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Enhancing Efficiency in Footwear Manufacturing: Reducing Pre-Production Lead Time through Value Stream Mapping and the Cut-to-Box System

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Abstract*— This article presents a comprehensive study on enhancing efficiency in footwear manufacturing through the implementation of Value Stream Mapping (VSM) and the innovative Cut-to-Box system. The case study focuses on a Footwear Company, a four-floor factory in Istanbul, Turkey. The current state of pre-production processes is analyzed using time metrics, contributing to the design and implementation of a future value stream mapping system. The newly introduced Cut-to-Box system revolutionizes the traditional production line, streamlining warehouse operations. The study evaluates the challenges faced by the existing system. The Cut-to-Box system is assessed for its transformative impact on lead time using VSM. The results indicate a significant improvement in overall efficiency, with a reduction in lead time, process time, changeover time, transfer time, and waiting time. It concludes by emphasizing the importance of continuous analysis and optimization for maintaining competitiveness and delivering high-quality products on time.

Index Terms*— Footwear manufacturing, Value Stream Mapping, Cut-to-Box system, Efficiency improvement.

I. INTRODUCTION

The global footwear industry has witnessed a paradigm shift in recent years. As consumers demand quality, variety, and timely delivery, production processes are being optimized. A footwear manufacturing, based in Turkey, has taken a proactive approach to addressing inefficiencies in its pre-production stage. This is where the focus is on creating a production sample before mass manufacturing.

Traditional pre-production processes involve multiple departments, each contributing to lead times. This article highlights the processing time, waiting time, and transfer time of various departments. Taking advantage of the innovative Cut-to-Box approach, we propose and implement a future value stream mapping system.

Cut-to-Box introduces a cellular manufacturing layout within the warehouse, optimizing departmental workflow. This layout, characterized by a U-shaped conveyor system, minimizes transportation and waiting times, fostering a seamless transition from the cutting department to stitching and assembly lines, packing and shipping to the customer.

The article explores Value Stream Mapping to pinpoint inefficiencies. It assesses the transformative impact of the Cut-to-Box system on lead time.

The intervention has been overwhelmingly positive. This includes substantial improvements in lead time from 21.43 days to 16.79 days, process time, changeover time, transfer time, waiting time, and a notable reduction in required personnel. The article concludes by emphasizing the importance of continuous analysis and optimization for companies to remain competitive in the footwear industry.

II. LITERATURE REVIEW

Efficiency is a key component of footwear manufacturing, directly affecting the industry's ability to meet the growing demand for customized and fast-paced products [1]. The term value stream was first used by Womack, Jones and Roos in their 1990 book The Machine That Changed the World, and by Womack and Jones in their 1996 book Lean Thinking. According to Martin and Osterling, value stream mapping reduces operational waste. In addition to transforming leadership thinking and defining strategy and priorities, value stream mapping can ensure that customers receive high levels of value. Value stream mapping has been discussed in the manufacturing environment since Toyota Motor Corporation used it [2]. In addition, researchers describe VSM as a method for visualizing the flow of information and objects. From human resources to data flow, it visualizes the time sequence for every stage of the supply chain. During the manufacturing process, VSM identifies and processes value-added activities to reduce non-value-added [3]. A value-added action is an activity or step in a process that contributes directly to meeting customer requirements and specifications. In other words, these are activities that the customer is willing to pay for to improve the product's form, fit, or function. The term non-value-added action refers to actions that do not contribute to the product's value from the perspective of the customer. Despite consuming resources, these activities do not improve the quality or functionality of the product [4]. Lead time measures the time between the initiation and completion of a process. It directly affects productivity. Producing more output in a short time period adds more value. From order to delivery, a value stream map

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provides a good overview.[5] Pre-production or prototyping is a very critical stage of new product development, where many decisions have to be made to get high-quality, zero-defect products on time at the lowest cost. As a result, any value-added prototyping improvements will increase manufacturers' competitiveness. It aims to benchmark best practices in prototype part manufacture to support early product introduction. [6]. Also, a similar study was conducted in Bangladesh to reduce lead time by utilizing lean tools such as Value Stream Mapping (VSM), Process Cycle Efficiency (PCE) and Pareto [7]. According to researchers' knowledge, a comprehensive review of the existing literature reveals that there are no studies specifically addressing the "Cut-to-Box" system in footwear manufacturing. This observation underscores the innovative nature of our research, positioned at the forefront of advancements in operational efficiency within the industry. In this paper, VSM is applied to enhance efficiency in footwear manufacturing by reducing waste and non-value-added activities, and a new concept of cut-to-box is proposed for the pre-production phase.

