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Adopting Value Stream Mapping as a Lean Tool to Improve Production Performance

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HIGHLIGHTS

- Simulate and improve practical production line performance using Value Stream Mapping (VSM) as the most essential Lean tool.
- Eliminate waste by focusing on the Value Added Activities and reducing Non Adding Value activities (NVA) by 90%.
- Reducing Work in Process (WIP) Inventory to improve the performance for the flow of material.
- Reducing lead time by 88% using hybrid push/pull strategies and Kanban production to improve the production line.
- The implementation of lean tools is successful in improving the leather factory.

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ABSTRACT

The main challenge facing industrial companies is how to stay competitive in a fast changing world. They should adopt an effective supply chain that enables them to deliver products in a short period of time. This forced organization to change their pattern of processing and become lean. Lean manufacturing system is the best philosophy to achieve the objectives of the industrial organizations and to reduce the waste activities. The unnecessary movement, defective, waiting, inadequate processing, unnecessary inventory, excessive transport, overproduction, and the underutilization of people and facilities are the most types of waste found in the industries. Many industries have experienced the benefits of applying the lean concept in their area to improve the production processes, resources utilization, reduce production lead time, and eliminate wastes in the activities which is the goal of lean concept in the manufacturing industry. In this research, the lean concepts are presented in the leather shoes manufacturing industry in the city of Baghdad, it aimed to decrease the lead time of production, minimize the non-value time, and improve the production line. By using the most essential lean tool, value stream mapping, where the current and future map capture the flow of material and information of the production line before and after the implementation of the proposed improvement. The hybrid push/pull strategies and Kanban production were implemented to improve the production line. After adopting the suggested improvement, the production lead time reduced from 130.6 to 14.8 hours and the non-value added reduced from 118 to 10.8 minutes.

1. Introduction

Lean manufacturing is a production systems philosophy that when properly integrated and implemented can reduce the waste in the activity of the production line. There are two types of value in the process of manufacturing, the value-added activities in which the customer can pay for the service or product, and the non-value added (NVA) activities that do not add value to the service or product. Some of the non-value activities are necessary but they still take up time and increase the cost and they should be minimized, and by using different types of lean tools in the manufacturing industry, all the wastes can be minimized [1]. As a result of the increasingly evolving market environment, organizations, whether manufacturing or service, are being challenged to address obstacles and difficulties; where each organization needs to respond to changes, therefore the principle of lean manufacturing was created to maximize the resource utilization by waste eliminating [2]. Delia [3] illustrated that the adoption of the Lean Production principles will improve the entire production process and increase the performance of the business, where the elimination of the waste will lead to reduce the cost and increase the customer satisfaction.

The most essential lean manufacturing tool is the value stream mapping (VSM) that has been successfully implemented, it will cause a reduction in the total lead time which has been proven through several scientific researches [4]. VSM is a graphical representation of the material and information flow in a manufacturing system. The map depicts the all steps in the process, beginning with the purchase of raw materials and finishing with the delivery of manufactured product to the customer [5]. VSM can be classified into two kinds, current state map (CSM) revealing the present configuration of the product and using special symbols and terminology to identify the wastes and places for improvement, and after identifying and eliminating the waste, a Future State Map (FSM) is a plan for the desired lean transformation in the future [6]. To improve the production,

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the cycle time of all the operations must be identified and measured, where the cycle time refers to the time the product takes in the operation of the production or assembly system from the start to the end [7]. In addition to the cycle time, takt time is another important time in the manufacturing system which is related to the maximum time that the product must be produced within it to meet the customer demand, daily or monthly demand. When the process cycle time is more than the takt time, the situation is identified as a bottleneck process in the production line because it cannot meet the customer demand, and in lean manufacturing, this bottleneck process must be minimized as possible [2]. Lead time is one of the most important metrics that is used to analyze the overall time spending to deliver the products to the consumer from the day the order has been placed [8]. Reduced manufacturing lead times can result in a variety of advantages, including decreased work-in-process and finished goods inventories, reduced costs, and increased productivity. They can also enhance the flexibility and minimize the time it takes to respond to customer orders [9]. A hybrid production control strategy has several workstations, some of which operate under a push system and others under a pull system. The hybrid strategy can help companies achieve better results than their applications. The choosing of a push/pull method is determined by the nature of the production line [10]. The implementation of some lean tools in the batch type manufacturing industry has a positive impact on the productivity of the system, where the defectives rate has decreased as a result of the use of lean tools [11].

