daily working time}} \right) = \frac{450 \times 0,59}{540} = 0,49$$

$$\text{Performance} = \frac{\text{Actual output} \times \text{Cycle time}}{\text{Daily working time} \times \text{Workload}} \times 100 = \frac{404 \times 0,59}{540 \times 0,49} \times 100 = 90\%$$

$$\text{Availability} = \frac{(\text{Daily working hours} - \text{Breakdown and adjustment times})}{\text{Daily working time} \times \text{Workload}} \times 100 = \frac{540 - 278}{540 \times 0,49} \times 100 = 99\%$$

$$\text{Quality} = \left(1 - \frac{\text{Daily repairing time}}{\text{Daily working time} \times \text{Workload}} \right) \times 100 = \left(1 - \frac{5}{540 \times 0,49} \right) \times 100 = 98\%$$

$$\text{OEE} = \text{Performance} \times \text{Availability} \times \text{Quality} = 90\% \times 99\% \times 98\% = 87\%$$

Segment 1 (Belt preparation line)

Belt fusing		Belt lining		Loop attaching		Waistband press	
467	0,32	250	0,45	100	0,3	160	0,96
	CT 0,26		CT 0,47		CT 0,35		CT 0,9
	Performance 100%		Performance 99%		Performance 102%		Performance 100%
	Availability 100%		Availability 98%		Availability 95%		Availability 99%
	Quality 99%		Quality 100%		Quality 89%		Quality 95%
123	OEE 99%	121	OEE 97%	41	OEE 86%	153	OEE 94%
	0,26		0,48		0,41		0,96
	0,26		0,47		0,35		0,9

Segment 2 (Pocket preparation line)

Pocket facing seam		Fusing fly		Pressing fly lining		Zipper attaching to fly		Front pocket facing overlock	
660	1,04	436	0,16	120	0,21	130	0,21	230	0,25
	CT 0,98		CT 0,17		CT 0,15		CT 0,17		CT 0,32
	Performance 98%		Performance 99%		Performance 77%		Performance 100%		Performance 90%
	Availability 80%		Availability 100%		Availability 100%		Availability 98%		Availability 80%
	Quality 91%		Quality 100%		Quality 100%		Quality 97%		Quality 80%
907	OEE 71%	75	OEE 99%	23	OEE 77%	23	OEE 95%	128	OEE 58%
	1,37		0,17		0,19		0,18		0,56
	0,98		0,17		0,15		0,17		0,32

Mainline (Front piece)

