Vedat Dal,
***Engin Akçagün,**
***Abdurrahim Yilmaz**

Using Lean Manufacturing Techniques to Improve Production Efficiency in the Ready Wear Industry and a Case Study

Marmara University,
Faculty of Technology,
Department of Textile Engineering
Göztepe Kampusu Kadıköy İstanbul, Turkey
E-mail: vedat@marmara.edu.tr

***Mimar Sinan Fine Arts University Vocational School Apparel Production Technology Program,**
Bomonti Campus Şişli/ İstanbul
E-mail: engin.akcagun@msgsu.edu.tr,
abdurrahim@msgsu.edu.tr

Abstract
Businesses apply different techniques to keep pace with the incremental competition conditions and changing consumer demands. Lean manufacturing is one of the most effective techniques, which is a systematic approach to identifying and eliminating waste through continuous improvement by flowing the product. The implementation of lean manufacturing starts with the development of Value Stream Maps. A value stream is comprised of all the actions, both value added and non-value added. The main strategy of lean manufacturing, is increasing the operating speed, reducing the duration of flow quality, and improving the cost and delivery performance. This study was carried out at a men's shirt producer i.e. a ready wear company. First of all, the current state of the production lines was analysed within the scope of the study. Then shirt production lines were organised with the lean manufacturing techniques. As a result, some improvements were made in productivity, quality and lead time.

Key words: *ready wear industry, lean manufacturing, men's shirt, productivity.*

Introduction

An overview of lean manufacturing

Taiichi Ohno of the Toyota Motor Company developed the lean strategy in the 1950s [1]. Lean manufacturing is a conceptual framework popularised in many Western industrial companies since the early 1990s. Initially the publication of the book 'The Machine that Changed the World' [2] started the diffusion of some lean manufacturing practices developed by the most competitive auto manufacturers in the world. Thereinafter lean manufacturing was studied in other industries [3, 4].

The main purpose of a lean strategy is to eliminate wastes (muda) or non-value added activities from a process [5]. Lean means "manufacturing without waste." Waste is anything other than the minimum amount of equipment, materials, parts, and working time that are essential to production. Waste ("muda" in Japanese) has seven types: waste from overproduction, waste of waiting time, transportation waste, inventory waste, processing waste, waste of motion, and waste from product defects [6].

Many sample studies were performed in different industries regarding lean manufacturing practice. For example, Gurumuthy [7] performed lean manufacturing practice by simulation and value stream mapping in an enterprise producing doors and windows. Moreover Gurumurty and Kodali determined in their study that lean manufacturing practices are performed mostly in production sectors [7]. Studies on lean manufacturing are mostly based on experimental studies about the efficiency of enterprises. The primary goal of introducing any lean manufacturing program in a shop, factory or company is to increase productivity, reduce lead times and costs, improve quality, etc. [4]. A study by Zayko et al. [8] points out that lean manufacturing can result in a 50 percent reduction in human effort, manufacturing space, tool investment and product development time, and a 200-500 percent improvement in quality [9]. A very brief description of the most common lean tools is given below [10 - 14];

- Cellular manufacturing: organises the entire process for a particular product or similar products into a group (or ''cell''), including all the necessary machines, equipment and operators. Resources within cells are arranged to easily facilitate all operations.
- Just-in-time (JIT): a system where a customer initiates demand, which is then transmitted backward from the final assembly all the way to the raw material, thus ''pulling'' all requirements just when they are required.
- Kanbans: a signalling system for implementing JIT production.
- Total preventive maintenance: workers carry out regular equipment maintenance to detect any anomalies. The focus is changed from fixing breakdowns to preventing them. Operators are included in maintenance and monitoring activities in order to prevent and provide warning of malfunctions.
- Setup time reduction: continuously try to reduce the setup time on a machine.
- Total quality management: a system of continuous improvement employing participative management that is centred on the needs of customers. Key components are employee involvement and training, problem-solving teams, statistical methods, long-term goals, and recognition that inefficiencies are produced by the system, not people.
- 5S: focuses on effective work place organisation and standardised work procedures.
- One piece flow: to minimise work-in-process, operators should focus on completing one part through the process before starting on the next.

Value stream mapping (VSM)

A value stream is all the actions (both value added and non-value added) currently required to bring a product through the main flows, starting from raw material and ending with the customer [15].

VSM is a pencil and paper tool that helps you to see and understand the flow of material and information as a product makes its way through the value stream [15]. These actions consider the flow of both information and materials within the overall supply chain. The ultimate goal of VSM is to identify all types of waste in the value stream and to try and eliminate these [15].

The first step is to choose a particular product or product family as the target for improvement. The next step is to draw a current state map that is essentially a snapshot capturing how things are currently being done. This is accomplished while walking along the actual process, and provides one with a basis for analysing the system and identifying its weaknesses. The third step in VSM is to create a future state map, which is a picture of how the system should look after the inefficiencies in it have been removed. Creating a future state map is done by answering a set of questions on issues related to efficiency, and on technical implementation related to the use of lean tools. This map then becomes the basis for making the necessary changes to the system [12].