Many researches used VSM as a lean tool to improve the production, Ghushe et al. [12] used Lean manufacturing tools, Value stream mapping, Kaizen, Poka-Yoke to improve the processes cycle time in the Coir product manufacturing industry. Integration of these tools led to reduce the total lead time, process time, and inventory time. Surabhi and Vinod [8] suggested using Lean Concepts and tools in pump manufacturing to deal with many production problems, like absence of inventory classification, increase in lead time, and disorganized storage area. The lead time was reduced by using VSM and selective inventory control approach for classification inventory, where the lead time reduction was from 61.64 hrs. to 44.773 hrs. Suganthini et al. [13] stated the implementation of lean tools by identifying the non-value activity and the bottleneck station using a value stream mapping to explain the current situation and 5S to minimize the excessive man and material motions, leading to increase the productivity of the water pump pipe by reducing the cycle time. Saboo et al. [14] applied the lean manufacturing VSM approach and pull system in Indian industry to improve their operations, and this application resulted in a reduction in the inventory, total production lead time, changeover time, and improved the quality. Kathem et al. [15] adopted lean manufacturing tools to improve the shoe manufacturing industry, where the bottleneck operations were found and analyzed by using the Yamazumi chart. Arena simulation software was used to validate the productivity of the shoes before and after the implementation of the proposed improvement. The suggested improvement resulted in increasing the productivity, reducing the non-value added time, and reducing the total cycle time of the production. Orynycz et al. [16] focused on decreasing production time, operation cycle time, wastes of raw material, and increasing of work efficiency, where achieved by the implementation of lean manufacturing tools as 5S, Value stream mapping, and Kaizen lean management to reduce the energy consumption.Gezahegn et al. [10] discussed the strengths and weaknesses of applying push and pull systems in the footwear production system. The hybrid push/pull valuable strategies were designed to cope with the characteristics of the production system; the high inventories, long lead time, uncertain raw material supply, and poor productivity.Punna Rao et al. [17] used time study, VSM, and flexsim simulation software to enhance the productivity. The current state VSM identified the value added, non-value-added activities, and wastes in the transportation. The transportation, waiting, and inventory wastes were reduced in the development of the future state VSM. Nallusamy [18] found the ability of implementing VSM in a broad base of observation in industry. VSM was developed to identify the activities that did not add value to the product, and by eliminating these wastes, the manufacturing process had a reduction in the lead time and an increasing throughput rate. Nallusamy [19] focused on finding the bottlenecks in the production line in order to eliminate the overall lead time. The bottleneck stations were clarified by drawing the current VSM. The TAKT time was calculated based on the time study results. The flexible line balancing software was used in the assembly line, and the future VSM was drawn after the implementation of some lean techniques, such as fish bone, layout optimization and Pareto chart. The results showed a reduction in the lead time and value added time. Sobya et al. [20] used different lean manufacturing tools to eliminate the cycle time and the value added time, by identifying the cycle time and the bottleneck stations. The line balancing was used to found the bottleneck processes, for effective housekeeping the 5S was implemented, also the layout of the industry was modified to the best alternative by using simulation. In this research, the lean concepts are adopted in the leather shoes manufacturing industry in the city of Baghdad as a different case study that requires improving, aiming to decrease the lead time of production, minimize the non-value time, and improve the production line. The leather shoes manufacturing industry is suffering from low production rates and low competitiveness.

2. The Research Methodology

In this research, Lean concepts are adopted in a real world case study. The methodology of the research is divided into two divisions. The first one clarifies the current state of the production line and the second one show the state of the production line after improving the performance of the production line. Seven stages are used to carry out the two parts of the research methodology. After product selection the second stage involves data are collected related to cycle time, working time per day, total production unit, number of workers, lead time, and process sequence using many various data collecting techniques. The third stage is constructing the current state value stream mapping of the manufacturing operation to explain and clarify the added and non- added value activities. In the fourth stage analysis for the current state is conducted. In the fifth stage the proposed improvement depending lean tools will be implemented in the production line. In the sixth stage, the future value stream map is drawn and new data is recorded in the map. In the last stage an implementing of the proposed improvement to utilize of resources and comparison is made between the current and future state of the production line to identify the amount and percentage improvement. The block diagram for this study is shown in Figure 1.

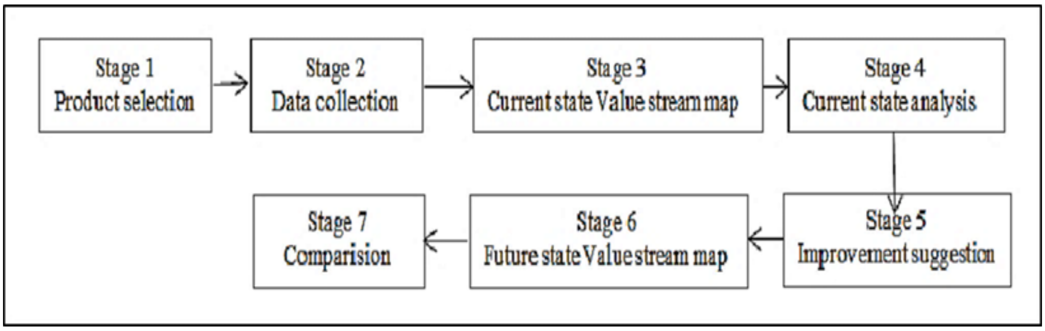


Figure 1: The research methodology

3. Implementation of the Research Methodology

The proposed approach has been validated through a case study in the State Company for Textile and Leather Industries with the focus on the selected factory which is the men's leather shoe factory 7 (MLSF 7). The factory produces various types of civilian and military leather shoes and occupational safety shoes in various models, colours, and sizes. Its products are distinguished by that they are made of natural leather, which is cowhide, with specifications approved by the Central Agency for Assessment and Quality Control. The manufacturing system that is used in this factory is made according to the forecast demand of customers and the demand of the Iraqi markets. The MLSF 7 industry is willing to minimize their production lead time and eliminate the non-value added time, also reorganizing the number of operators in the factory in order to improve the production line. The stages implementation are as follows:

3.1 Selection of The Product

The shoe model (77220) that is considered one of the most standard models with a high demand has been selected to implement the proposed methodology of the research, as evinced in Figure 2.

Figure 2: The model of man shoes

3.2 Collecting The Data

The data collected in this research depends on interviews with the production manager of the industry, time management department, planning department, in addition to monitoring the production line and using the reports.

MLSF 7 works for one shift per day, and the available time in the shift is 7 hours (420 minutes), including a 30-minute lunch break, and the factory works for 20 days per month. The cycle time of operations in each stage was calculated and recorded through the observation. The production line is classified into four production stages namely; cutting and preparation, sewing, lasting, painting and packaging, Figure 3 manifests these production stages. As shown in Table 1, the process flow is described with the cycle time of the batch, the details about the production stages, work sequence, number of operators, and cycle time, as well as classifying operations into added value (VA) if the operation transits the raw material to finished product or necessary but non-added value (NNVA) for the support operation.