III. METHODOLOGY

Value stream is a complete group of some performance containing value added and non-value added actions. VSM is regarded as the flow of products that is initiated by the raw material and ending by consumer. VSM aims to reduce waste by reorganizing all types of waste in the value stream. The footwear industry in this study was the population, and its court shoe production line was the sample. Based on the researcher's observations of a leading export-oriented footwear industry in Turkey at the pre-production stage, the primary data was collected. A stopwatch was used to record the observed time. Every stage of the production line was observed for cycle time, changeover time, processing time, transferring time, waiting time, lead time, and material and labor flow. The factory has a 10-hour shift on a five-day workweek. In addition, each workday includes a *one-hour* break, and the factory works *20* days each month. The factory's total monthly working hours are 200 hours, and its net monthly available working hours are *180 hours* after deducting rest hours.

The *cycle time* is the amount of time required to complete the production of one unit (in this case, a pair of footwear). A *changeover time* refers to the period of time spent in transitioning from one type of production to another. The *batch quantity* is the number of pairs of shoes needed for preproduction and shipping to the customer, which in this study equals *200* pairs. The processing time is the total amount of time required to complete a particular task or operation, which consists of both cycle time and change over time.

Processing Time= (Cycle Time of 200 pairs) + Changeover Time *(1)*

Lead time in this study refers to the comprehensive period of time required for a product to progress through different stages. The process begins with the initiation of a customer order and ends with the completion and delivery of a sample production. In general, this entails processing times, waiting times, and transfer times associated with tasks such as placing orders and procuring materials, planning, quality control, laminating, cutting, stitching, assembling, and completing final quality checks prior to packaging and shipment. The waiting time is the period during which materials or products do not undergo processing or are inactive. Transferring time represents the time taken to move materials or products between different stages or locations within the manufacturing process.

Lead Time= Processing Time + waiting Time + Transferring Time *(2)*

A pre-production stage is started by the footwear company before mass production begins with 200 pairs of shoes produced to better understand the entire process. Pre-production consists of the following stages in Fig. (1):

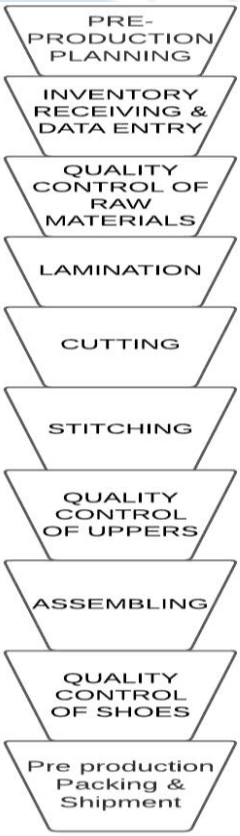

Fig. 1 PRE-*PRODUCTION STAGE*

Current Value Stream mapping Stages:

Step I- On-Site Data Collection: Utilizing stopwatches, we conducted a floor-by-floor analysis of the Footwear Company's pre-production processes, capturing cycle times, changeover times, transferring times, and waiting times.

Step II- Quantitative analysis: We calculated key metrics for each department, generating Table I as a reference for total cycle time, changeover time, transferring time, and waiting time.

