

Lean Tools and Techniques for Improving Production Performance and Waste Reduction in A Plastic Company: A Case Study

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Abstract

Lean approach has been applied in the production floor in recent times. Started in the automotive industry lean tools have been applied in different production and management floors. Lean principles are adopted in a reputed plastic manufacturing company of Dhaka, Bangladesh with a view to increasing financial profit by increasing efficiency and reducing waste. Value stream mapping (VSM), Cause and effect diagram, Pareto analysis, control charts, key lean tools have been used to identify the improvement opportunists, DMIAC (Design, Measure, Improve, Analyze and Control) and 5s have been used for continuous improvement, Control Chart. A team was formed consisting 7 workers and then trained about these tools. After one month of implementing these tools and techniques it was found that that lead time was reduced by 10%. Total value addition time increased from 34310hr to 35564hr (3.5 % increased). Total production increased from 41154890 to 43009168 pieces (4.3% increased), defective products decreased from 2050736 to 1793154 pieces (12.56% decreased), sigma level improved from 3.18 σ to 3.21 σ , manufacturing lead time reduced from 19 days to 18 days for every type of product, process time reduced from 18sec to 15sec for every type of product, non-value-added time reduced from 36sec to 26sec, process efficiency increased from 33.33% to 36.58%. This paper demonstrates the use of the above-mentioned tools and discuss their application in LP initiative in a manufacturing plant.

Keywords

Lean Principle, VSM, LSS, DPMO and DMAIC.

1. Introduction

The competitiveness of Bangladeshi plastic industry lies in the use of cheap labor. But as the country is graduating from lower development country to developing one, Industries will not be able to use this leverage anymore. So, the companies are trying to implement Lean tools and techniques in their production processes and management activities to reduce waste and non-value adding activity. The focus of this approach is on cost reduction through eliminating waste and non-value adding activity in each step of their operations. Since the birth of Toyota production system many of the tools and techniques (e.g., Just-in-Time (JIT), Total productive maintenance, single minute exchange of die, cellular manufacturing, Value stream mapping etc.) have been extensively used in the industries.

In this regard, the use of Value Stream Mapping (VSM), an important technique used in lean manufacturing to identify waste, by adapting, as necessary, for green and sustainable manufacturing has received attention. A value stream is defined as all the actions, both value added and non-value added, currently required to bring a product

through the main flows essential to every product: the production flow from raw material into the arms of the customer, and the design flow from concept to launch. VSM differs from traditional recording methods in that it records information about each station's cycle time, up time or resource usage, set-up time or change over time, work-in-process inventory, manpower requirements, and information flow from raw materials to finished products. It covers both values adding as well as non-value-adding activities (Sethet al.2008).

This paper begins by providing a brief synopsis of the principles used in the case industry followed by providing a background on the work done. In a general view, Lean is a technique used to reduce waste and non-value-added activities for running a production or service operations. The activities and techniques may differ depending on the application but there are some core principles which are same irrespective of the selected industry. The types of wastes listed in this work includes seven *Muda*(Juran, J.M.; Godfrey and A.B. *Lean*1990) was chosen as the main ingredient for the purpose of reducing waste in this work. By applying tools that could identify major sources of waste, and then using tools such as, DMAIC, DPMO (Defective per million), the project team applied the following related lean tools such as Setup time reduction, Total quality management (TQM), 5S and VSM: A collection of all actions (value added as well as non-value-added) that are required to bring a product through the main flows.

1.1 Objectives

The objective of this research work is to use a case-based approach to demonstrate how lean manufacturing tools are used to help the process industry to reduce waste, produce better quality product and enhance the capability of operation control. The team adopted Value stream mapping to find the waste and used different lean tool to eliminate them.