Analyse and application studies

The main aim of this study is to increase efficiency and working activity by using lean manufacturing techniques in the production line. Practice in line with this aim was performed in a ready wear enterprise producing shirts. The firm produces 1650 shirts a day with 128 employees. There are two production lines in the firm. One of the production lines is set for production of classical shirts and the other for production of sports shirts. Quality control, ironing and packaging works are set in a single production line.

Increasing the number of models and decreasing the number of orders in parallel with the changing sense of fashion pose the biggest problem for the firm. The current production structure of the firm is set up according to mass production in parallel with these problems, and it works with high internal stock. And this brings along with it both quality and efficiency problems. In addition, setting the ironing and packaging departments in one line and high stock between the sewing lines result in extending the lead time and also realising quality problems late. Due to all these problems the firm planned lean manufacturing practice to solve them.

Method and material

Lean manufacturing techniques and especially that of value flow analysis are used to acquire data in this study. Moreover REFA work and time study techniques were used in determining process times of shirt models. The material of this study consists of data obtained from the enterprise producing shirts both for national and international customers.

Analysis studies

First of all, the current state of production lines is analysed in this study. The main topics and practice studies of the study performed are as follows:

- Revealing current and future state via value flow chart
- Analysis of product tree of present models
- Analysis of the process time of each model group
- Analysis of the production labour plan and layout plan

Value stream mapping

Firstly value stream mapping is formed in order to reveal the current situation. As is seen in ***Figure 1***, VA (Value Added) the