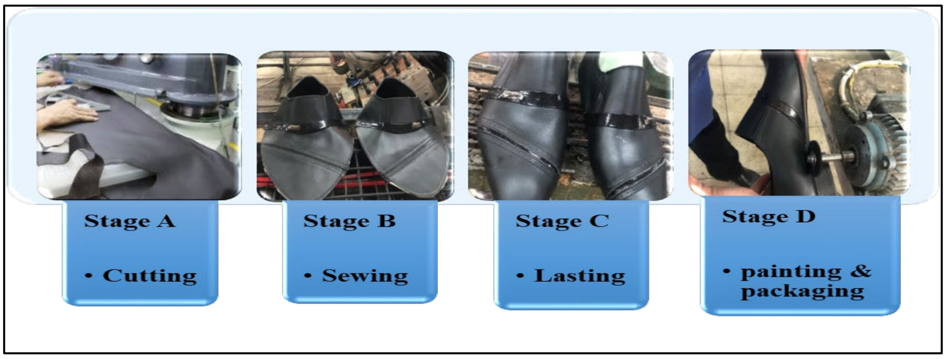


Figure 3: The man shoe production stages

Table 1: The processes chart of the shoe production line

No.	Symbols: Operation	Symbols: Transfer	Symbols: Inspection	Symbols: Delay	Symbols: Storage	The Description of the Operation	Cycle time of 1 pair of shoes (second)	Number of workers	VA \N NVA
1			■			Inspection the raw material in stage A	60	1	NNVA
2	●					Leather cut	96	1	VA
3	●					Cut linen and elastic	48	1	VA
4	●					Reducing the thickness of one side for sewing	60	1	NNVA
5	●					put a mark to facilitate sewing	48	2	NNVA
6	●					Put a gluing to the tongue of the shoe and Folded up	60	1	VA
		➡				Transferring to stage B for sewing			
7	●					Shoe face perforation	84	1	VA
8	●					Shoe face engraving	108	1	NNVA
9	●					Stitching the two side pieces together and then with the shoe face and Cut off the appendages after Stitching and Reducing the thickness of the two side pieces Manually	96	1	VA
10	●					Sewing pull tab of the shoe	60	1	VA
11	●					Gluing the side pieces of the shoe and folded up	60	1	VA
12	●					Glue and paste the inside linen piece and Toecap and Cut the appendages	72	2	VA
13	●					Glue and paste the elastic	48	1	VA
14	●					sewing of the parts together	84	2	VA
15	●					Gluing the piece that contains the size and branding of the shoe	72	1	NNVA
16	●					Edge engraving, two side engraving, and elastic reinforcement	120	2	NNVA
17	●					Clean the thread	48	1	NNVA
		➡				Transferring to stage C for lasting			
18	●					Fixing the base on the template, gluing and strengthening the back of the shoe with a strong piece	60	1	NNVA
19	●					Hot and cold back part molding machine	120	1	NNVA
20	●					Gluing all inner edges and the base	180	1	NNVA
21	●					toe lasting	60	1	VA
22	●					Heel seat and sides lasting	120	1	VA
23	●					Smoothing the corners and thermally modifying the face	144	2	NNVA
24	●					Roughen the base	144	1	NNVA
25	●					Gluing shoe and sole	180	2	NNVA
26	●					Convection Oven	180	1	NNVA
27	●					Air Compressor	120	1	VA
28	●					Chiller the Shoe in the oven	120	1	NNVA
29	●					Take off the last	60	1	VA
		➡				Transferring to stage D finishing			
30	●					Removing the excess glue	120	1	NNVA
31	●					Finishing (polish and dye)	60	1	VA
32			■			Quality control	60	2	NNVA
33	●					Packaging	80	1	VA
		➡				Transportation to the depot			

The system of work in the factory is a batch production; the batch size of the work is 15 pairs of shoes. The calculation of the batch cycle time of the operations is:

$C/T_{batch} = B_S \times C/T_{operation}$
C/T_{batch} = The batch cycle time of operation
B_S = The batch size
Table 2 shows the cycle time of the batch calculation for each production stage.

Table 2: The batch operations cycle time

No.	The Operations Names	The Cycle Time of the Batch (15 pair/minute)
1	Inspection the raw material	15
2	Cutting leather	24
3	Cutting 2	12
4	Reducing the thickness	15
5	Marking	12
6	Gluing 1	15
7	Perforation	21
8	Engraving 1	27
9	Stitching	24
10	Sewing 1	15
11	Gluing 2 and folded up	15
12	Gluing 3 and paste	18
13	Gluing 4 and paste	12
14	Sewing 2	21
15	Gluing 5	18
16	Engraving 2	30
17	Cleaning 1	12
18	Fixing	15
19	Molding	30
20	Gluing 6	45
21	Toe lasting	15
22	Lasting	30
23	Smoothing	36
24	Roughing	36
25	Gluing 7	45
26	Convection oven	45
27	Air compressor	30
28	Chillier oven	30
29	Extraction	15
30	Cleaning 2	30
31	Dyeing and polishing	15
32	Shoes final inspection	15
33	Packaging	20

3.3 Creating The Current State Value Stream Mapping

Mapping the current state is a powerful tool to analyze and identify the waste in the production line. The all information and data related to the product manufacturing are recorded on the map. The current state map starting from the arrival of raw leather from the warehouse until the end of the manufacturing processes and delivering the shoes to the customers is displayed in Figure 4.

3.4 Analysis of The Current State

The pie chart in Figure 5 clearly elucidates the percentage of value-added time and necessary but non-value-added operations time. Only 46% of the overall operations time is the value-added, whereas 54% is the non-value-added; although, these non-value-added operations are still necessary for manufacturing and they are considered as supported processes.