2. Literature Review

Lean manufacturing assists associations with accomplishing designated efficiency and more by acquaintance of simple with apply and viable strategies and apparatuses. Lean manufacturing works on identifying and eliminating wastages from each step in the manufacturing cycle of a product. The wastages in manufacturing cycle of a product may be energy, time, motion and resources. Many manufacturing organizations are effectively using lean tools and techniques to identify and eliminate wastages through continuous improvement. The main objective of lean manufacturing is to keep cost down (Narke and Jayadeva 2020). At present the accomplishment of the plastics manufacturing fundamentally relies upon a few factors, for example, nature of items, fabricating cost, item plan and so on These elements are hampered because of different deformities happens in the organizations. These imperfections can't be repairable that tends to defectives of item that prompts disposal. In around the world, the vast majority of the plastics manufacturing tormenting because of their dismissal of their yield's items. Minimization of deformities is an absolute necessity in quality and usefulness improvement. Whereas rejection causes waste which mainly due to man-made mistakes which is from Pareto chart analysis. In these consequences, plastics industry is selected for research work for elimination of defect products waste by implementing 5S, Fishbone diagram, lean tool in all departments of plastics industry and DMAIC Six Sigma methodology.

Lean principles define the value of the product/service as perceived by the customer and then making the flow in-line with the customer pull and striving for perfection through continuous improvement to eliminate waste by sorting out Value Added activity (VA) and Non- Value-Added activity (NVA). The sources for the NVA activity wastes are Transportation, Inventory, Motion Waiting, Overproduction, Over processing and Defects. The NVA activity waste is vital hurdle for VA activity. Elimination of these wastes is achieved through the successful implementation of lean elements (Sundar et al. 2014). Lean six sigma is a hybrid methodology of continuous improvement initiatives whose objective is to increase quality and reduce time in processing. A successful LSS implementation can generate great economic benefits for companies (Vallejo et al. 2020). LSS has evolved through the combination of Lean and Six Sigma both being recognized as leading Total Quality Management (TQM) tools for performance improvement in organizations with a proper infrastructure that are built on leadership and change of culture (Shokri and Li 2020). Lean Six Sigma (LSS) through proposing a novel DMAIC-based approach to systematize Sus-VSM. It addresses a notable shortfall in Sus-VSM by offering a continuous improvement process where, based on the establishment of a current-state Sus-VSM map and after achieving its future-state map, subsequent future-state Sus-VSM maps can be drawn to enable a continuous improvement cycle (Jamil et al. 2020).

The implementation of DMAIC concept and implementation of 5S concept in all sections of selected industry for elimination of lean wastes like defects and unnecessary motion occurs in manufacturing industry due to

identification of different types of problem related to lean waste (Vijayakumar and Robinson 2016). There are different lean manufacturing tools are used to improve or address various issues in a manufacturing system. 5S lean tool is a workplace organization technique and it is a way to involve associates in the ownership of their workspace. It helps to create and maintain the efficiency and effectiveness of the manufacturing area (Nallusamy and Ahamed 2017). Value Stream Mapping (VSM) is one of the important lean tools which identify all types of wastes in the value stream and take steps to eliminate these (Narke and Jayadeva 2020). VSM helps in documenting the relationships between ‘processes and controls’, for example, relationships between manufacturing processes and controls like production scheduling, inventory release and production rate. It captures product flow and links it with information flow, such as; when and what triggers the movement of materials. Thus, it intelligently links product planning and demand forecast to production scheduling and shop floor control. (Braglia et al. 2006). Value stream mapping has the reputation of uncovering waste in manufacturing, production and business process. This helps in identifying and removing or streamlining value added steps and eliminating non-value-added steps (Nallusamy and Ahamed 2017).

To the best of the authors knowledge, this work is very first of its kind in which we have tried to find out the common scenarios of plastics injection molding sector by depicting the existing situation of plastic manufacturing industry in Bangladesh.

3. Methods

3.1 Value Stream Mapping

In lean manufacturing, one of the effective tools is value stream mapping. The entire process is approached in three steps in VSM (Gahagan and Sean M. 2007) in which the first step involves producing a diagram showing the actual material and information flow or the existing state on how the actual process operates. This is created while walking down the production line. Secondly, a lean process flow, which could give great financial impact to the process, is produced through process improvements after a Future State map is produced to identify the root causes of waste. These improvements are then conducted, the Implementation Plan as part and partial details and action needed to gain the project objectives in process kaizen (continuous improvement) and poka-yoke (Abdulmalek. et al., 2007). Manos (2006) developed the following Figure 1 that shows a map of a simple value stream. This example is a material-flow-only value stream map. A weekly truck shipment of material is kept as inventory for 5 days before being assembly and inspected. Assembly process and inspection activities are being captured in the data box. Complete products are kept for another 30 days in the inventory before is scheduled for delivery.