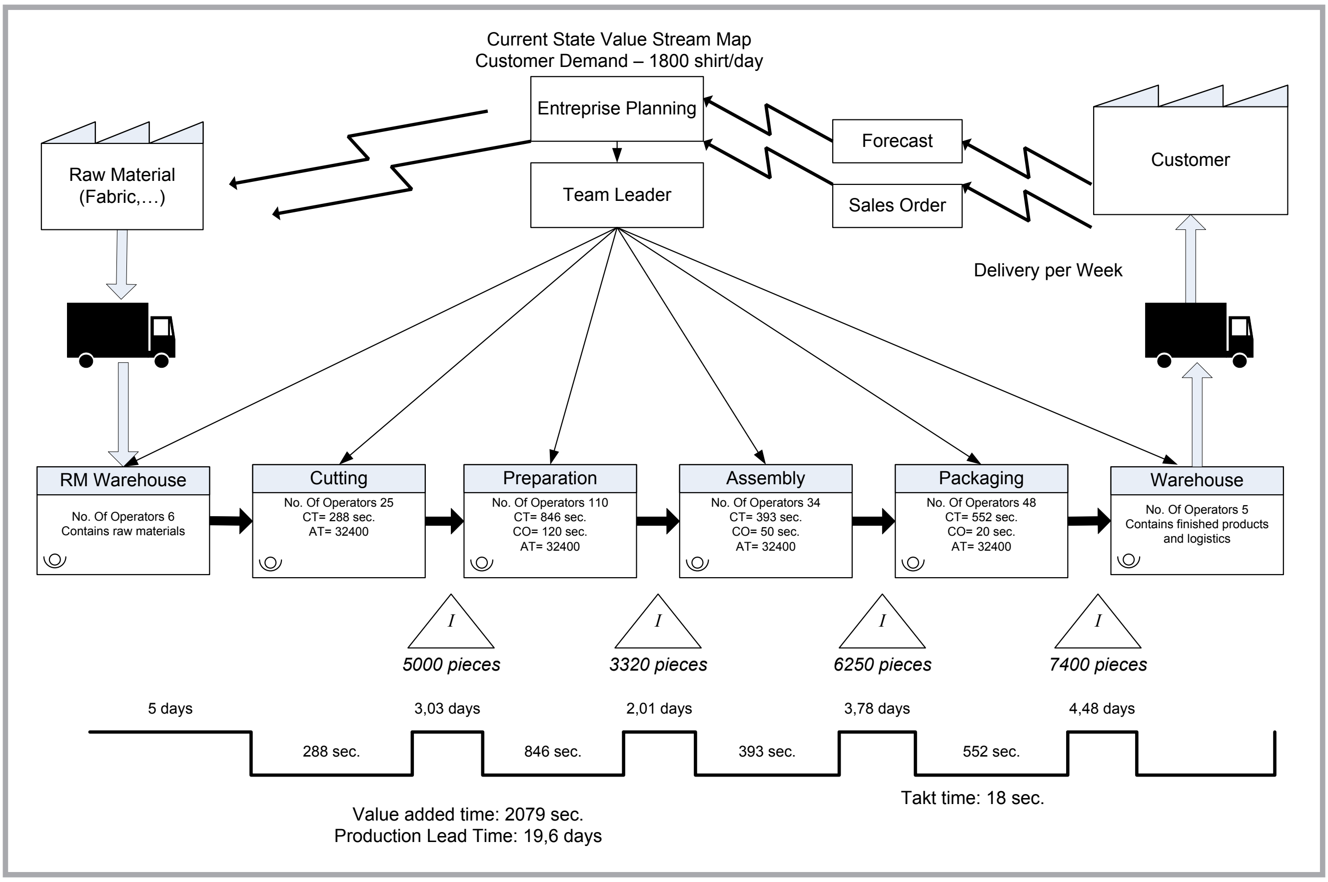

Figure 1. *Current state value stream map.*

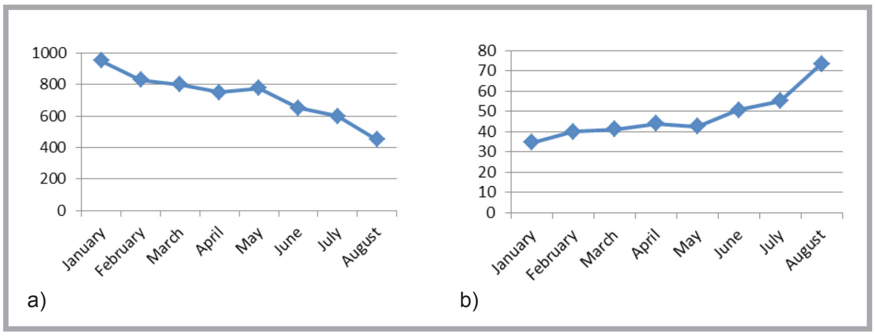

Figure 2. *Average order quantity (a) and counts of models (b).*

time is 2079 seconds and the production lead time 18.36 days. It is determined that a very long lead time is mostly caused by buffer stock and non-value added operations. The takt time is calculated by proportioning with the daily demand. The daily demand is 1800 pieces/day, and the firm works 9 hours a day. Therefore the available working time is found to be 9 × 60 × 60 = 32400 seconds. As a result the takt time is found as 9 × 60 × 60/1650 = 19.6 seconds. As the amount of buffer stock in production is 21970 pieces, it constitutes one of the main reasons for high time loss.

Analysis of product flows

Shirt models which will be produced for a customer of the enterprise are analysed in this phase of the analysis study. While making the analysis study, shirt models are distributed into 3 main groups by comparing with a classical shirt. In this grouping process the difficulties to be experienced in production are especially considered. Shirt group number 1 is accepted as models for easy models, shirt group number 2 - for moderate hard models, and shirt group number 3 is for extremely hard models.

Analysis values of shirt models belonging to one of the customers of the enterprise are shown. As seen in ***Table 1***, the total rate of moderate and extremely hard models is 54 %. This is an important factor which will directly affect sewing lines to be set. The average order number of models to be produced in 2010 by the enterprise and values of the model number are shown in ***Figure 2***. When these values are assessed it appears that the model number within orders of the enterprise will increase in 2010, but the average order number will decrease. In spite of the increase in the model number, the decrease in the order number will directly affect the flexibility of production lines to be set up.

Analysing process times of shirt models

After grouping shirt models according to their production difficulties, process flows are determined according to shirts of each group. Then during the model sewing of 10 shirts from each group, process times are determined by using REFA work and time study techniques. ***Table 2*** shows processes in the assembly line of a sample shirt and standard times.

Analysis studies of workers plan of current shirt production line

When current sewing lines are assessed, there are two sewing lines: One is for the production of a classical shirt and the other for the production of sports shirts, with one ironing and packaging line as indicated above. 110 persons are working in the preparation department of current first and second lines, and 25 operators are working in the assembly line of the current first line. ***Table 3*** shows a worker plan of operators and their operations. 9 persons are working on the assembly line of the current second line. When current operations are examined it is decided to make a kaizen study for the operation performed by operators performing the matching operation.

In the current situation the ironing-packaging line is working in a body as a separate unit from the sewing line. 48 operators are working in this department in the current situation. ***Table 4*** shows a labour distribution plan of the ironing-packaging line and operations of 45 operators. In addition to this table, 3 operators are used in carrying processes caused by stock and layout problems both between sewing and ironing-packaging and within ironing-packaging. It is decided to re-

Table 1. *Shirt analysis data.*

Model group	Order count (count)	Percentage, %	Model count (adet)	Percentage, %	Average order count per model
1. Easy group	38.991	46	59	39	661
2. Moderate hard group	12.187	14	20	13	609
3. Highly hard group	33.786	40	74	48	457
Total	**84.964**	**100**	**153**	**100**	

Table 2. *Operation standard times of shirt assembly line.*

No	Name of Operation	Time, s
1	Front-back joint on shoulder	0.51
2	Collar joint to shoulder	0.43
3	Collar closing	0.54
4	Joint sleeves	0.47
5	Sleeve edge stitch	0.46
6	Closing side stitch	0.50
7	Matching	0.12
8	Joint cuff	0.46
9	Hem folding and stitch	0.44
10	Stitch collar buttons	0.14
11	Yarn cleaning	2.48
12	Yoke ironing	0.19
13	Body ironing	1.07
14	Collar cuff pressing	0.18
15	Shirt buttoning	0.24
16	Final inspection	1.11
17	Shirt folding	1.51
18	Packaging-barcode	0.42

Table 3. Current state of Line 1 and Line 2 assembly worker plan.