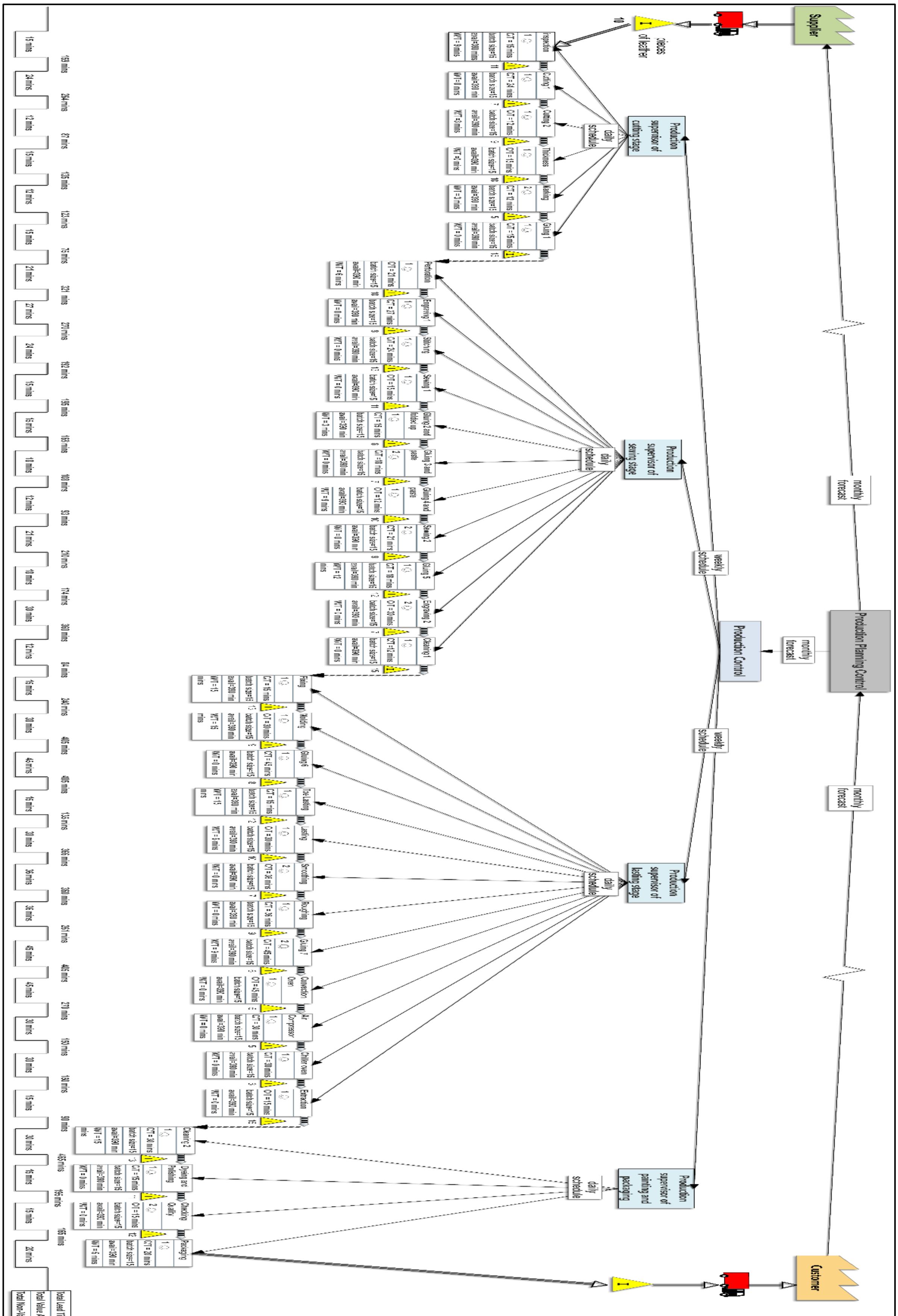


Figure 4: The current production line value map

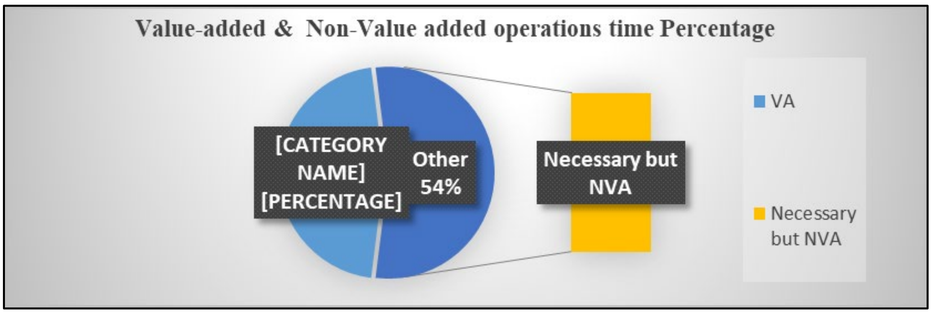


Figure 5: Value-added and non-value added percentage

From the current value map, the total production lead time is 130.6 hours, the NVA time percentage is 90% due to WIP inventory, and only 10% of the total production lead time is an actual processing time. The shoe processing are done through 33 operations, as well the No. of operators in the production line are 40 operators. There are several operations with a high cycle time and operations with a short cycle time, as well as a large batch size effect on the production lead time. Improving the current state production line and eliminating the production lead time can be achieved by reengineering the working system in the factory as well as regarding the batch size in each operation, and the improvement is related to the operations, including recalculating the required operators for each stage, and merging some operations with a short cycle time.