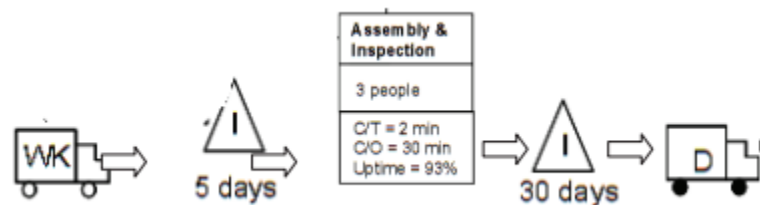


Figure 1. Value Stream Mapping Common Icon

3.2 Six Sigma and Lean Six Sigma

The term “sigma” comes from the Greek letter σ which is the symbol for standard deviation of a population in statistical mathematics. It was introduced by engineer Bill Smith while working at Motorola in 1986. Jack Welch made it central to his business strategy at General Electric in 1995. Six Sigma centers around decreasing interaction variety and upgrading measure control, while lean drives out squander (non-value-added cycles and methodology) and advances work normalization and stream. Whereas Six Sigma mainly focuses on defect and variation reductions, Lean ads more focus on process standardization and simplification as well as waste reduction (Watson et al. 2010).

3.3 Problem Solving Process DMAIC

DMAIC is the basic problem-solving process of Six Sigma. It includes five steps which are: Define, Measure, Analyze, Improve and Control. This problem-solving process can be described as “A rigorous, step-by-step, logical

discipline for defining the most critical business improvement issues, converting them into statistical problems, and then resolving them as standardized daily work practices” (Pepper et al. 2010).

3.4 DPMO

Defects per Million Opportunities (DPMO) is a ratio of the number of defects in one million opportunities when an item can contain more than one defect.

$$DPMO = \left(\frac{\text{Total number of defects found in a sample}}{\text{Total number of defect opportunities in the sample}} \right) \times 1000000$$

4. Case Study

4.1 Company and process Background

Company that the team referred to SME (Small and Medium Enterprise) is involved in Bangladesh plastic industry since 1969. It is one of the largest garment hanger manufacturers in the country which is capable of producing more than 2 million pieces of plastic garment hangers every day.

The management has selected a major product order. But unfortunately, SME failed to achieve its daily production forecast. Then the management proposed lean approach as a mode to tackle the waste and enhance the ability of better operational control. The data and information provided through this study can help management to make comparison between the lean system and the existing production system.

4.2 Product Process Flow

The Products Flow diagram for Hanger by Injection molding machine is illustrated in Figure 2, Firstly here raw materials are mixing with master batch and different types of additives and then it feed through by a big hopper. After feed the ingredients are melt in barrel then it injects into the mold after close the mold. After sufficient time has passed, the cooled parts are ejected from the mold by the ejection system. Then it can be visual inspection if it is accepted then again it going to under final inspection process. After final inspection all accepted, products are going to assembly line, in assembly line hooking and clipping is the main process. After assembly then all products are going to under full products inspection process, if the products are accepted then it going to packaging section, after packaging all finished goods are inventorying in storage room. In this research our main focus was on mainly three section these are Injection molding section, hooking section, and Clipping section.