Opr. No	Operation	Department	Time, s	Machine	Line 1		Line 2	
					Work load	No. of workers	Work load	No. of workers
1	Front-back joint on shoulder	Assembly	0.51	Lock Stitch M.	3.06	3	1.02	1
2	Collar joint to shoulder		0.43		2.56	3	0.85	1
3	Collar closing		0.54		3.25	3	1.08	1
4	Joint sleeves		0.47		2.85	3	0.95	1
5	Sleeve edge stitch		0.46		2.74	3	0.91	1
6	Closing side stitch		0.50	Double Chain Stitch M.	3.03	3	1.01	1
7	Matching		0.12	Manuel	0.72	1	0.24	1
8	Joint cuff		0.46	Lock Stitch M.	2.79	3	0.93	1
9	Hem folding and stitch		0.44		2.64	3	0.88	1

move work free of value added of these 3 operators by arranging the layout here.

Analysing multiple skills of employees

When current multiple skills of employees are analysed (***Table 5***), it is seen that employees mostly know only one operation, which poses one of the biggest problems for increasing the model number and decreasing production. Training plans are drawn aimed at teaching employees the closest operations to theirs on the flow to solve this problem. As a result of this training, operators learn new operations and there are attempts to reduce problems experienced during model change and to provide a continuity of flow.

Layout plan of current production line

When the current layout of shirt production lines are analysed, the findings below are obtained (***Figure 3,*** see page 20).

It consists of two sewing lines and an ironing-packaging unit which irons all products sewed. As the ironing-packaging unit is a separate unit, it causes intermediate stock and carrying.

As the products coming from both of the lines are ironed in the same place and stock between lines is high, quality problems are realised late. Distances between units are very large and this causes carryings, resulting in unnecessary cost according to lean manufacturing philosophy.

Practice studies

Future state value stream mapping

To reduce the problems revealed by the current state VSM (***Figure 1***), the following elements of LM techniques were planned to be implemented: 5S for organising the work place, line balancing for continuous flow processing, layout change to reduce people movement and non-value added operations such as unnecessary transportation, and supermarket for inventory reduction. After this, the future state VSM was developed for the finishing line in ***Figure 4*** (see page 20). Due to the future demand of 2400 pieces/day (targeted demand), the takt time changed to 13.5 seconds. In addition to this it is attempted to reduce stocks within production with the one-piece flow technique in the assembly line and supermarket between the preparation and assembly lines. In this way the production lead time becomes 6.14 days. Moreover it is attempted to determine operations free of value added and it is planned to remove them.

Organisational structuring studies

A preplanning department is formed in the enterprise to provide continuity of the improvement and arrangement works performed, to enable the enterprise to plan its activities in the long term, and to end the complicity The main tasks of this department are as follows:

- Classifying ordered shirt models according to their degree of difficulty
- Executing time, method studies and preparing product trees and labour plans.
- Preparing weekly production programs.

New production line balancing and layout plans for future state

Labour plans of new lines are formed to implement changes planned in the value stream map for the future state. The plan is started from assembly lines in the new production lines. Assembly lines are arranged as 4 lines to provide continuous flow. Ironing and packaging (finishing) units of each assembly line are supplemented to ends of lines (***Table 6*** see

Table 4. Current state of iron-packaging line workers plan.

Opr. No	Operation	Department	Time, s	Work load	No. of workers	Machine
1	Stitch collar buttons	Assembly	0.14	1.07	1	Lock Stitch M.
2	Yarn cleaning		2.48	12.44	13	
3	Yoke ironing		0.19	2.67	3	
4	Body ironing		1.07	4.93	5	
5	Collar cuff pressing		0.18	1.33	2	
6	Shirt buttoning		0.24	1.78	2	Double Chain Stitch M.
7	Final inspection		1.11	5.26	6	Manuel
8	Shirt folding		1.51	8.22	9	Lock Stitch M.
9	Packaging-barcode		0.42	3.11	4	

Table 5. Current multiple skills of employees

Operation	Operator A	B	C	D	E	F	G	H
Front-back joint on shoulder	■							
Collar joint to shoulder		■						
Collar closing		■						
Joint sleeves			■					
Sleeve edge stitch				■				
Closing side stitch					■			
Joint cuff							■	
Hem folding and stitch								■