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Table I. Pre-production time measurements Current State

PRE-PRODUCTION STAGES	CYCLE TIME(200 PAIRS)(HOUR)	CHANGE OVER TIME (HOUR)	PROCESSING TIME (HOUR)	TRANSFERING TIME (HOUR)	WAITING TIME (HOUR)	LEAD TIME IN DAYS	VAUE-ADDED-TIMES (HOUR)	NON-VALUE ADDED - TIMES (HOUR)
PRE- PRODUCTION PLANNING	2.5	0.42	2.92	0.50	1.53	0.55	2.5	2.5
INVENTORY RECEIVING & DATA ENTRY	6.3	0.97	7.30	6.92	2.80	1.89	6.3	10.7
QUALITY CONTROL OF RAW	4.7	0.77	5.43	2.00	2.43	1.10	4.7	5.2
LAMINATION	1.9	0.80	2.72	1.70	1.48	0.66	1.9	4.0
CUTTING	13.3	0.68	14.02	3.42	2.82	2.25	13.3	6.9
STITCHING	50.0	0.60	50.60	3.25	6.12	6.66	50.0	10.0
QUALITY CONTROL OF UPPERS	3.3	0.42	3.75	1.43	0.42	0.62	3.3	2.3
ASSEMBLING	40.0	0.63	40.63	2.47	4.75	5.32	40.0	7.9
QUALITY CONTROL OF SHOES	10.0	0.47	10.47	0.92	0.60	1.33	10.0	2.0
PRE PRODUCTION PACKING & SHIPMENT	6.7	0.58	7.25	1.10	1.12	1.05	6.7	2.8
TOTAL	138.8	6.3	145.1	23.7	24.1	21.4	138.8	54.1

Step III- *Visual representation*:

Fig. 2 illustrates the current value stream mapping, offering a visual overview of sequential activities and their corresponding time metrics across all four floor.

Step IV- *Analyzing the challenges in the current situation:* The current value stream mapping of this footwear company's pre-production process revealed several significant inefficiencies and challenges. There were prolonged lead times, substantial waiting periods, and excessive material transfers between floors and departments in the linear production line. Inefficiencies led to bottlenecks, longer cycle times, and higher error rates. The production floor layout also contributed to logistical challenges, requiring materials to traverse multiple floors, increasing handling times and transportation delays. Cut-to-Box was implemented to streamline and optimize this convoluted workflow. With a U-shaped conveyor layout, the Cut-to-Box system sought to minimize unnecessary material movements, reduce waiting times, and foster a more efficient and lean pre-production process. In the dynamic footwear manufacturing industry, this approach was driven by a desire to enhance operational flow, decrease lead times, and ultimately improve competitiveness.