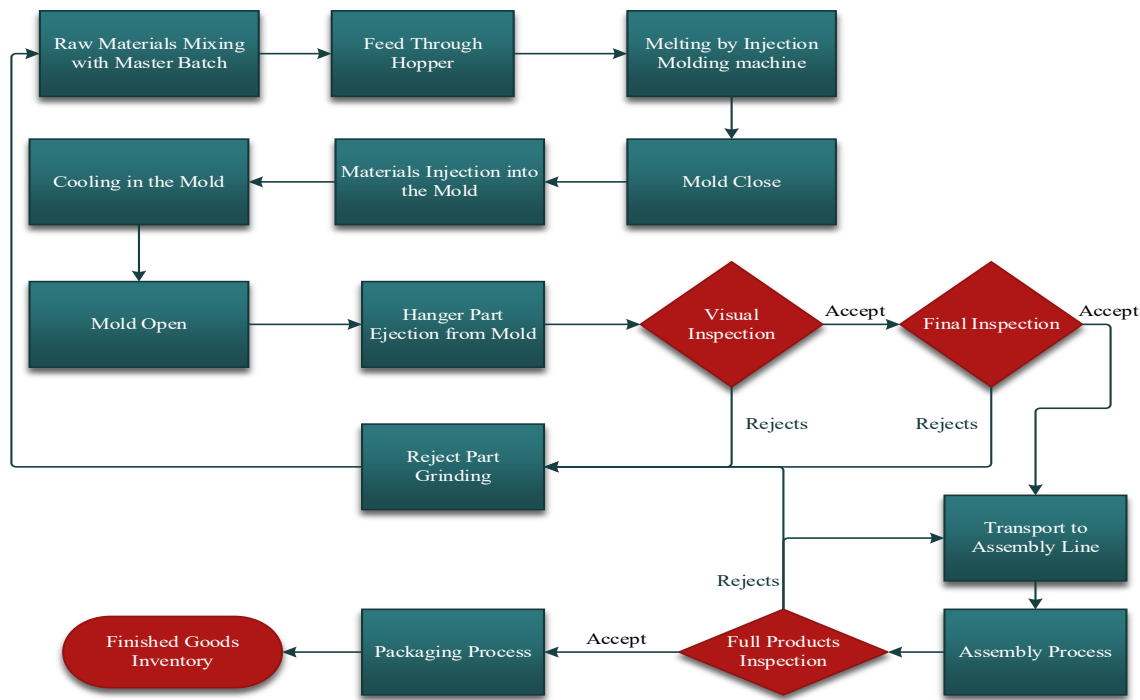


Figure2. Products Flow diagram for Hanger by Injection molding Machine

4.3 Current Scenario

The current production scenario has been observed for two weeks. The production process, defects per million observation and current sigma level have been studied. Table 1 shows the DPMO and sigma level of the current set up.

Table 1. Current DPMO and sigma level of observed company

Defect Criteria	DPMO	Sigma Level
Injection Molding	43536	3.22 σ
Hooking	46852	3.18 σ
Clipping	47766	3.17 σ
Reject (others problem)	49312	3.15 σ

4.4 Current State Map

Part of practicing lean is to walk and head out to floor to assess how well SME is doing. Walking through the floor allowed the team to see issues, finding their cause, clearing them and the next step is to resolve them.

The team gathered data and information by walking the flow and interviewing the operator who performs the specific task to produce a current state map. The benefit of walking the flow is that it is a helpful method of creating the map as opposed to compiling the data from office meetings and discussions. The team also got to see the entire process firsthand and keep an eye out for waste. Operators, assemblers, and technicians can answer questions during interviews and further clarify any misunderstandings or preconceived notions about how jobs are carried out.

The process object consists of small boxes in the map represent the process and the number inside the box displays CT, CO, Yield percentage, up time, and number of shifts. Figure 3 represents the Current Map of hanger section which was completed right after the plant floor visits and interviews. The current lead time and process time is also shown in the Figure 3.

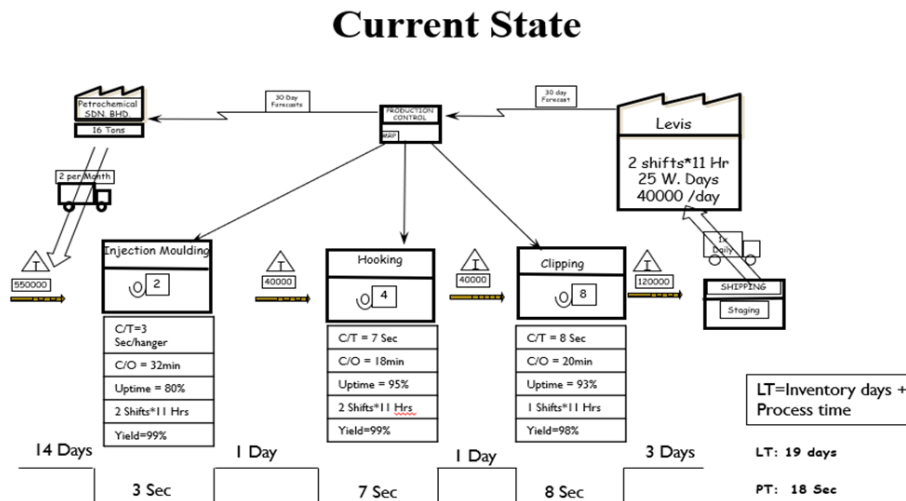


Figure 3. Value-Stream Mapping of Hanger Section.

