Value Stream Mapping: Case Study in a Water Heater Manufacturer

Ali Turkyilmaz[#1], Ali Gorener[*2], Humeyra Baser[#3]

[#] *Department of Industrial Engineering, Fatih University*
34500, Istanbul, Turkey
[1]aturkyilmaz@fatih.edu.tr
[3]melhumeyramel@hotmail.com

* *Department of International Logistics, Istanbul Commerce University*
34672, Istanbul, Turkey
[2]agorener@ticaret.edu.tr

***Abstract*— The value stream mapping is a lean production technique used by Toyota Production System (TPS) to visualize and design flow of information, material and production to analyze non-value added and value added operations.**

In this paper, the method of value stream mapping (VSM) was revealed by literature investigation and an application in a lean manufacturer firm. By drawing the value stream maps of an electric water heater assembly line non-value added (NVA) operations were determined and then they were eliminated in the improved case. It is shown that efforts on effective use of resources with prevention of waste in their source increase value added (VA) operations and also productivity. This study also emphasizes the VSM's important role in the supply chain while describing and recognizing extravagances for manufacturing facilities.

***Keywords*—** *Value Stream Mapping, Toyota Production System, Lean, Manufacturing*

1. Introduction

Lean systems are operations systems that maximize value added by each of company's activities by removing waste and delays from them [1]. From design to delivery, to increase the profitability of company, it needs to reduce waste production in all areas of production-from creating the products, to mistakes, over productions, unnecessary work, unnecessary movement and unnecessary storages. In turn, strict controls from the starts of manufacture to finish target cost reduction, increase customer satisfaction, gain the flexibility to adapt which is appropriate to market conditions, to accelerate cash flow, which increases of profitability of the company [2].

Seth and Gupta [3] pointed that the goal of lean manufacturing is to eliminate waste in human effort, inventory, time to market and manufacturing space to become highly responsive to customer demand while producing quality products in the most efficient and economical manner. Re-evaluate the production system and to purify wastes, very effective tool Value Stream Mapping is a used in the lean production. VSM is a technique used for understand the shape of the current functioning of the enterprise, wasted resources and see lean practices to plan.

Value stream mapping is one of the key lean techniques to identify the opportunities for other various lean techniques [4].

2. Literature Review

A value stream is a assortment of all actions (value added as well as non-value added) that are required to bring a product through the essential flows, starting with raw material and ending with the customer. These actions considered the flow of both information and materials within the overall supply chain [5, 6].

In the literature, value stream mapping approach is applied by Hines et al. [7] to the development of a supplier network around a prominent distributor of electronic, electrical and mechanical component. Brunt [8] suggested an approach to create a picture of the value stream for the whole supply chain in automotive industry.

Seth and Gupta [3] used VSM to achieve productivity improvement at supplier for an auto industry, by Seth et al. [9] to determine miscellaneous wastes in the supply chain of the

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edible cottonseed oil industry. Singh and Sharma [10] deals with the mapping of crank shaft gear manufacturing line in India. This approach is used by Vinodh et al. [11] for the analysis of a camshaft manufacturing organization in a manufacturing company of India. Chen et al. [12] present a case study of lean implementation at a small manufacturer in the United States using value stream mapping.

Chowdary and George [13] used VSM to analyze of the problems existing in the production line and improvement of operations at a pharmaceutical company, by Ar and Ashraf [4] to determine how value stream mapping is utilized to help the process industry eliminate waste for the engine component manufacturer in Malaysia, by Li et al. [14] to analyze carbon emission for electronics manufacturing process. Similarly, VSM is used by Teichgräber and Bucourt [15] to eliminate NVA waste for the procurement of endovascular stents, by Xie and Peng [16] to represent the entire operating room process and patient flow to identify problems.

2.1 Value Stream Mapping

The term "lean" means a series of activities or solutions to reduce waste, and improve the value added operations. VA and NVA expressions were came from Toyota Production System [17]. VSM is one of the many tools, working methods and concepts in the Lean environment. Other familiar tools are Just-in-Time (JIT), Single Minute Exchange of Die (SMED), 5S and Kanban.