3.5 Suggested Improvements

After the collected data being analyzed, some changes are required to be implemented in the production system to eliminate the production lead time and improve the factory. The proposed improvements are as follows:

3.5.1 The proposed hybrid push/pull strategies

Each of the individual systems has positive characteristics when applied in the production. The nature of production planning is a push system (make to stock) by the forecast system of the demand. It cannot be changed to a full pull system (make to order) due to the type of product manufactured. The combination of push and pull systems inside the production lines together provides many advantages in terms of reducing WIP inventory and improving production. Designing suitable push/pull strategies for the movement of the shoes between the production stages is depicted in Figure 6. The schedule of the production from the production planning control is a push strategy depending on the monthly forecast. Only when the raw material is demanded from the supplier to the store of the MLSF No.7 industry and then to the cutting stage will be a pull strategy. After the cutting stage, the push strategy is applied to feed the shoes to the sewing stage in batch production. In the lasting stage, the pull strategy is implemented with the FIFO (first in first out) system to eliminate the WIP. From the painting and packaging stage until delivering the shoes to the customer, the shoes feed-in push strategy because of the industry production is based on the forecasting.

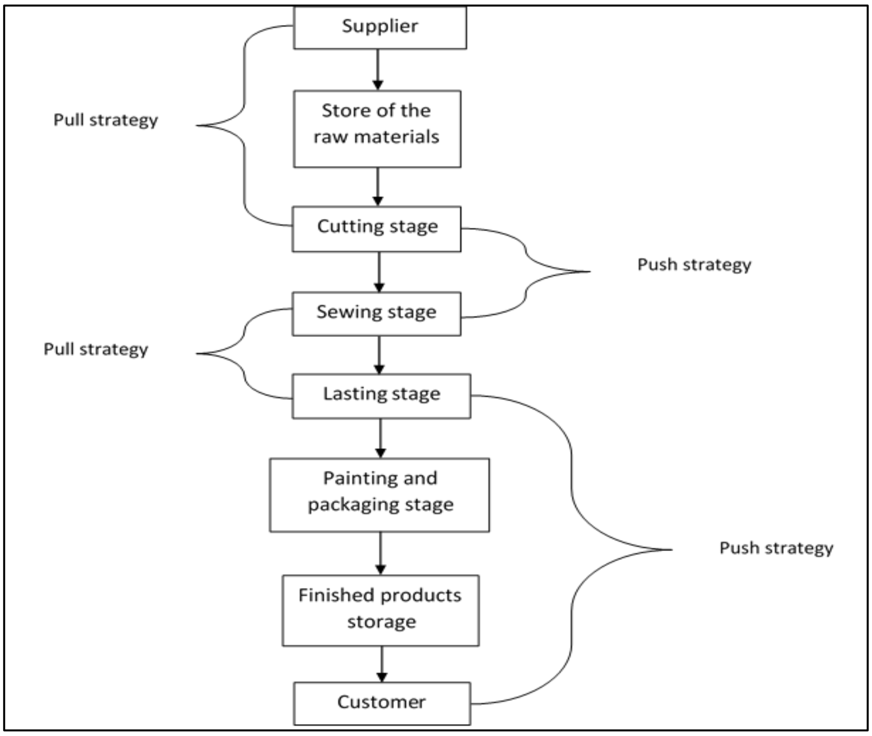


Figure 6: The proposed hybrid push/pull strategies

3.5.2 The proposed Kanban production

The production Kanban will be applied to the production line. The production control makes a Heijunka box, and the Kanban card is placed into the box, it contains the schedule, the information of the shoes, and the quantity of production. After defining the schedule, the Kanban card is then delivered to the first stage (cutting and preparation stage) to start the manufacturing.

3.5.3 Establishing the batch size

Reducing the batch size is one of the lean concepts to eliminate the wastes and increase the throughput. The batch size of the production lines is 15 pairs of shoes, working on minimizing the batch size that has a positive impact on the processes cycle time, eliminating the inventory, reducing the NVA time, eliminating the number of defects, and improving the processes efficiency. The batch size is reduced to the lowest possible level so as not to affect the transfer time between the operations, therefore the batch size in cutting, sewing, painting, and packaging stages will be reduced to 10 pairs of shoes, except for the lasting stage, where the FIFO will be used because of the ability to use the shoe conveyor in this stage, where the shoes transfer from one operation to another operation smoothly and faster.

3.5.4 The proposed modification of the production stages

The required number of operators in each production stage as the first step to improve it is determined, so the required operator will be calculated using the following formula:

$$R_{operator} = \frac{C/T_{of\ the\ stage}}{T_{time}} \tag{1}$$

where: $R_{operator}$: The required operator
T_{time}: Takt time C/T: The cycle time

Takt time will be calculated using the following formula:

$$T_{time} = \frac{available\ time\ for\ production\ in\ the\ month}{No.units\ required\ per\ month} \tag{2}$$

The No. of units required = 300 pairs of shoes per month
The working days in the month = 20 day
The available time/day = 420 – 30 (lunch time) = 390 minutes
The available time/month = 390 x 20 = 7800 minutes
So that the Takt time = 26 minutes.

To minimize the number of operators as possible, the combining of the short operations (operation time is so small) in one workstation will reduce the waste time due to the WIP inventory.

3.5.4.1 The proposed modification of the cutting stage

Finding the required number of operators in this stage is the first step to improve it, so the required operator will be calculated by using the formula of the required operator. Where, the current total cycle time of the stage is 93 minutes, and the number of operators working in the stage is 7 operators, therefore

$$R_{operator} = \frac{93}{26} \cong 4\ operators \tag{4}$$

To minimize the number of operators as possible and balance the workload, combining the short operations (operation time is so small) in one workstation will reduce the waste time, and the improvement that will be implemented in the operations is as follows:

- Combining inspection and (gluing 1) operations and replacing the manual operation (gluing 1) to be working by machine, this change will make the cycle time of the workstation 80 seconds for one pair of shoes and free up one operator.
- Combining cutting 1 and cutting 2 operations, this combination will make the cycle time of the workstation 144 seconds for one pair of shoes and free up one operator.
- Combining thickness and marking operations, this combination will make the cycle time of the workstation 108 seconds for one pair of shoes and free up one operator.