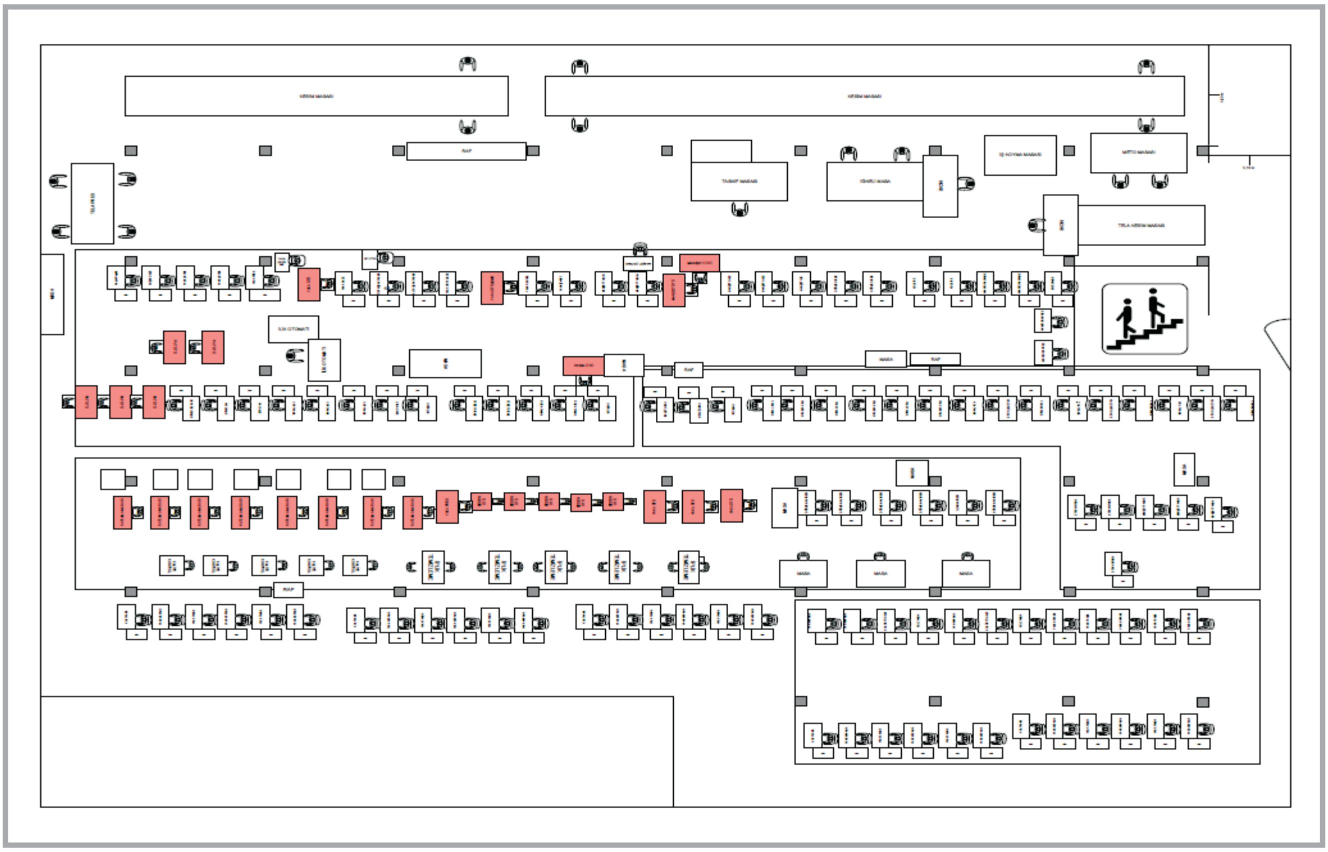

Figure 3. Current layout plan of shirt production lines.