500	<table border="1"> <tr><td colspan="2">Color separation and opening</td></tr> <tr><td colspan="2">0,95</td></tr> <tr><td>CT</td><td>0,64</td></tr> <tr><td>Performance</td><td>100%</td></tr> <tr><td>Availability</td><td>100%</td></tr> <tr><td>Quality</td><td>100%</td></tr> <tr><td>OEE</td><td>100%</td></tr> </table>	Color separation and opening		0,95		CT	0,64	Performance	100%	Availability	100%	Quality	100%	OEE	100%	230	<table border="1"> <tr><td colspan="2">Color separation and dispatching</td></tr> <tr><td colspan="2">0,1</td></tr> <tr><td>CT</td><td>0,04</td></tr> <tr><td>Performance</td><td>100%</td></tr> <tr><td>Availability</td><td>100%</td></tr> <tr><td>Quality</td><td>100%</td></tr> <tr><td>OEE</td><td>100%</td></tr> </table>	Color separation and dispatching		0,1		CT	0,04	Performance	100%	Availability	100%	Quality	100%	OEE	100%	475	<table border="1"> <tr><td colspan="2">Front cuff overlock</td></tr> <tr><td colspan="2">0,96</td></tr> <tr><td>CT</td><td>0,92</td></tr> <tr><td>Performance</td><td>102%</td></tr> <tr><td>Availability</td><td>95%</td></tr> <tr><td>Quality</td><td>95%</td></tr> <tr><td>OEE</td><td>92%</td></tr> </table>	Front cuff overlock		0,96		CT	0,92	Performance	102%	Availability	95%	Quality	95%	OEE	92%	120	<table border="1"> <tr><td colspan="2">Frontcrotch overlock</td></tr> <tr><td colspan="2">0,65</td></tr> <tr><td>CT</td><td>0,75</td></tr> <tr><td>Performance</td><td>99%</td></tr> <tr><td>Availability</td><td>97%</td></tr> <tr><td>Quality</td><td>96%</td></tr> <tr><td>OEE</td><td>92%</td></tr> </table>	Frontcrotch overlock		0,65		CT	0,75	Performance	99%	Availability	97%	Quality	96%	OEE	92%	79	<table border="1"> <tr><td colspan="2">Sewing right fly</td></tr> <tr><td colspan="2">0,38</td></tr> <tr><td>CT</td><td>0,27</td></tr> <tr><td>Performance</td><td>99%</td></tr> <tr><td>Availability</td><td>98%</td></tr> <tr><td>Quality</td><td>99%</td></tr> <tr><td>OEE</td><td>96%</td></tr> </table>	Sewing right fly		0,38		CT	0,27	Performance	99%	Availability	98%	Quality	99%	OEE	96%	105	<table border="1"> <tr><td colspan="2">Sewing left fly</td></tr> <tr><td colspan="2">0,32</td></tr> <tr><td>CT</td><td>0,45</td></tr> <tr><td>Performance</td><td>86%</td></tr> <tr><td>Availability</td><td>98%</td></tr> <tr><td>Quality</td><td>99%</td></tr> <tr><td>OEE</td><td>83%</td></tr> </table>	Sewing left fly		0,32		CT	0,45	Performance	86%	Availability	98%	Quality	99%	OEE	83%	150	<table border="1"> <tr><td colspan="2">Facing seam</td></tr> <tr><td colspan="2">0,67</td></tr> <tr><td>CT</td><td>0,67</td></tr> <tr><td>Performance</td><td>88%</td></tr> <tr><td>Availability</td><td>92%</td></tr> <tr><td>Quality</td><td>93%</td></tr> <tr><td>OEE</td><td>75%</td></tr> </table>	Facing seam		0,67		CT	0,67	Performance	88%	Availability	92%	Quality	93%	OEE	75%
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78	<table border="1"> <tr><td colspan="2">Attaching waistband</td></tr> <tr><td colspan="2">1,81</td></tr> <tr><td>CT</td><td>1,72</td></tr> <tr><td>Performance</td><td>105%</td></tr> <tr><td>Availability</td><td>98%</td></tr> <tr><td>Quality</td><td>90%</td></tr> <tr><td>OEE</td><td>93%</td></tr> </table>	Attaching waistband		1,81		CT	1,72	Performance	105%	Availability	98%	Quality	90%	OEE	93%	40	<table border="1"> <tr><td colspan="2">Right fly lining bagging and label attaching</td></tr> <tr><td colspan="2">0,83</td></tr> <tr><td>CT</td><td>0,75</td></tr> <tr><td>Performance</td><td>90%</td></tr> <tr><td>Availability</td><td>90%</td></tr> <tr><td>Quality</td><td>91%</td></tr> <tr><td>OEE</td><td>74%</td></tr> </table>	Right fly lining bagging and label attaching		0,83		CT	0,75	Performance	90%	Availability	90%	Quality	91%	OEE	74%	27	<table border="1"> <tr><td colspan="2">Left belt end finishing</td></tr> <tr><td colspan="2">0,32</td></tr> <tr><td>CT</td><td>0,25</td></tr> <tr><td>Performance</td><td>100%</td></tr> <tr><td>Availability</td><td>99%</td></tr> <tr><td>Quality</td><td>98%</td></tr> <tr><td>OEE</td><td>97%</td></tr> </table>	Left belt end finishing		0,32		CT	0,25	Performance	100%	Availability	99%	Quality	98%	OEE	97%	35	<table border="1"> <tr><td colspan="2">Right and left belt end ironing</td></tr> <tr><td colspan="2">0,65</td></tr> <tr><td>CT</td><td>0,59</td></tr> <tr><td>Performance</td><td>104%</td></tr> <tr><td>Availability</td><td>95%</td></tr> <tr><td>Quality</td><td>100%</td></tr> <tr><td>OEE</td><td>99%</td></tr> </table>	Right and left belt end ironing		0,65		CT	0,59	Performance	104%	Availability	95%	Quality	100%	OEE	99%	21	<table border="1"> <tr><td colspan="2">Left fly foot stitch</td></tr> <tr><td colspan="2">0,34</td></tr> <tr><td>CT</td><td>0,45</td></tr> <tr><td>Performance</td><td>89%</td></tr> <tr><td>Availability</td><td>95%</td></tr> <tr><td>Quality</td><td>92%</td></tr> <tr><td>OEE</td><td>78%</td></tr> </table>	Left fly foot stitch		0,34		CT	0,45	Performance	89%	Availability	95%	Quality	92%	OEE	78%	25	<table border="1"> <tr><td colspan="2">Sewing right fly</td></tr> <tr><td colspan="2">0,32</td></tr> <tr><td>CT</td><td>0,38</td></tr> <tr><td>Performance</td><td>86%</td></tr> <tr><td>Availability</td><td>100%</td></tr> <tr><td>Quality</td><td>95%</td></tr> <tr><td>OEE</td><td>82%</td></tr> </table>	Sewing right fly		0,32		CT	0,38	Performance	86%	Availability	100%	Quality	95%	OEE	82%	14	<table border="1"> <tr><td colspan="2">Hook tacking</td></tr> <tr><td colspan="2">0,5</td></tr> <tr><td>CT</td><td>0,35</td></tr> <tr><td>Performance</td><td>86%</td></tr> <tr><td>Availability</td><td>86%</td></tr> <tr><td>Quality</td><td>98%</td></tr> <tr><td>OEE</td><td>72%</td></tr> </table>	Hook tacking		0,5		CT	0,35	Performance	86%	Availability	86%	Quality	98%	OEE	72%
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Quality	98%																																																																																																														
OEE	98%																																																																																																														
	3,58		1,23		3,04																																																																																																										
	3,4		0,8		2,98																																																																																																										