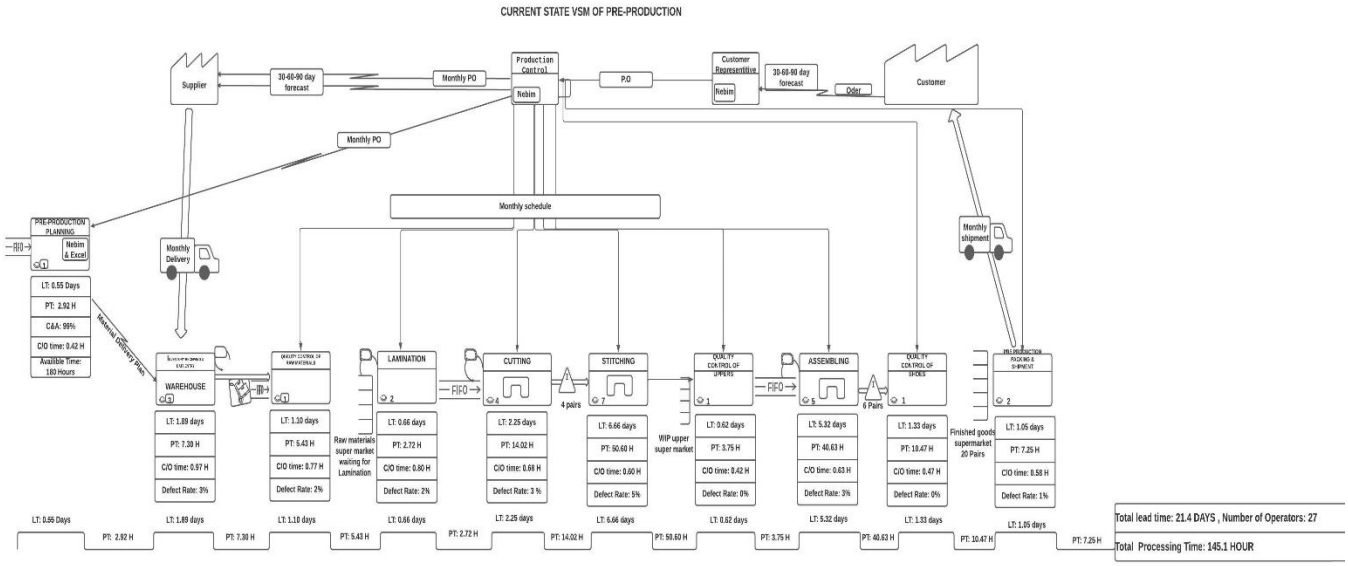

Fig. 2 Current Value Stream Map for Pre-Production

Future Value Stream Mapping:

Our proposal advocates a strategic departure from the current four-floor production line at the footwear factory. We favor a consolidated warehouse environment augmented by the Cut-to-Box cellular manufacturing system. This transformative initiative involves the meticulous arrangement of departments, the introduction of a U-shaped conveyor layout, and the streamlining of material transitions. Fig. 3 visually articulates the harmonized workflow envisioned in this reimagined state. Anticipated outcomes include a significant reduction in lead time, cycle time, changeover time, transferring time, and waiting time. This is detailed in Table II. This strategic move not only addresses existing challenges but positions the footwear factory as a trailblazer in operational excellence within the competitive footwear manufacturing industry. This is evidenced by the tangible results derived from our future value stream mapping.

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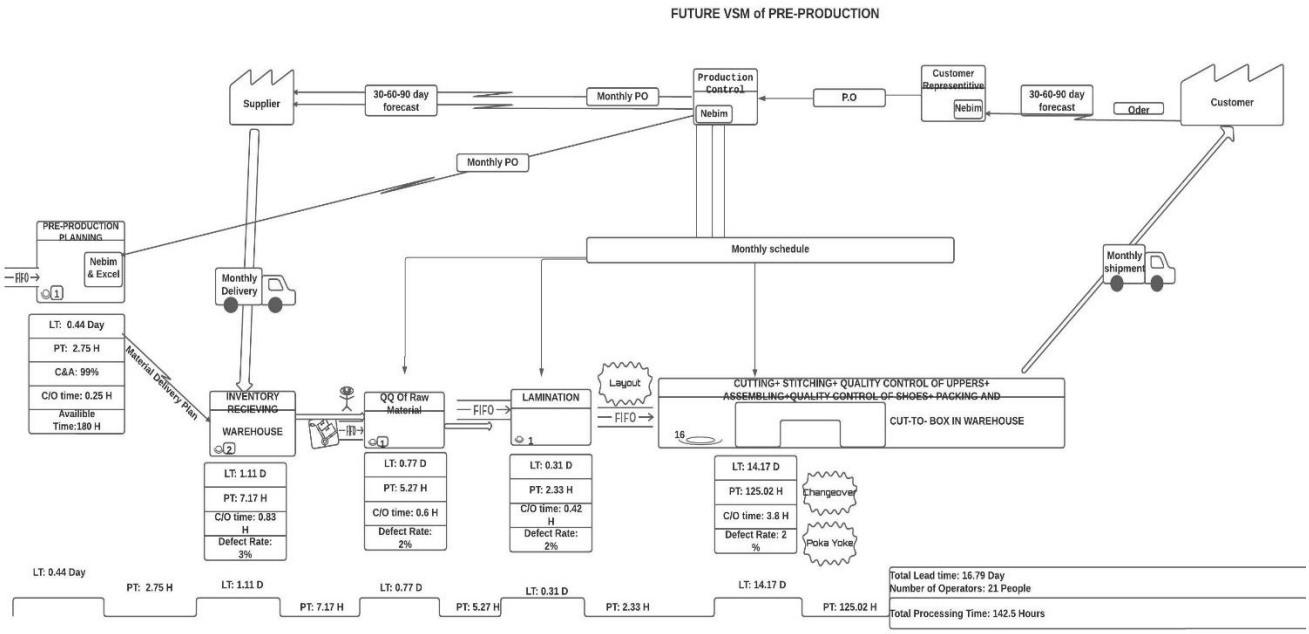