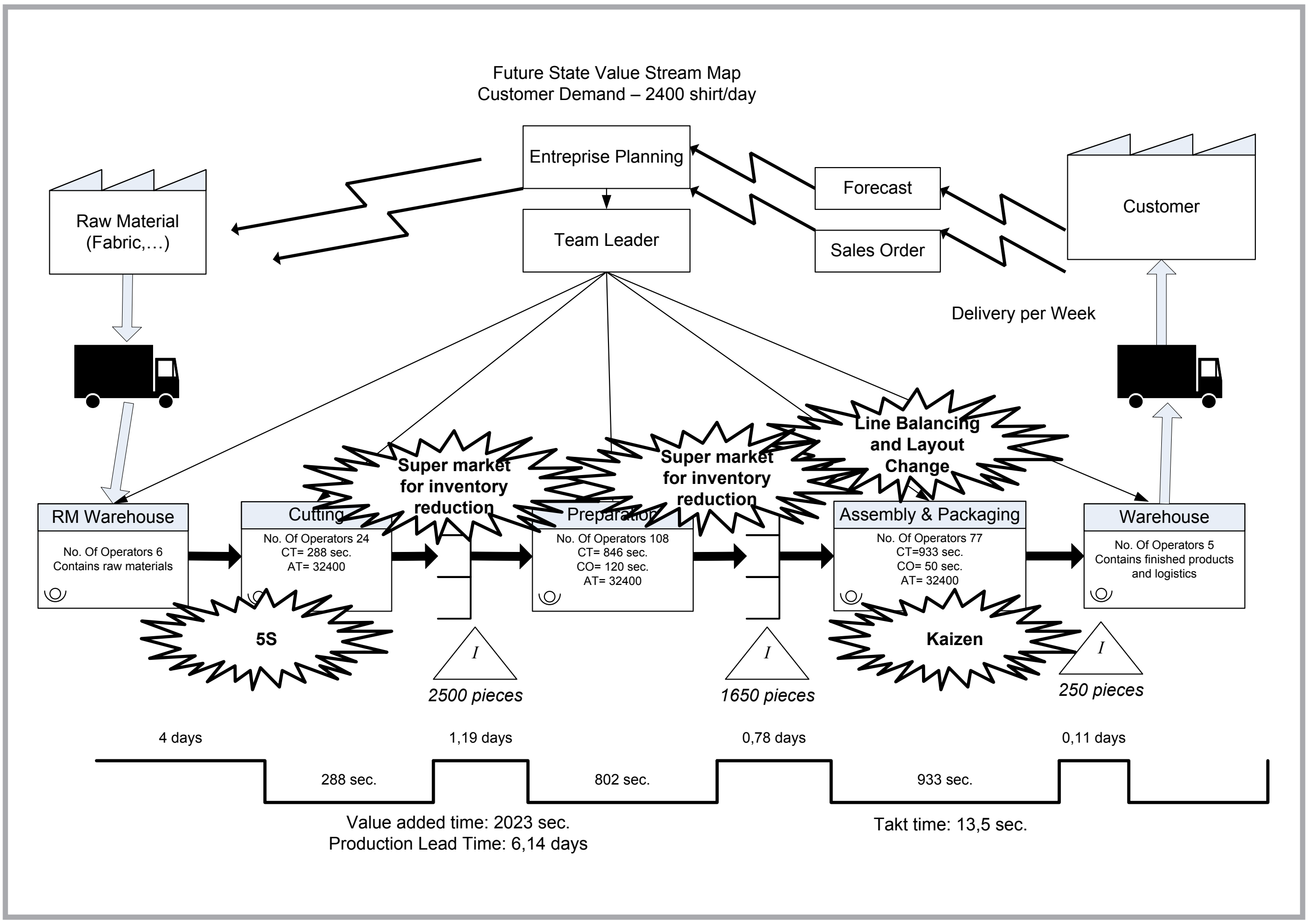

Figure 4. Future state value stream map.