Segment 3 (Back Piece)

480	Back trimming overlock		100	Back rise overlock		35	Sewing back dart		67	Back dart ironing		45	Sewing back welt pocket		120	Back pocket press		58	Back pocket bartacking	
	0,57			0,3			0,36			0,67			0,83			0,47			0,46	
	CT	0,6		CT	0,24		CT	0,6		CT	0,82		CT	0,8		CT	0,59		CT	0,5
	Performance	93%		Performance	100%		Performance	70%		Performance	91%		Performance	104%		Performance	90%		Performance	99%
	Availability	99%		Availability	98%		Availability	94%		Availability	100%		Availability	92%		Availability	99%		Availability	99%
Quality	99%	Quality	99%	Quality	98%	Quality	99%	Quality	96%	Quality	98%	Quality	99%							
316	OEE	91%	25	OEE	97%	33	OEE	64%	61	OEE	90%	39	OEE	92%	81	OEE	87%	30	OEE	97%
	0,66			0,25			0,93			0,91			0,87			0,68			0,52	
	0,6			0,24			0,6			0,82			0,8			0,59			0,5	
89	Back pocket bagging		95	Closing back pocket mouth		76	Tack back pocket to waist													
	0,7			0,33			0,51													
	CT	0,51		CT	0,25		CT	0,5												
	Performance	98%		Performance	96%		Performance	101%												
	Availability	99%		Availability	95%		Availability	100%												
Quality	98%	Quality	99%	Quality	99%															
48	OEE	95%	26	OEE	90%	38	OEE	100%												
	0,54			0,28			0,50													
	0,51			0,25			0,5													

Figure 2. Value stream of men's trousers assembly line

Total cycle time is 40.84 min, total WIP stock in the line is 6630 and total process lead time is 4762 minutes for current state as seen in Table 2. The process cycle efficiency of the current situation is 0.9%. Nakajima indicated that under ideal conditions, the companies should have availability > 90%, performance > 95%, quality > 99% values which result in OEE > 84% and this OEE value is a good benchmark for a typical manufacturing capability [14]. When the current situation map is examined, the sources of inefficiency for each operation can be seen by checking the OEE values, which are under 85%. The reasons of losses at performance, availability and the quality values should be examined in order to increase low OEE values. The improvement points and the activities to be done were determined as in Table 1.

After these improvements, OEE values of 21 operations changed as given in the future state part of Table 2. As a result of the improvement studies, no changes have been observed in the information flow, material flow and raw material supply processes. Only control checking operation has been removed. Therefore, future state map was not shown again. After the elimination of this operation, the future cycle time is 40.19 min. Improvements in availability, performance and quality ratios increased most of the OEE values over 85% and accordingly, WIP levels dropped as seen in Table 2.

In the future state, the WIP stock level has been reduced from 6630 to 4460. The time losses because of WIP stocks have been eliminated and the total process lead time decreased from 4762 to 2702 minutes. This has led to the implementation of lean flow in production. Thus, the PCE value of the line increased from 0.9% to 1.5% and the production pace raised.