Fig. 3 Future Value Stream Map for Pre-Production

Table II. Pre-production time measurements Future State

PRE-PRODUCTION STAGES	CYCLE TIME(200 PAIRS)(HOUR)	CHANGE OVER TIME (HOUR)	PROCESSING TIME (HOUR)	TRANSFERING TIME (HOUR)	WAITING TIME (HOUR)	LEAD TIME IN DAYS	VAUE-ADDED-TIMES (HOUR)	NON-VALUE-ADDED - TIMES (HOUR)
PRE- PRODUCTION PLANNING	2.50	0.25	2.75	0.50	0.67	0.44	2.5	1.4
INVENTORY RECEIVING & DATA	6.33	0.83	7.17	1.72	1.08	1.11	6.3	3.6
QUALITY CONTROL OF RAW MATERIALS	4.67	0.60	5.27	1.03	0.60	0.77	4.7	2.2
LAMINATION	1.92	0.42	2.33	0.27	0.23	0.31	1.9	0.9
CUTTING	13.33	0.53	13.87	0.57	0.53	1.66	13.3	1.6
STITCHING	50.00	0.30	50.30	0.00	0.28	5.62	50.0	0.6
QUALITY CONTROL OF UPPERS	3.33	0.17	3.50	0.08	0.15	0.41	3.3	0.4
ASSEMBLING	40.00	0.40	40.40	0.13	0.35	4.54	40.0	0.9
QUALITY CONTROL OF SHOES	10.00	0.13	10.13	0.07	0.10	1.14	10.0	0.3
PRE PRODUCTION PACKING & SHIPMENT	6.67	0.15	6.82	0.08	0.17	0.79	6.7	0.4
CUT-TO-BOX TOTAL	123.33	1.68	125.02	0.93	1.58	14.17	123.33	4.20
TOTAL	138.8	3.8	142.5	4.5	4.2	16.79	138.8	12.4

IV. RESULTS AND DISCUSSION

The comparative analysis between the traditional four-floor pre-production system and the newly implemented Cut-to-Box system with U-shaped conveyors reveals a transformative impact on key metrics, substantiating the efficacy of the strategic shift.

1. Lead Time Reduction:

The implementation of the Cut-to-Box system has resulted in a substantial reduction in lead time, decreasing from 192.85 hours to *151.15 hours* (*21.43* working days to *16.79* working days). This equates to a remarkable *21.62%* decrease in lead time, enhancing the company's ability to respond faster to customer orders.

2. Waiting Time and Transfer Time:

Total waiting time has decreased drastically, plummeting from 24.07 hours to *4.17* hours, an impressive 82.68% improvement. Simultaneously, transferring time has been reduced from 23.70 hours to 4.45 hours, reflecting an *81.22%* decrease. These reductions underscore the streamlined material flow and minimized delays facilitated by the Cut-to-Box system.

3. Changeover Time and Processing Time:

Changeover times have notably decreased from 6.33 hours to 3.78 hours, indicating a 40.26% reduction. This reduction is emblematic of enhanced efficiency in transitioning between production phases. Additionally, processing time has been trimmed by 1.75%, contributing to overall time savings during pre-production.

4. Resource Utilization:

The number of required personnel for the pre-production process has seen a significant decrease, dropping from *27* people to *21* people. This *22.22%* reduction in workforce aligns with operational efficiency goals but also contributes to cost-effectiveness.

5. Operational Efficiency and Quality improvement:

The accrued reductions in lead time, waiting time, transferring time, changeover time, and workforce requirements attest to the operational efficiency gains realized through the implementation of the Cut-to-Box system. The newly implemented Cut-to-Box system not only enhances operational efficiency but also positively influences product quality through centralized and streamlined workflow, ensuring meticulous monitoring at each pre-production stage. A visual representation of the transformational impact of the Cut-to-Box system on the footwear company's pre-production processes can be found in Fig. 4 and a quantitative analysis can be found in Table III.