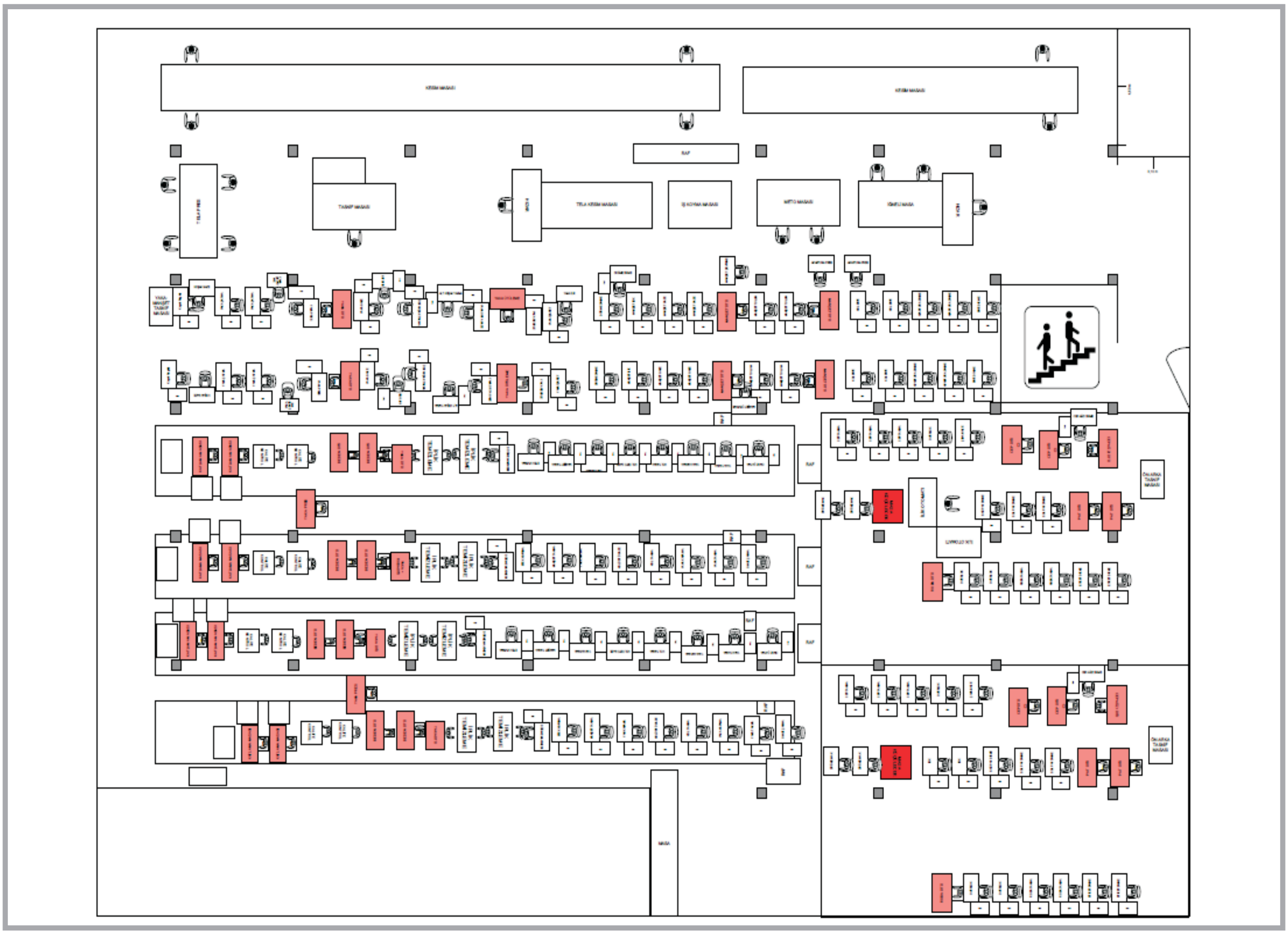

__Figure 5.__ Layout plan of new shirt production lines.

page 22), (***Figure 4, 5***). To accomplish this plan, Line 1, Line 2 and packaging operators (25 + 9 + 45 = 79) were reorganised by means of the line balancing plan. Firstly the finishing line operators were divided into 4 lines so that L1 finishing has 12, L2 finishing 11, L3 finishing 11, and L4 finishing 11 operators. Stitch collar buttons, collar cuff pressing and shirt buttoning operations are common, performed by 2 operators. After the settlement of the finishing department, the sewing department was divided into four lines. Hence L1 sewing has 8, L2 sewing 8, and L3 and L4 sewing lines have 8 operators. As a result, in total Line 1 has 20, Line 2 19, Line 3 19 and Line 4 19 operators.

After the settlement of operators, the work flow was organised by the one-piece flow technique. There are two main aims here: The first one is to send different production models to the customer at the same time. The second one is to make production lines smaller in order to increase production efficiency and quality due to decreased order numbers. Making production lines smaller leads to reducing stocks within production.

Continuous work flow is provided by settling the finishing unit at the end of assembly lines and unnecessary carrying is removed by placing shirts into parcels at the end of the same production line. Moreover by providing continuity of work flow, faults are realised immediately and quality problems are minimised. While assembly lines are organised like this, the preparation unit is rearranged with cellular production and planned to serve each assembly line. Preparation groups are planned to firstly serve feeding assembly lines of supermarket points.

In the layout change, the production line is rearranged according to the work flow plan. In the new layout plan, supermarket points are formed between cutting and preparation-montage as indicated above. The aim is to control the amount of order and to produce in the amount of the order.

Kaizen studies

Kaizen studies are performed in order to remove operations free of value added within the enterprise.

1st sample Kaizen study - matching operation

A study is done to improve the operations of operators matching bodies and sleeves on the assembly line, which is determined as operations free of value added. The reason for the matching operation is sought. The reason is found that labels (meto) indicating size and sequence number fall and operators mounting sleeves look for labels. To solve this problem, the type of label is changed and a stickier label is chosen. Moreover the place where labels are pasted is standardised. In addition, tables and trestles present in the operation of mounting the sleeve are rearranged. In this way mounting the sleeve by controlling the label is added to methods of operators who mount sleeves and those who fulfil an operation free of value added are taken to other departments.

Table 6. New production lines worker plans.