4. CONCLUSION

The apparel companies try to cater for the customer demands, which have high variety of models with low quantities in recent volatile market. This situation forces the companies work flexible with low costs. Therefore, the companies have to revise themselves according to the needs and expectations of their customers continuously. Lean manufacturing provides being highly responsive to customer demand while producing quality products economically and efficiently by reducing various waste in workforce, inventory, time to market. Shorter process lead time provides increasing customer satisfaction and gives flexibility to change schedules. OEE infers how much the equipment is doing compared to it is expected to do. Losses are activities that absorb resources without creating value and OEE reveals the losses that hinders equipment from performing its maximum effectiveness.

The present study aimed to find the hidden waste present in the men's trousers assembly line with the help of VSM and OEE values of operations and eventually to increase the PCE value in this line. After the calculation of OEE values of operations, the OEE values under 85% were determined. In these operations, main reason of the losses was rhythm problem, which stem from the minor stoppages and these stoppages affect the performance of the worker. Some precautions were taken to minimize the stoppages. Machine breakdowns and the setup times were the reasons of low machine availability in some operations. Machine changes and the maintenance program were planned for these wastes. In order to accelerate the speed and to overcome some quality problems, some machine changes were made. As a result of these activities, the WIP stock level in the assembly line was reduced from 6630 to 4460 pieces and the total

process lead time decreased from 4762 to 2702 minutes. Finally, the process cycle efficiency of the line increased from 0.9% to 1.5%.

OEE is one of the most important performance measurements in manufacturing companies. The companies

can increase capacity, decrease costs, improve quality in production lines by optimizing OEE. It is expected that this research will be a good example of OEE application for other apparel companies.

Table 1. Problems and improvements in current situations

No	OPERATION	PROBLEM	ARRANGEMENTS
Segment 2 (Pocket preparation)			
1	Pocket facing seam	Sewing adjustment	Machine to be exchanged
2	Pressing fly lining	Rhythm problem	Apparatus to be made for fly pressing
3	Front pocket facing overlock	Sewing adjustment problem	Machine to be exchanged
Segment 3 (Back Piece)			
5	Sewing back dart	Long SMED time in one and double dart models	The machine will be modified in order to put apparatus on the machine for both models at the same time.
MAINLINE (Front Piece)			
6	Sewing left fly	Fly- lining notch alignment problem	A nest will be made on the machine in order to align the notch.
7	Facing seam	Rhythm problem	Pieces to be sewn will be on the operator's lap and the facing pieces will be stacked on the machine. The operator will take a piece from his lap and place it on the machine with his two hands. After placing the facing on the piece and sewing it, he will leave the finished piece to the table on the left.
8	Front pocket press	Rhythm problem	The pieces will be stacked in the direction of the press and there will be no need for the worker to turn the piece for placing on the press.
9	Topstitch inseam	Rhythm problem	Machine speed and type will be changed.
10	Right fly lining bagging and label attaching	Fly cutting problem	Blade machine will be used to eliminate cutting time.
11	Left fly foot stitch	Rhythm problem	A line will be drawn 1 cm away from the presser foot in order to make the pursuance of the sewing line easy.
12	Right fly edge stitch	Rhythm problem	An auxiliary piece will be put near to presser foot to lean the fabric for making the tracking of the sewing line easy.
13	Hook tacking	Frequent machine breakdown	Machine engine will be changed
14	Inspection	Hand-to-hand flow deceleration between operations	The steps of control operations that affect the finished product quality will be eliminated by integrating it into other operations.
15	Waistband blind stitch	Failure to set the depth of needle penetration of blind stitch machine	Needle and yarn number will be changed.
16	Bartacking crotch	Loss of time during transport of crotch components	Stock space will be made on the machine for the pieces.
17	Crotch point bartacking	Rhythm problem	In the current situation, the work piece standing at the table on the left was taken, the bartacking process was done, and the work piece was moved to the table on the right side. In the new case, the piece is shifted to the table, which is placed in front of the sewing machine. Thus, the transport was reduced.
18	Trimming blind stitch	Rhythm problem	The worker stops more than expected in order to arrange the piece because of the round and narrow shape of the hem. A guide piece will be attached around the cylinder arm of the blind stitching machine. The worker will stop less with the guidance of this piece.
19	Sewing tape to hem	Rhythm problem	To make the worker less stop for checking the distance from edge of hem, laser light will be used to keep the distance
20	Trousers cuffs pressing	Rhythm problem	For decreasing the bundle transporting time, another bundle holding apparatus will be put oppose the current one.
21	Leg Press	Failure to set machine according to fabric type.	All machine maintenance will be done and upper buck material will be changed with 10 mm thick silicone foam. This material will prevent shine and pressure problem and reduce the time for setting machine.
22	Creasing press	Failure of size fixing during ceasing press and chronic machine failure	The machine will be maintained every week and the laser will be installed at the starting and end points to prevent the measurement problem for ceasing.