Value stream is a collection of all actions (VA as well as NVA) that are required to bring a product (or a group of products that use the same resources) through the main flows, starting with raw material and ending with the customer. These actions consider the flow of both information and materials within the overall supply chain.

The ultimate goal of VSM is identify all types of waste in the value stream and take steps to try and eliminate these. While researchers have developed a number of tools to optimize individual operations within a supply chain, most of these tools fall short in linking and visualizing the nature of the material and information flow throughout the company's entire supply chain.

Taking the value stream viewpoint means working on the big picture and not individual processes. VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream [5, 18]. When one member of the supply chain becomes lean, other members in the process also have to be lean, in order to reap the benefits. Thus VSM is a powerful tool to spot where the waste is and where in the supply chain the actions have to be taken to be efficient. Few advantages of VSM are [19]:

- It helps to see the sources of waste in the value stream
- It provides a common language for talking about the manufacturing process
- It makes the decision about flow apparent
- It ties together lean concepts and techniques, which helps avoid cherry picking
- It forms the basis of an implementation plan by designing the whole door-to-door flow

However, since VSM is a paper and pencil method, it is limited in its modelling power. VSM is also a static tool that cannot describe dynamic behaviour and cannot handle either complexity or uncertainty. Moreover, we might need at least a few months of a continued monitoring to observe the effects of changes and improvements. On the other hand, we would like to preserve the VSM modelling language, because of its ease of use and its widening dissemination within the manufacturing community. VSM also includes a step by step approach to transform a current manufacturing state into a Lean Future State, which is the basis of its success in practice [20].

Value Stream Maps are drawn as pictures of the process. Simple, yet logical and powerful representations of the process (i.e., the value stream) are used to document both the current state (i.e., reality) and the future state (i.e., the goal) [21]:

-*The Current State Map* is the baseline view of the current situation from which all improvements are measured.

-*The Future State Map* represents the vision of how the project team sees the value stream at a point in the future after improvements have been made.

Figure 1 shows a simple value stream map. This situation is a material-flow-only value stream map. A weekly truck shipment of material is kept as inventory for 7 days before being processes. Assembly and inspection processes are being captured in the data ore process box. Finished products are kept for another 30 days in the inventory before is scheduled for delivery [4].

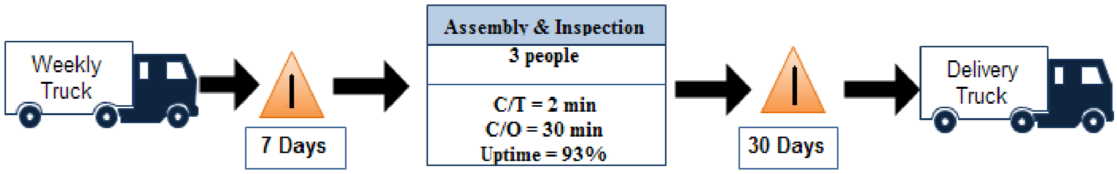

Figure 1. Example of common icon using VSM

2.1.1 Value Stream Mapping Measures

Takt Time (T/T): "Takt" is the German word for the baton that an orchestra conductor uses to regulate the speed, beat or timing at which musicians play. Lean terminology uses Takt time as the rate at which a completed product needs to be finished in order to meet customer demand. Takt time is determined according to the following account:

Takt time = Production Time Available / Customer Demand

Cycle Time (C/T): Cycle time is the total time from the beginning to the end of your process, as defined by you and your customer. Cycle time includes process time, during which a unit is acted upon to bring it closer to an output, and delay time, during which a unit of work is spent waiting to take the next action. Cycle Time is the total elapsed time to move a unit of work from the beginning to the end of a physical process.

Lead Time (L/T): The amount of time, defined by the supplier, that is required to meet a customer request or demand. Lead time is the commitment to deliver final product to your customer.

Value Added Time (V/A): Cumulative time of all the value added activities in a process. Value added time is an activity for which the customer is actually paying for.

Non-Value Added Time (NV/A): Cumulative time of all the non-value added activities in process. NV/A is an activity for which the customer is not actually paying for.