Depending on the proposed modifications, the number of operators was decreased from 7 to 4 operators, where 3 operators have free up from work.

3.5.4.2 The proposed modification of the sewing stage

The cycle time of two operations is more than the takt time, where these two operations are considered as bottleneck operations in the proposed modification for the cutting stage, the required number of operators for this stage will also be calculated, where the total cycle time of the sewing stage is 213 minutes and 14 operators are working in this stage. By using the formula (1) of the required operators, the results manifested that the required operators to complete the work are 8 operators, and the followings are the proposed improvement of sewing stage:

- Combining perforation and sewing operations, this combination will make the cycle time of the workstation 144 seconds for one pair of shoes and free up one operator.
- Combining the operations (gluing 2, gluing 3, gluing 4, and gluing 5) and replacing the manual operations to be working by machine, these modifications will change the cycle time of the workstation to 80 seconds for one pair of shoes and free up three operators.
- Combining sewing 2 and (cleaning 1) operations, by this combination, the cycle time of the merging operation will be 132 seconds for one pair of shoes and free up one operator.

According to the proposed modification plan, only 5 operators will free up in the sewing stage, where the number of operators will not be reduced to 8 operators but reduced as possible from 14 to 9 operators.

3.5.4.3 The proposed modification of the lasting stage

In this stage, the layout of the operation is in a U-shape to give flexibility and makes a balanced line, also the FIFO method will be applied to eliminate the WIP inventory between the operations and give a continuous flow of shoes. The lasting stage will be considered as one continuous process in one workstation. The result of the calculation of the required operators is 14 operators which are the same quantity of the operators working in the lasting stage, but the operators will be reduced because of the improvement that applied to the stage. The operations will be modified as follows:

- Combining toe lasting and lasting operations into one machine to make the two operations work together, where the cycle time of the workstation will be 60 seconds for one pair of shoes with one operator to do the operation and free up one operator.
- Combine smoothing and roughing operations, the combination of these operations will free up one operator and the cycle time of the workstation will be 264 seconds for one pair of shoes.
- Modify the convection oven operation, where the cycle time of one pair of shoes is 180 seconds, this operation can be improved by increasing the degree of heat and the speed of the oven, and as a result, the cycle time will be reduced to 92 seconds for one pair of shoes.

After this improvement, the final number of operators is 12 operators working on producing shoes in this stage.

3.5.4.4 The proposed modification of the painting and packaging stage

The final stage of the production line contains 4 operations with 5 working operators; there is one bottleneck operation in the stage that must be eliminated. The result from the calculation of the required operators is 3 operators working, therefore the proposed modification includes combining dye & polish operation with packaging operation, and the cycle time of the workstation will be 140 seconds for one pair of shoes and free up one operator. The total number of operators working in this stage is minimized as possible to 4 operators.

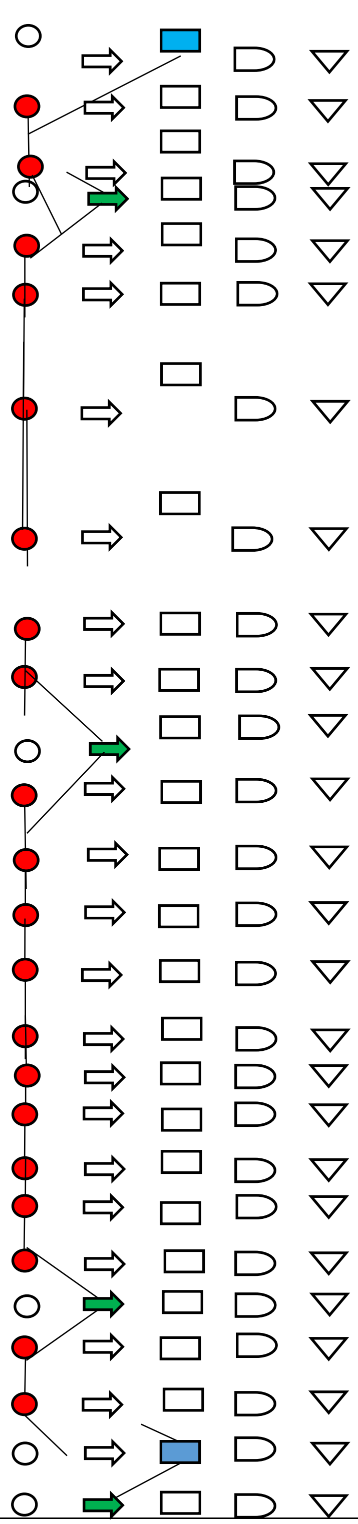
3.6 Creating The Future State Value Stream Mapping

Table 3 presents the new operations chart, which contains the operations description, cycle time, number of workers, and the classification of operations after implementing the proposed improvements.

The batch size in each operation in stages A, B, and D is 10 pieces of shoes according to the proposed modification, where Table 4 contains the batch cycle time of each operation which will be recorded in the future value map except for stage C where the cycle time that will be recorded is for one pair of shoes. After identifying the waste issues in the manufacturing by the current value map, the improvement is proposed and implemented in the production line and evinced in the future value map illustrated in Figure 7.