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Based on this comparative analysis, we can clearly see the stark differences between the traditional four-floor production system and the innovative Cut-to-Box system with U-shaped conveyors.

Table III. Quantitative Comparison

METRIC	TRADITIONAL SYSTEM	CUT-TO-BOX SYSTEM	REDUCTION (%)
TOTAL LEAD TIME	192.85	151.15	21.62
TOTAL PROCESS TIME	145.08	142.53	1.76
CHANGE OVER TIME	6.33	3.78	40.26
TRANSFERING TIME	23.70	4.45	81.22
WAITING TIME	24.07	4.17	82.69
NUMBER OF PEOPLE	27	21	22.22

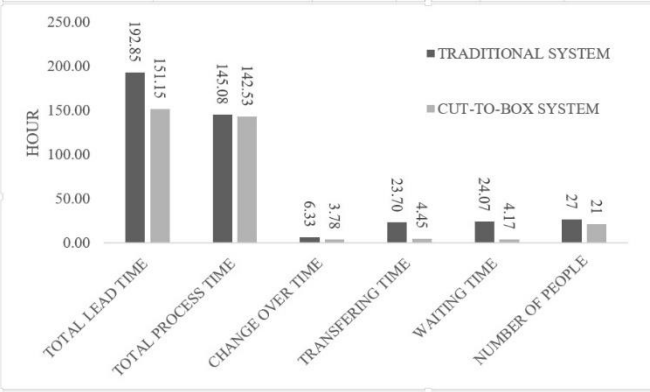

Fig. 4 Comparative analysis of traditional and new system

V. FUTURE WORK

As we delve into future discussions, the associated cost savings and increased efficiency will be integral considerations for the Footwear Company's sustained competitiveness in the industry.

In summary, the comprehensive data comparison underscores the tangible benefits of the Cut-to-Box system, positioning the footwear company for heightened efficiency, reduced lead times, and increased competitiveness in the dynamic landscape of footwear manufacturing. The observed improvements not only validate the strategic shift but also lay the foundation for continued operational excellence.

REFERENCES

[1] J. Aminata and S. Grandval, "Energy efficiency in production process: A case of footwear trade development," *Bus. Manag. Rev.*, vol. 4, no. October 2015, pp. 104–113, 2014.

[2] A. H. Chowdhury, S. Shahriar, T. Hossen, and P. Mahmud, "Reduction of Process Lead Time Using Lean Tool - Value Stream Mapping (VSM)," *Appl. Mech. Mater.*, vol. 860, pp. 74–80, 2016, doi: 10.4028/www.scientific.net/amm.860.74.

[3] Z. S. Mojib, A. Hashemi, A. A. Abdi, A. Shahpanah, and J. M. Rohani, "Lean Manufacturing Implementation Through Value Stream Mapping : A Case Study . Jurnal Teknologi Full paper Lean Manufacturing Implementation Through Value Stream Mapping : A," *J. Teknol.*, vol. 3, no. eISSN 2180-3722, pp. 119–124, 2014.

[4] K. C. Ng, C. P. Lim, K. E. Chong, and G. G. G. Goh, "Elimination of waste through value Add/Non value add process analysis to improve cost productivity in manufacturing - A case study," *IEEE Int. Conf. Ind. Eng. Eng. Manag.*, pp. 410–414, 2014, doi: 10.1109/IEEM.2013.6962444.

[5] A. S. Patil, M. V Pisal, and C. T. Suryavanshi, "Journal of Applied Research and Technology," vol. 19, pp. 11–22, 2021.

[6] D. T. Safarov, A. G. Kondrashov, and I. I. Khafizov, "Improving the process efficiency of helical gears' toothed rims at the stage of pre-production," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 570, no. 1, 2019, doi: 10.1088/1757-899X/570/1/012082.

[7] C. Science, "Footwear Industry in Bangladesh: Reduction of Lead time by using Lean Tools," *J. Environ. Sci. Comput. Sci. Eng. Technol.*, vol. 6, no. 3, 2017, doi: 10.24214/jecet.c.6.3.25159.