Every Part Every (EPE): For example, every three days, a product from one production lot size model, replacing the "three-day track" means.

Change Over Time (C/O): A period of transition from one model.

Uptime: The machine utilization rate.

Operator Number: The number of employees in the process.

Available Working Time: Times are removed from the total production time. Break time, meeting time etc.

3. Methodology

3.1 Company Background

Established in 1975 and started to production, Ihlas Domestic Appliances Production Industry and Trade Incorporated Company (IHEVA) presented its small appliances, which takes human health as a priority and facilitates the domestic life from the very beginning, to the consumers. Situated with its energetic coaching staff in Beylikduzu Organised Industrial Zone (BOSB) in a closed area of 21175 m² which employs 300 personnel composed of 220 assembly staff and 80 administrative staff, the Company continues its production in Cleaning Robots Factory, Water Heaters and RO Water Purifiers Factory, Carpet Washing Machine Factory and Plastical Injection Printing Plant.

3.2 The Analysis of the Current Situation

In the factory, parts produced by the Company and the pieces such as cables screws coming from the subsidiary industry is combined together and packed after quality control and served to the market. There are 31 workers in the production line of the electrical water heaters. The working hours for them are from 08:05 to 18:25. All the works under the production process is labor intensive. In the workplace, there are three control machines and U-shape assembly line on that the production is made. Currently, the total area of the workplace is 100 m^2. The 25.6 m^2 part of this area is for the assembly line and the remaining 74.4 m^2 part is for workers and buffer stocks.

The production of a water heater occurs in 31 steps and each step is taken by a different operator.

Table 1. Operations for water heater production

1. Tank control and nut fastening	**11.** Cable assembly	**21.** Hand-eye control
2. Attaching the o-ring and resistor to the tank	**12.** Switch screwing	**22.** Closing the front box
3. Flange screwing	**13.** Cable assembly to the resistor	**23.** Attaching the screw and tag to the front box
4. Flange screwing	**14.** Attaching clamp and socket	**24.** Attaching the button and the stage tag
5. Assembly of reset thermostat	**15.** Thermostat screwing	**25.** Attaching the barcode and front front panel tag
6. Flange screwing	**16**. Limit thermostat assembly	**26.**Packaging and putting in the operating manual
7. Back door assembly	**17.** Key screwing	**27.**Putting the product into the box
8. Clemens screwing	**18.** Checking before closing the front box	**28.** Separator and assembly
9. Aperture grouping	**19.** Partial Checking	**29.**Closing the box, sticking the barcode and warning label
10. Aperture body assembly	**20.** Mosten control	**30.**Product installation and sticking the barcode onto the box
		31. Packaging

As followes, you can see the existing operator settlement plans in figure 2.