Table 3: The processes chart of the shoe production line after improvements

Symbols: Operation, Transfer, Inspection, Delay, Storage



No.	The Description of the Operation	Cycle time of 1 pair of shoe/sec	Number of Operators	VA\NVA
1	Stage A, inspection the raw material also put a gluing to the tongue of the shoe and folded up by machine	80	1	NVA
2	Leather, linen, and elastic Cut	144	1	VA
3	Reducing the thickness of one side for sewing and putting a mark to facilities sewing	108	2	NVA
	Transferring to stage B for sewing			
4	Shoe face perforation and sewing pull tab of the shoe	144	1	VA
5	Shoe face engraving	108	1	NVA
6	Stitching the two side pieces together and then with the shoe face and Cut off the appendages after Stitching and Reducing the thickness of the two side pieces manually	96	1	VA
7	Gluing the side pieces of the shoe and folded up, also glue and paste the inside linen piece and Toecap, Cut the appendages, glue and paste the elastic, finally gluing the piece that contains the size and branding of the shoe, where all gluing are by machine	80	2	VA
8	Sewing of the parts together and Clean the thread	132	2	VA
9	Edge engraving, two side engraving, and elastic reinforcement	120	2	NVA
	Transferring to stage C for lasting processes			
10	Fixing the base on the template, gluing and strengthening the back of the shoe with a strong piece	60	**1**	NVA
11	Hot and cold back part molding machine	120	1	NVA
12	Gluing all inner edges and the base	180	1	NVA
13	Toe lasting and heel seat and sides lasting by special machine	60	1	VA
14	Smoothing the corners and thermally modifying the face and roughen the base	264	2	NVA
15	Gluing shoe and sole	180	2	VA
16	Convection Oven	120	1	NVA
17	Air Compressor machine	120	1	VA
18	Chiller the Shoe in the oven	120	1	NVA
19	Take off the last	60	1	VA
	Transferring to section D finishing			
20	Removing the excess glue	120	1	NVA
21	Finishing (polish and dye) and then Packaging after passing the quality control	140	1	VA
22	Quality control	60	2	NVA
	Transportation to the depot			