Table 2. Comparison of current and future state

Segment 1(Belt preparation)	CURRENT STATE								FUTURE STATE							
	Cycle time	Actual cycle time	Performance	Availability	Quality	OEE	WIP	PLT	Performance	Availability	Quality	OEE	Actual cycle time	WIP	PLT	
Belt fusing	0,26	0,26	100%	100%	99%	99%	467	121	100%	100%	99%	99%	0,26	230	59	
Belt lining	0,47	0,48	99%	98%	100%	97%	250	121	99%	98%	100%	97%	0,48	45	22	
Loop attaching	0,35	0,41	102%	95%	89%	86%	100	41	102%	95%	89%	86%	0,41	90	37	
Waistband press	0,9	0,96	100%	99%	95%	94%	160	153	100%	99%	95%	94%	0,96	70	67	
Segment 2 (Pocket preparation)	Cycle time	Actual cycle time	Performance	Availability	Quality	OEE	WIP	PLT	Performance	Availability	Quality	OEE	Actual cycle time	WIP	PLT	
Pocket facing seam	0,98	1,37	98%	80%	91%	71%	660	907	100%	95%	96%	91%	1,07	450	484	
Fusing fly	0,17	0,17	99%	100%	100%	99%	436	75	99%	100%	100%	99%	0,17	375	64	
Pressing fly lining	0,15	0,19	77%	100%	100%	77%	120	23	92%	100%	100%	92%	0,16	70	11	
Zipper attaching to fly	0,17	0,18	100%	98%	97%	95%	130	23	100%	98%	97%	95%	0,18	95	17	
Front pocket facing overlock	0,32	0,56	90%	80%	80%	58%	230	128	95%	99%	98%	92%	0,35	375	130	
Mainline (Front piece)	Cycle time	Actual cycle time	Performance	Availability	Quality	OEE	WIP	PLT	Performance	Availability	Quality	OEE	Actual cycle time	WIP	PLT	
Color separation and opening	0,64	0,64	100%	100%	100%	100%	500	320	100%	100%	100%	100%	0,64	475	304	
Color separation and dispatching	0,04	0,04	100%	100%	100%	100%	230	9	100%	100%	100%	100%	0,04	200	8	
Front cuff overlock	0,92	1,00	102%	95%	95%	92%	475	474	102%	95%	95%	92%	1,00	90	90	
Frontcrotch overlock	0,75	0,81	99%	97%	96%	92%	120	98	95%	100%	96%	91%	0,82	0	0	
Sewing right fly	0,27	0,28	99%	98%	99%	96%	79	22	100%	98%	99%	97%	0,28	45	13	
Sewing left fly	0,45	0,54	86%	98%	99%	83%	105	57	95%	98%	99%	92%	0,49	45	22	
Facing seam	0,67	0,89	88%	92%	93%	75%	150	133	98%	92%	93%	84%	0,80	45	36	
Front pocket press	0,21	0,26	82%	100%	99%	81%	40	10	95%	100%	99%	94%	0,22	40	9	
Side pocket tacking	1,78	1,78	100%	100%	100%	100%	67	119	100%	100%	100%	100%	1,78	45	80	
Front pocket bagging	0,52	0,56	94%	100%	99%	93%	66	37	100%	100%	99%	99%	0,53	45	24	
Sewing sides	1,4	1,46	99%	99%	98%	96%	90	131	100%	99%	98%	97%	1,44	50	72	
Top stitch inseam	0,6	0,71	96%	94%	93%	84%	78	56	97%	100%	95%	92%	0,65	20	13	
Press side in seams	0,7	0,72	107%	98%	93%	98%	130	93	105%	98%	93%	96%	0,73	45	33	
Attaching waistband	1,72	1,86	105%	98%	90%	93%	78	145	105%	98%	90%	93%	1,86	45	84	
Right fly lining bagging and label attaching	0,75	1,02	90%	90%	91%	74%	40	41	93%	98%	99%	90%	0,83	0	0	
Left belt end finishing	0,25	0,26	100%	99%	98%	97%	27	7	100%	99%	98%	97%	0,26	35	9	