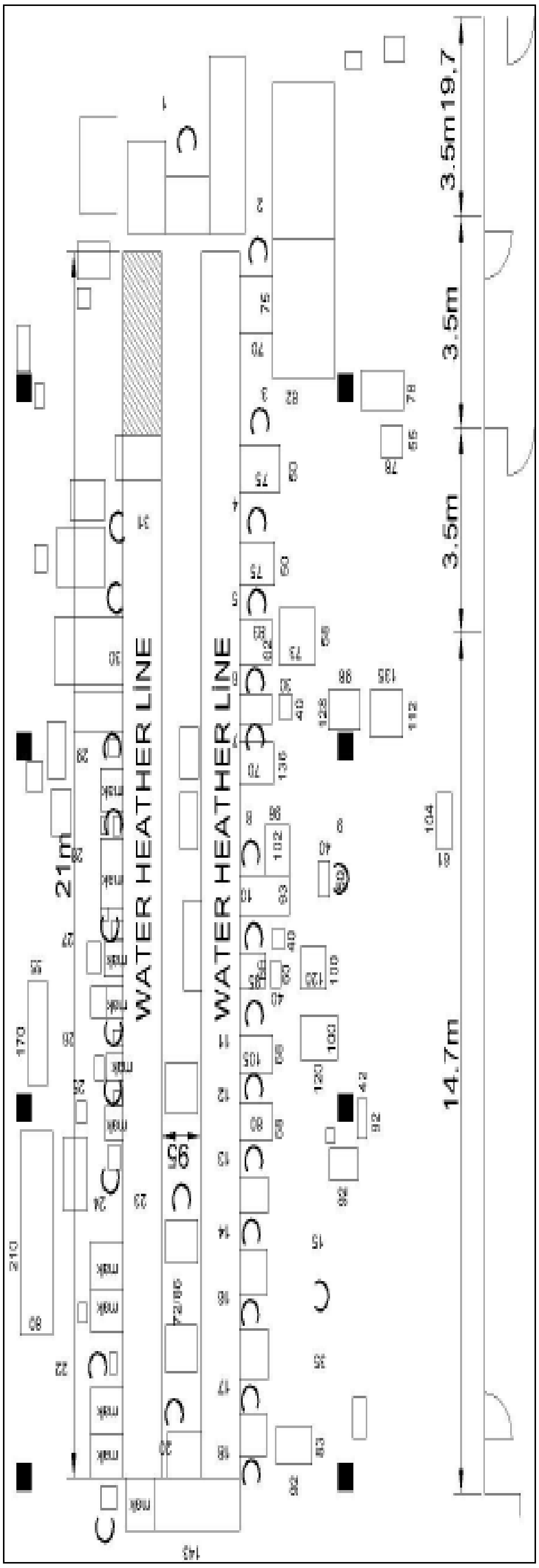

Figure 2. Existing production line and operator settlement plan

3.3 Current State Situation and Map

We can define the current situation and existing problems in the production line of electrical water heaters as follows:

The Company determines the number of water to be produced on a monthly base. The number is between maximum 31000 and minimum 9000 water heaters. The line of Electrical water heater produces according to the demand. Generally, it produces on alternate days and workers produce different products when not producing water heaters. This is the first and the most important problem. For this reason, sometimes producing on time becomes a problem. While sometimes there is overproduction leading the excess to product to wait, in other days there is overtime because the product does not match up. In addition, another important thing to mention is that the Company is not able to have production breaks in order to decrease its financial expenses and make the maintenance for the assembly line. Figure 3 represents the map showing the value flow of current production of electrical water heaters.