4.5 Cause and Effect Analysis

After developing the current value stream map, the team then did a cause-and-effect analysis to find out the possible causes of higher rate of production defects. A fishbone diagram was drawn to find out the possible causes of high defect rate. Figure 4 shows the cause-and-effect diagram for manufacturing defects.

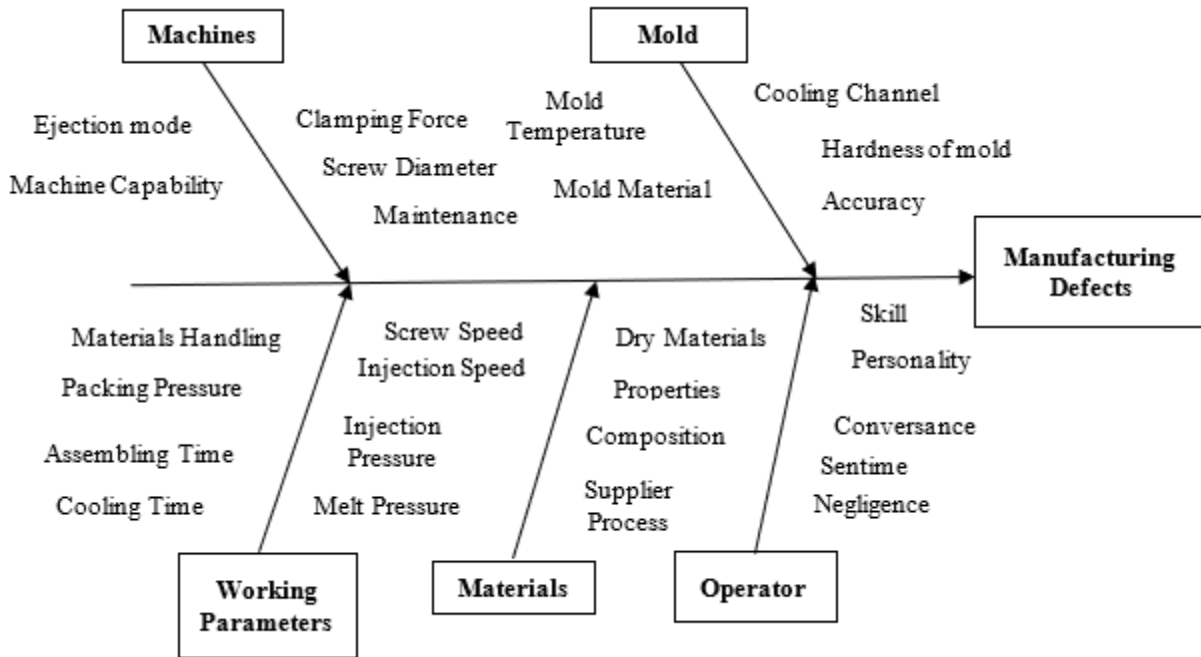


Figure 4. Cause and Effect Diagram for Manufacturing Defects

4.6 Pareto Analysis

Pareto chart is used to show different manufacturing defects after production process. Figure 5 shows Pareto charfor different manufacturing defects such as flash in hanger, spot on hanger, short mold, shrinkage, burning, bend, dirty eject pin, bubbles, sink marks, and other defects. Here, Figure 5 shows the flash in hanger is the biggest defects among all the defects. We used pare to chart to develop root causes so that we can able to reduce the number of defects and it helps to increase production and reduce to wastage.