Right and left belt end ironing	0,59	0,60	104%	95%	100%	99%	35	21	104%	95%	100%	99%	0,60	35	21	
Left fly foot stitch	0,45	0,58	89%	95%	92%	78%	21	12	99%	96%	95%	90%	0,50	21	10	
Sewing right fly	0,38	0,47	86%	100%	95%	82%	25	12	100%	100%	95%	95%	0,40	25	10	
Hook tacking	0,35	0,48	86%	86%	98%	72%	14	7	93%	100%	98%	91%	0,38	14	5	
Stop	0,3	0,33	100%	95%	95%	90%	22	7	100%	95%	95%	90%	0,33	22	7	
Point check	0,65	1,58	42%	100%	98%	41%	35	55	ELIMINATED							
Back rise closure	1,71	1,82	108%	98%	89%	94%	100	182	108%	98%	89%	94%	1,82	45	82	
Back rise sewing and pressing	0,56	0,58	104%	98%	95%	96%	20	12	104%	98%	95%	97%	0,58	20	12	
Waistband blindstitch	0,62	0,77	98%	91%	90%	80%	34	26	100%	95%	94%	89%	0,69	34	24	
Crotch Bartacking	0,2	0,53	42%	98%	92%	38%	55	29	98%	98%	94%	90%	0,22	20	4	
Crotch point bartacking	0,7	1,04	74%	93%	98%	67%	12	12	98%	95%	98%	91%	0,77	12	9	
Pocket and loop bartacking	1,8	1,97	107%	95%	90%	91%	35	69	107%	95%	90%	91%	1,97	35	69	
Bartacking	0,53	0,54	102%	98%	98%	98%	45	24	102%	98%	98%	98%	0,54	45	24	
Check before pressing	1,7	1,73	100%	100%	98%	98%	50	87	100%	100%	98%	98%	1,73	50	87	
Trimming blindstitch	0,29	0,58	56%	95%	94%	50%	65	38	86%	100%	94%	81%	0,36	35	13	
Cuff press	0,47	1,37	38%	95%	95%	34%	19	26	83%	95%	95%	75%	0,63	0	0	
Sewing trimming band	0,46	0,95	52%	97%	96%	48%	3	3	90%	97%	96%	84%	0,55	5	3	
Leg Press	1,05	1,30	100%	84%	96%	81%	15	20	100%	94%	96%	90%	1,16	15	17	
Pressing	3,4	3,58	95%	100%	100%	95%	5	18	97%	100%	100%	97%	3,51	5	18	
Ceasing press	0,8	1,23	90%	85%	85%	65%	10	12	100%	95%	85%	81%	0,99	10	10	
Final inspection	2,98	3,03	100%	100%	98%	98%	17	52	100%	100%	98%	98%	3,04	17	52	
Segment 3 (Back Piece)	Cycle time	Actual cycle time	Performance	Availability	Quality	OEE	WIP	PLT	Performance	Availability	Quality	OEE	Actual cycle time	WIP	PLT	
Back trimming overlock	0,6	0,66	93%	99%	99%	91%	480	316	100%	95%	95%	90%	0,66	475	316	
Back rise overlock	0,24	0,25	100%	98%	99%	97%	100	25	100%	98%	99%	97%	0,25	200	49	
Sewing back dart	0,6	0,93	70%	94%	98%	64%	35	33	97%	96%	98%	91%	0,66	90	59	
Back dart ironing	0,82	0,91	91%	100%	99%	90%	67	61	91%	100%	99%	90%	0,91	0	0	
Sewing back welt pocket	0,8	0,87	104%	92%	96%	92%	45	39	104%	92%	96%	92%	0,87	45	39	
Back pocket press	0,59	0,68	90%	99%	98%	87%	120	81	98%	99%	98%	95%	0,62	25	16	
Back pocket bartacking	0,5	0,52	99%	99%	99%	97%	58	30	99%	99%	99%	97%	0,52	45	23	
Back pocket bagging	0,51	0,54	98%	99%	98%	95%	89	48	100%	99%	98%	97%	0,53	45	24	
Closing back pocket mouth	0,25	0,28	96%	95%	99%	90%	95	26	100%	92%	99%	91%	0,27	45	12	
Tack back pocket to waist	0,5	0,50	101%	100%	99%	100%	76	38	101%	100%	99%	100%	0,50	0	0	
Total	40,84						6630	4762						4460	2702	

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