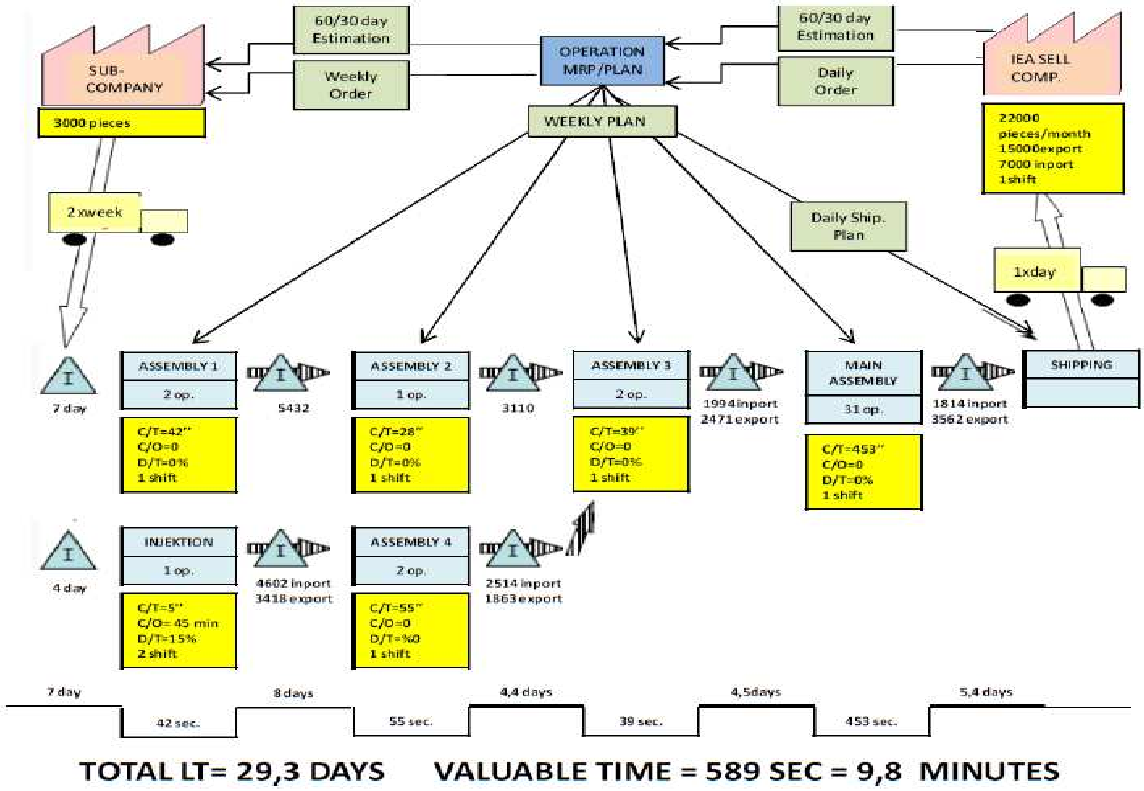

Figure 3. Current state value stream mapping

In line with the value stream map and enumerated objectives mentions above, the following changes in the production process are made in order to improve the existing conditions

3.4 Takt Time Calculation

In manufacturing, takt time refers to frequency of a part or component must be produced to meet customers' demand. The formula used in the takt time calculation is the time available (per shift) divided by the demand (per shift) [4].

The average of monthly production is 33000 and monthly work day is 22. So that the average number of daily production is 1500.

The average of daily working time of the factory is 33600 seconds. Out of this time, 2400 is spared for tea breaks and the remaining 31200 seconds is pure working time. The daily demand of the product by consumers is 1500. So, the takt time is 31200/1500= 20.8 seconds.

3.5 Work Sequence

The working time of the operators is determined and the cycle time for each operator is recalculated. The deviations in workers' work are determined. In this process, it was observed that the cycle time of operations is below the takt. For this reason, with drawing the work sequence and time towards the takt time by the method of balancing the assembly line, the work division among the operators is rearranged.

3.6 Regulated Work Environment

In order to create an organized, clean and high efficiency work environment, we have utilized 5S which is a work process and work method. The materials that are disorderly and occupy unnecessary space are removed. Chairs and junks are removed, too. The places and the sizes are the desks are changed. By creating an evaluation measure, the materials used in the production are rearranged. Only the materials necessary in a day or an hour are allowed to be present in the work area. The unnecessary space usage in the production area is prevented.

As a result, the initial 100m^2 work environment composed of a line of 25.6 m^2 and a remaining part of 74.4 m^2 is decreased to a 60.5 m^2 area, composed of a 25.6 m^2 line and a 34.9 m^2 remaining part, as a result of the improvements made.

Table 2. Space savings

	Line(m^2)	Others (m^2)	Total(m^2)
Before Kaizen	25.6 m^2	74.4 m^2	100 m^2
After the First Application of Kaizen	25.6 m^2	34.9 m^2	60.5 m^2
Pure Amount Of Space Saved = 39.5 %			

3.7 Kanban System

It is observed that there are some problems in the production because the system of vehicles is weak and there is waiting times for the finished materials of the operators to be supplied. To prevent this, we have established the kanban system. We have determined the backup time for each material according to size of the parts and the frequency of use. The name and number of the material used is enumerated in the attachment named “operation phases”. Kanban boxes are made according to the number of the materials. Because “pulling system” is aimed and installed in each works, we prepared pulling kanban cards. And application of “spiderman” who checks the production environment and transports the necessary materials to the operator in a lean production initiated.

3.8 Future State Map

You can find below the future state value stream mapping after the application of lean techniques to the existing system (Fig. 4). Fig. 5 represents the situation of workshop area before and after situation. And Fig. 6 shows a picture abandoned manufacturing line after application.

4. Discussion and Conclusion

This application in water heater manufacturer shows that VSM is a very useful tool to realize potential improvement opportunities and constitute lean systems. In the workshop, there is a significant amount of the time spent on the manufacturing from waiting and non-value added operations.