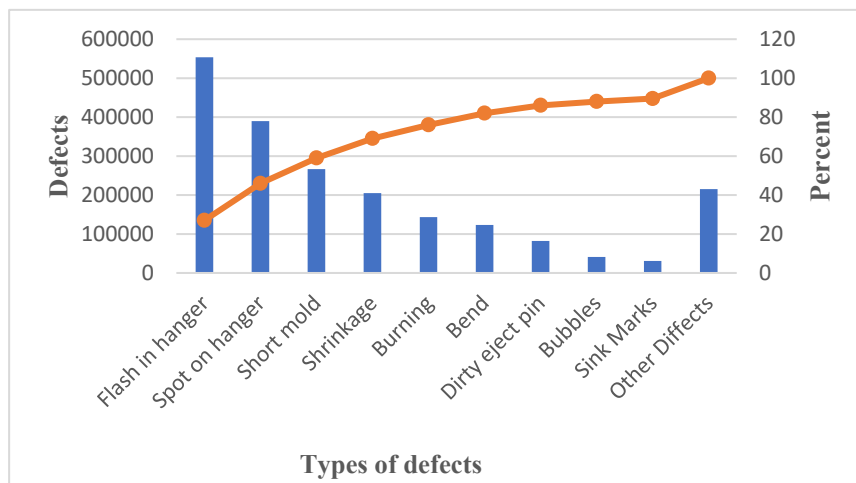


Figure 5. Pareto chart for different manufacturing defects

4.7 Work measure – Takt time

The lean flow through the production line and the eradication of the detected wastes' root causes are the goals of creating the future state map. To get feedback and reach consensus on the Future State's direction, the senior management reviews the Future State's key features once they are defined and in progress.

A number of things became apparent when the current state map for SMC was examined, including (a) intermediate inventories between machines and (b) non-systematic manual handling. Therefore, aside from examining the schedule across the hanger production line, the team looks for lean manufacturing techniques to reduce these in order to produce an ideal future state map. The team used a method of structured inquiries to enable them to critique the current manufacturing system and create a map of the ideal future state that will assist reduce or even eliminate various sorts of waste. The following objectives served as the foundation for the questions asked during the production flow walk-about: First of all, what is Takt time? What bottlenecks and limits have been identified? Where may inventory (or wait times) be decreased? Where can we make the flow better? Possible process enhancement for upcoming state design.

For hanger production line, volume demands changes slightly every month. It means the takt time is also changing. The table below showed the takt time production of hangers from September to December 2021. Calculation refers on two shifts with total of eleven working hours per day.

Table 2. Time study of previous compared to the hanger process line

Machine and Man	Injection Molding	Hooking	Clipping	Total
Time (Second)	3	7	8	18

History data referred in Table 2 includes the set-up times and the machine process time and the individual processing data.

4.8 Bottlenecks or constraints

Any point where the CT exceeds the takt time, which could result from work in progress (WIP) or additional processing time, is a potential candidate for the presence of bottlenecks or limitations in the line. CT in this production line refers to the time needed to execute one operation, or to finish a job, task, or function completely. Cycle Time is used to distinguish between a process's run time and overall duration. Cycle time in manufacturing is the overall amount of time it takes to fulfill a request.

$$\text{Cycle Time (CT)} = \text{Machine Time} + \text{Man Time}$$

All information is respectively connected and shows the scheduled planning independently. Total man and machine time of previous process layout and machining method showed total of 18s-time consumption to produce a unit of hanger.

4.9 Waste Identification

Several types of waste are described in Table 3. Effort was given to identify waste in the production floor and then categorized ten ways. Finally, the priority is identified so that the waste can be minimized. Lastly estimated the difficulty to eradicate the waste. It is a visual way to know about the waste and ability to solve the problem with a minimum time. Where priority to solve the problem is arranged based on quality. High priority is given when minor defect will reject the product.

Table 3. Waste Identification Worksheet

WASTE IDENTIFICATION SHEET		COMPANY:		SME											
PROCESS OBSERVED: -	Hanger production process	Category of Waste						Priority			Estimated difficulty to eradicate				
		Transportation	Inventory	Motion	Waiting	Over processing	Over producing	Defects	Skills	High	Medium	Low	Easy	Medium	Hard
START POINT :-	Line A														
END POINT :-	Line J														
PROCESS STEP (Name or Op No.)	DESCRIPTION OF WASTE														
1	Short molding							Y	Y				Y		
2	Assembly process	Y	Y	Y	Y				Y				Y		
3	Crashing of defective hanger			Y				Y			Y			Y	
4	Burning of products							Y	Y	Y			Y		
5	Mold change			Y	Y			Y	Y					Y	
6	Maintenance			Y	Y			Y	Y					Y	
7	Flash in hanger					Y		Y	Y	Y			Y		
8	Dirty eject pin							Y	Y	Y			Y		
9	Spot on products							Y		Y			Y		
10	Power off			Y				Y						Y	

5. Assessment and Result

The project's objectives were to determine the possible benefits of applying lean and to create a pleasant future state map. The team concentrated on three lean manufacturing techniques: improving takt time, decreasing handling to eliminate or at least minimize changeover/handling time, and production leveling through minimizing process WIP.