Opr. No	Operation	Old line 1	Old line 2	Line 1	Line 2	Line 3	Line 4
1	Front-back joint on shoulder	1	3	1	1	1	1
2	Collar joint to shoulder	1	3	1	1	1	1
3	Collar closing	1	3	1	1	1	1
4	Joint sleeves	1	3	1	1	1	1
5	Sleeve edge stitch	1	3	1	1	1	1
6	Closing side stitch	1	3	1	1	1	1
7	Matching	1	1	-	-	-	-
8	Joint cuff	1	3	1	1	1	1
9	Hem folding and stitch	1	3	1	1	1	1
10	Stitch collar buttons	1		1	-	-	1
11	Yarn cleaning	13		3	4	3	3
12	Yoke ironing	3		1	1	1	1
13	Body ironing	5		1	1	1	1
14	Collar cuff pressing	2		1	-	1	-
15	Shirt buttoning	2		1	-	1	-
16	Final inspection	6		1	2	1	2
17	Shirt folding	9		2	2	2	2
18	Packaging-barcode	4		1	1	1	1
Total operators		**79**		**20**	**19**	**19**	**19**

Table 7. Results of lean manufacturing practices.

No	Performance measure	Target situation	Previous situation	Next situation	Change, %
1	Production units, unit/day	2400	1800	2400	33
2	Productivity, %	80	62	80	29
3	Production lead time, days	6.14	18.36	6.14	66
4	RFT, %	90	65	88	35
5	Takt time, s	13.5	18	13.5	25
6	VA times, s	2023	2079	2035	2
7	Total WIP	4400	21970	4400	80
8	Manpower used in production	221	228	221	3

2nd sample Kaizen study – bunch system

Cut products are transferred to the production line in the current situation without making any arrangement. In this case, balancing and following products within production is not possible. A bunching unit is formed after cutting to make the product follow within production and cut products are bunched. The bunch system provides ease of product matching and maintaining product efficiency and product sequence.

Results

The product line was rearranged in line with labour and layout plans prepared in order to achieve the future state targeted. Production lines were followed for 30 days after organising production in this way and the results obtained are briefly summarised in the ***Table 7***.

When data acquired after practice is assessed, the biggest improvement is achieved in the production lead time as a result of decreasing stock within production. The production lead time went down to 6.14 days. The total stock within production occurred to be 440 pieces. In this way, customers were answered faster. Very important improvements were experienced in the rate of Right First Time (RFT) by decreasing stock within production and the practice of one piece flow, especially in the assembly lines. The RFT rate increased to a value like 88%, and the daily production capacity rose to 2400 pieces/day with increased efficiency. A 29% increase in efficiency was also achieved. Separating production lines and combining ironing-packaging lines for each assembly line have a strong effect here. The takt time occurred to be 13.5 seconds. During these practices, 5S practices were performed in the whole production and arrangements were made within production.

Consequently the current situation is first put forward via the value flow chart in the simple production practice performed and additional current situation analyses were made inside and

outside the field. And then a value flow chart for the future situation is planned. Necessary labour plans, layout plans, and kaizen points are determined to achieve this situation and necessary arrangements in these points are applied according to a designated calendar. This practice was performed with a group within the company and after practice it is continued by a team formed within it.

In the next studies of simple production practice, practices to be performed before production via simulation may be useful to see possible problems beforehand.

References

1. Ohno T. *Toyota Production System: Beyond Large-Scale Production.* Productivity Press, 1988.
2. Womack J. *The Machine that Changed the World.* New York: Rawson Associates, 1990.
3. Womack J. *Lean Thinking: Banish Waste and Create Wealth in your Corporation.* New York: Simon & Schuster, 1996.
4. Sanchez A. *International Journal of Operations & Production Management* 2001; 21(11): 1433-1451.
5. Tapping D. *The Lean Pocket Guide XL-Tools dor the Elimination of Waste.* Kindle Edition, Kindle Book, 2006.
6. Taj S. *Journal of Manufacturing Technology Management* 2008; *19*(2): 217-234.
7. Gurumurthy A, Kodali R. *Journal of Manufacturing Technology Management* 2011; *22*(4): 444-473.
8. Zayko See M, Broughman D, Hancock W. *Lean Manufacturing Yields World-Class Improvements for Small Manufacturer*. HE Solutions, April *1997*, pp. 36-40.
9. Rahman SL. *Journal of Manufacturing Technology Management* 2010; 21(7): 839-852.
10. Monden Y. *Toyota Production System-An Integrated Approach to Just-In-Time,third ed.* Georgia: Engineering & Management Press,Norcross, 1998.
11. Feld W. *Lean Manufacturing: Tools, Techniques and How To Use Them.* London: he St. Luice Press, 2000.
12. Abdulmalek FR. *International Journal of Production Economics* 2007; 107: 223-236.
13. Czarnecki H. Simulation of lean assembly line for high volume manufacturing. http://www.scs.org/confernc/hsc/hsc02/hsc/papers/hsc037.pdf (5 August 2011).
14. Kalaoğlu FS. *Fibre & Textiles in Eastern Europe* 2007; 15, 3 (62): 93–96.
15. Rother MS. *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda.* Cambridge, MA: The Lean Enterprise Institute, Inc., 2003.

Received 10.10.2012 Reviewed 18.12.2012