The most salient problem under the existed circumstances was the differences in cycle times and remaining below the takt time of these. The main source of the problem is unequal distribution of work load and flow among the operators and unnecessary waiting time. The other problem is the changing nature of production demand and time.

In line with the changes in demand for production, monthly plans for production changes too. In order to balance the production the factory was producing on alternate days. For this reason, while determining the future map of production under the pulling system we have designed a continuous production plan. With time measurement, we draw cycle times towards takt time. We have revised waiting times and other extravagancies one by one and redetermined the work flow and capacity of the operators. In order to increase work efficiency, we have regulated the work environment and encouraged the workers to work while standing.

The method of mapping the value stream helps us to easily recognize the extravagancies. To achieve a continuous development in the system and to gain efficient results, the participation of the operators to the system is necessary. This is because, they are the ones who do this job the best.

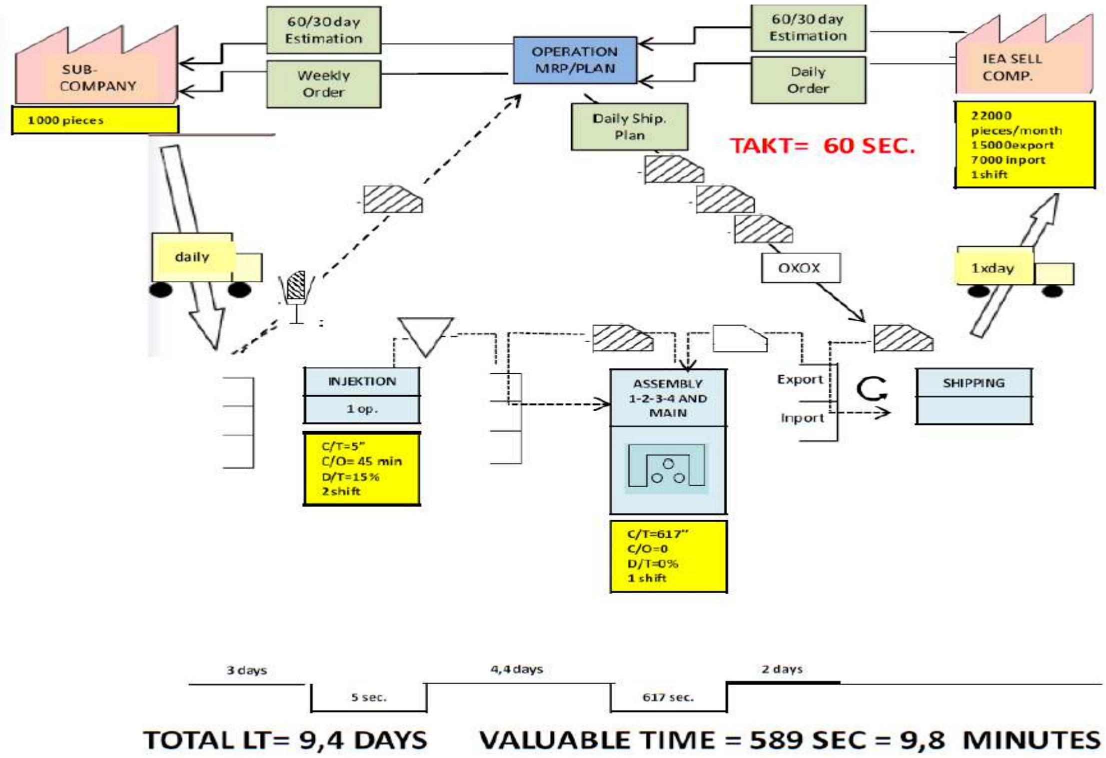

Figure 4. Future state value stream mapping

Figure 5. Situation of workshop area, a) Before application, b) After application

Figure 6. Redundant manufacturing line

References

[1] Krajewski, L. J., Ritzman, L. P., Malhotra, M. K., *Operations Management: Processes and Supply Chains*, Ninth Edition, Prentice Hall, USA, 2010.

[2] Shah, R., Ward, P., *"Defining and Developing Measures of Lean Production"*, Journal of Operations Management, Vol. 24, No. 4, pp. 785-805, 2007.