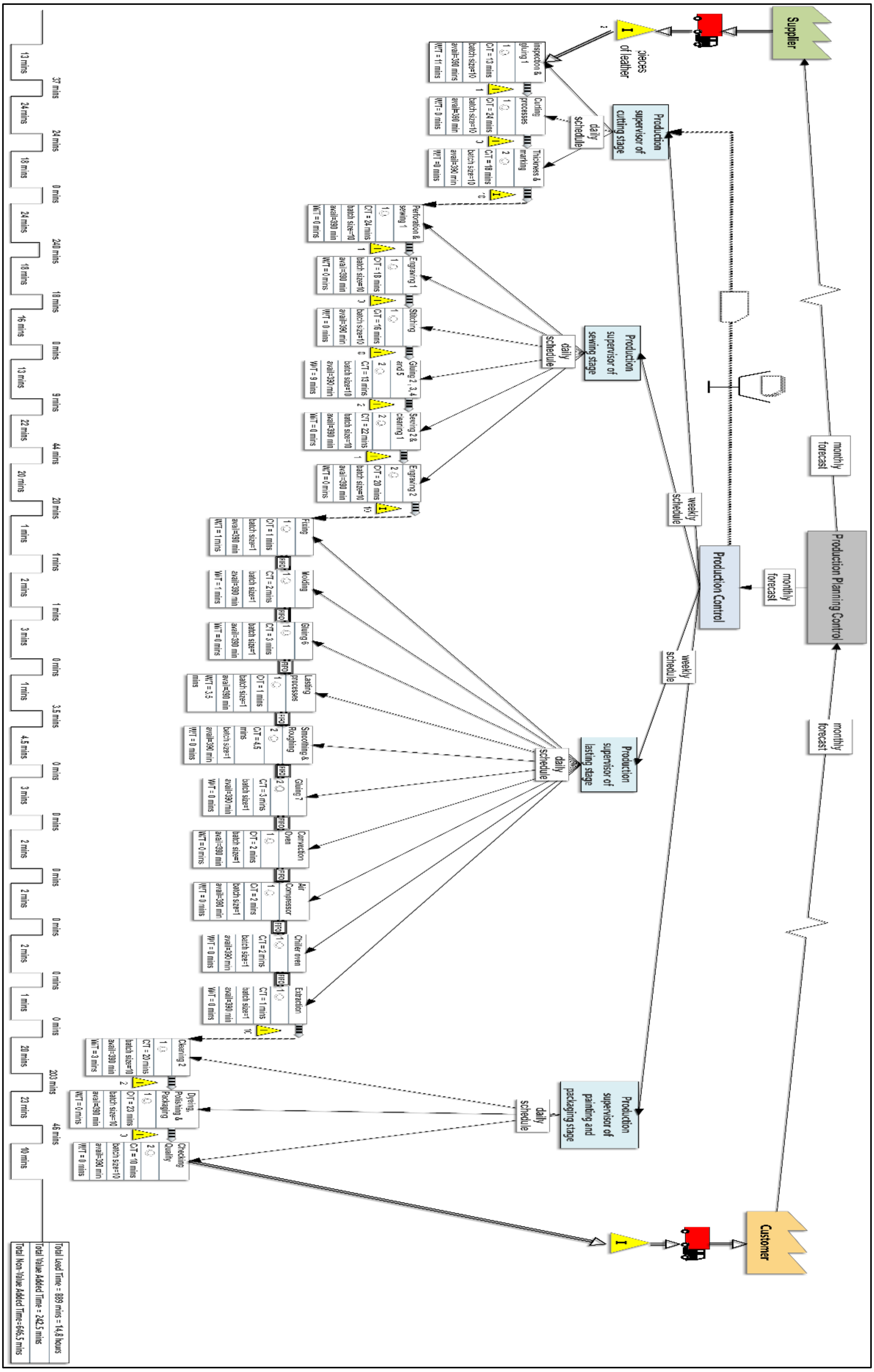


Figure 7: The future production line value map

Table 4: The operations cycle time that recorded in the future map

NO	The Operations Names	The Operation Cycle Time after Improvement
1	Inspection and gluing 1	13 min
2	Cutting processes	24 min
3	Thickness and marking	18 min
4	Perforation and sewing 1	24 min
5	Engraving 1	18 min
6	Stitching	16 min
7	Gluing 2 and folded up, Gluing 3, 4 and paste, gluing 5	13 min
8	Sewing 2 and cleaning 1	22 min
9	Engraving 2	20 min
10	Fixing	60 sec
11	Molding	120 sec
12	Gluing 6	180 sec
13	Lasting	60 sec
14	Smoothing and roughing	264 sec
15	Gluing 7	180 sec
16	Convection oven	120 sec
17	Air compressor	120 sec
18	Chillier oven	120 sec
19	Extraction	60 sec
20	Cleaning 2	20 min
21	Dyeing, polishing, and packaging	23 min
22	Checking quality	10 in

4. Results and Discussion

The current state and the future state (improvement) are analyzed and compared for evaluation both states. Improvements adopting lean tools are suggested. These tools are Value stream Mapping, hybrid push and pull system and combining processes focusing on reducing the non-added value processes according to the process chart. Table 5 shows the comparisons between the current state and the future state for each stage of the production line. After applying the lean tools, a significant reduction indicates in the future state. Figure 8 shows a bar chart which indicates a significant reduction in the future state operations cycle time for one pair of the shoes compared with the current state, and in the number of operations as well as the No. of operators. It is obvious that the future state has resulted in a significant reduction in terms of operations cycle time and their numbers. The operation cycle time reduced from 50 minutes to 42.6 minutes for one pair of shoes, that means an improvement of 15% is performed. The number of operations reduced from 33 to 22 operations, which means the percentage of the improvement, is 33%. The number of operations in the cutting stage reduced from 6 to 3 operations, in the sewing stage reduced from 11 to 6 operations, in the lasting stage reduced from 12 to 10 operations, and in the painting and packaging stage reduced from 4 to 3 operations. As well the No. of operators in the production line decreased from 40 to 29 operators which means the improvement percentage is 28%. The future state also depicts that a reduction occurs in the production lead time from 130.6 to 14.8 hours, and in the NVA time from 118 to 10.8 hours. This will substantially increase the total production quantity. The operation and operators reduction will affect the cost toward minimizing. Improving production rates and cost reduction has an obvious effect upon competition improvement, which is the most important problem that faced the leather shoes manufacturing industry.

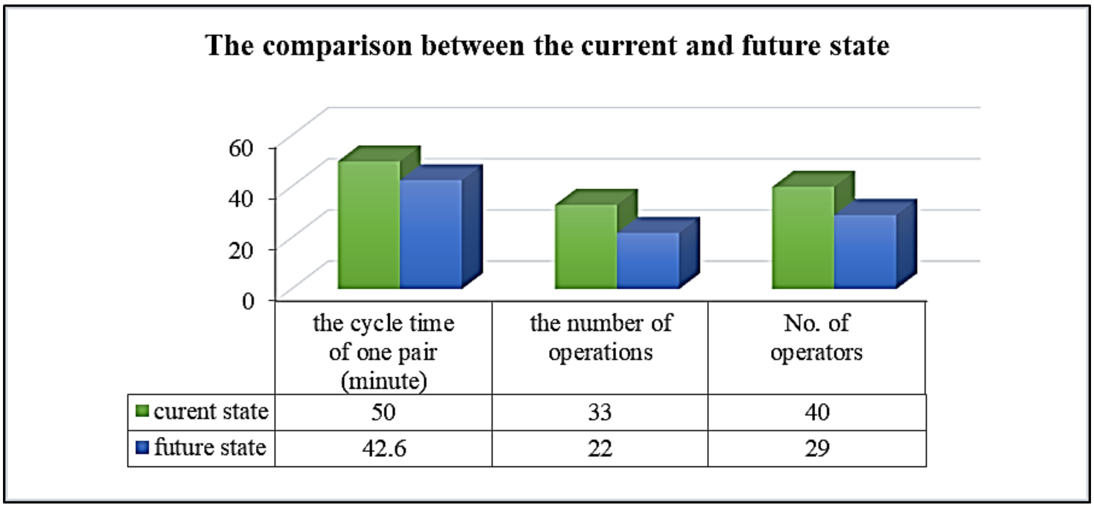


Figure 8: The comparison between the current and future state

Table 5: The comparison between the stages information before and after improvement

The Stages Comparisons	No. of Operations		Cycle Time of 1 Pair		No. of Operators	
	Current	*Future*	*Current*	*Future*	*Current*	*Future*
Cutting	6	3	372 sec	332 sec	7	4
Sewing	11	6	852 sec	680 sec	14	9
Lasting	12	10	1488 sec	1284 sec	14	12
Painting & Packaging	4	3	320 sec	320 sec	5	4

5. Conclusion

The application of lean manufacturing tools to improve the production of the leather shoes manufacturing industry is presented in this research which has a great impact on the factory improvement. The most important conclusions are as follows:

- Value stream mapping is an efficient visual tool to capture and illustrate the processes and information flow in the men's leather shoe factory No.7 (MLSF No.7), where all the data and information of the production line before and after the implementation of the proposed improvement are recorded in it.
- The implementation of hybrid push/pull strategies can result in minimizing the non-value added.
- One efficient improvement step to enhance the factory performance balanced the workload by improving the takt time that led to minimize the number of operators from 40 to 29 operators.
- The proposed methodology led to reduce the number of operations from 33 to 22 operations by merging the operations that have a short cycle time in one workstation.
- The production lead time reduced from 130.6 to 14.8 hours with 88% percentage improvement.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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