[3] Seth, D., Gupta, V., *"Application of value stream mapping for lean operations and cycle time reduction: An Indian case study"*, Production Planning & Control, Vol. 16, No. 1, pp. 44-59, 2005.

[4] Ar, R., Ashraf, M. A., *"Production flow analysis through Value Stream Mapping: A Lean manufacturing process case study"*, Procedia Engineering, Vol. 41, pp. 1727-1734, 2012.

[5] Abdulmalek, F. A. Rajgopal, J. *"Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study"*, International Journal Production Economics, Vol. 107, pp. 223-236, 2007.

[6] Rother, M., Shook, J., *Learning to see: Value STREAM Mapping to add value and eliminate muda*, Version 1.4, The Lean Enterprise Institute, USA, 2009.

[7] Hines, P., Rich, N., Esain, A., *"Value stream mapping:A distribution industry application"*, Benchmarking: An International Journal, Vol. 6, No. 1, pp. 60-77, 1999.

[8] Brunt, D., *"From current state to future state: mapping the steel to component supply chain"*, International Journal of Logistics: Research and Applications, Vol. 3, No. 3, pp. 259-271, 2000.

[9] Seth, D., Seth, N., Goel, D., *"Application of value stream mapping(VSM) for minimization of wastes in the processing side of supply chain of cottonseed oil industry in Indian context"*, Journal of Manufacturing Technology Management, Vol. 19, No. 4, pp. 528-550, 2008.

[10] Singh, B., Sharma, S.K., *"Value stream mapping as a versatile tool for lean implementation: An Indian case study of a manufacturing firm"*, Measuring Business Excellence, Vol. 13, No. 3, pp. 58-68, 2009.

[11] Vinodh, S., Arvind, K. R., Somanaathan, M., *"Application of value stream mapping in an Indian camshaft manufacturing organisation"*, Journal of Manufacturing Technology Management, Vol. 21, No. 7, pp. 888-900, 2010.

[12] Chen, J. C., Li, Y., Shady, B. D., *"From value stream mapping toward a lean/sigma continuous improvement process: an industrial case study"*, International Journal of Production Research, Vol. 48, No. 4, pp. 1069-1086, 2010.

[13] Chowdary, B. V., George, D., *"Improvement of manufacturing operations at a pharmaceutical company: A lean manufacturing approach"*, Journal of Manufacturing Technology Management, Vol. 23, No. 1, pp. 56 -75, 2012.

[14] Li, H., Cao, H., Pan, X.,*"A carbon emission analysis model for electronics manufacturing process based on value-stream mapping and sensitivity analysis"*, International Journal of Computer Integrated Manufacturing, Vol. 25, No. 12, pp. 1102-1110, 2012.

[15] Teichgräber, U. K., Bucourt, M. D., *"Applying value stream mapping techniques to eliminate non-value-added waste for the procurement of endovascular stents"*. European Journal of Radiology, Vol. 81, pp. 47-52, 2012.

[16] Xie, Y., Peng, Q., *"Integration of value stream mapping and agent-based modeling for OR improvement"*, Business Process Management Journal, Vol. 18, No. 4, pp. 585-599, 2012.

[17] Wee, H. M., Wu, S., *"Lean supply chain and its effect on product cost and quality: a case study on Ford Motor Company"*, Supply Chain Management: An International Journal, Vol. 14, No. 5, pp. 335-341, 2009.

[18] Başer, H., *"Lean manufacturing, value stream mapping: A case study in a production company"*, MSc Thesis, Fatih University, 2011.

[19] Chitturi, R. M., Glew, D.J., Paulls, A., *"Value stream mapping in a jobshop"*, IET Conference Publications", International Conference on Agile Manufacturing (ICAM 2007). Durham, UK, pp. 142-147, 2007.

[20] Lian, H., Landeghem, H., *"Analysing the effects of lean manufacturing using a value stream mapping-based simulation generator"*, International Journal of Production Research, Vol. 45, No. 13, 3037-3058, 2007.

[21] Nash, M. A., Poling S. R., *Mapping the total value stream: A comprehensive guide for production and transactional processes*. Taylor & Francis Group, USA, 2008.