5.1. Process Cycle Time (CT)

The cycle time of one machine is according to man time and machine time. When both this time is added it will become cycle time and from cycle time, it will affect the capacity output of one machine. From the study of time measurement of three operators, the process workflow for operator 1, 2, and 3 and the capacity of the production line, the overall capacity output of current hanger section can be shown in the following Table 2. Die is one of the most important parts of injection molding machine. It used to hold part in machine and at the same time, produces the shape of the part. During the assessment, it is monitored that the operator spent too long time setting the die. This resulted in having high value of man time. At the same station, it was also observed that the man time is too long (idle time) due to the movement of operator when unloading part from machine. These motions are wasting the operator time and increase the handling time (waste) further than required. To resolve the matter, the team suggested to use single minute exchange of die philosophy. It was also observed that the hooking operation used to take place in two separate sections which resulted in the increased transportation i.e., man time. The team merged the two sections which resulted in the reduction of handling time. The new CT was measured, and the results are shown in Table 4. The future process state is also shown in Figure 6.

Table 4. Time study of previous compared to the new hanger production line

Machine and Man	Injection Molding	Hooking	Clipping	Total
Time (Second)	3	5	7	15

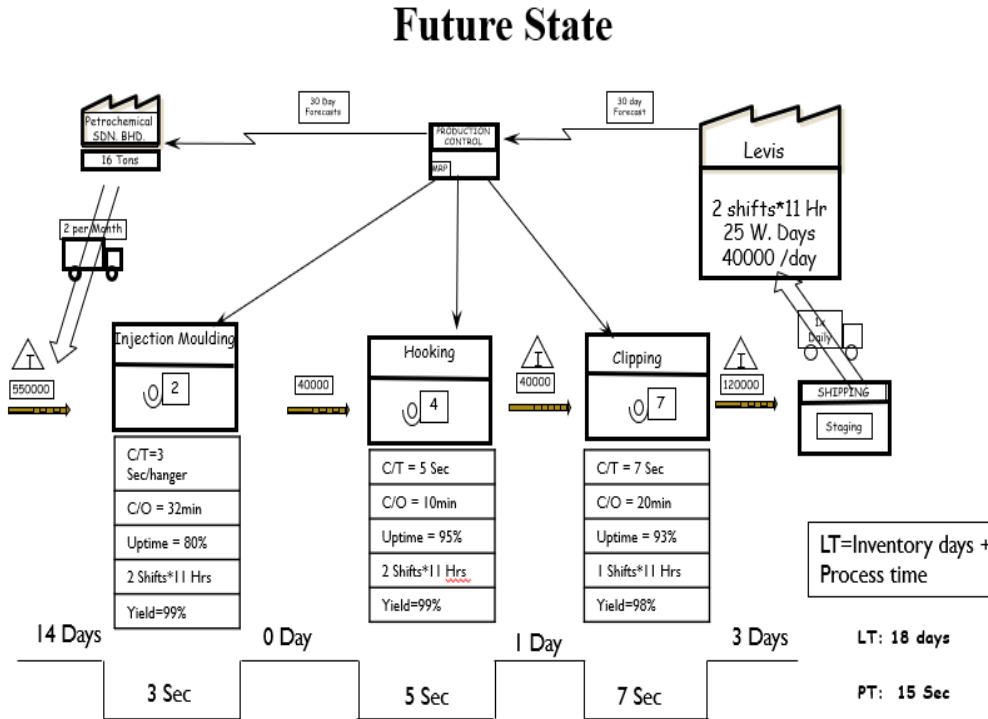


Figure 6. Value stream mapping after improvement

5.2 Changing Line Layout

Figure 7 Shows the previous line layout (Left side) and current line layout (Right side). In previous line layout was L shaped it includes unnecessary body movement which causes increased man time. After changing this layout, it reduces body movement and reduces handling time and man time.

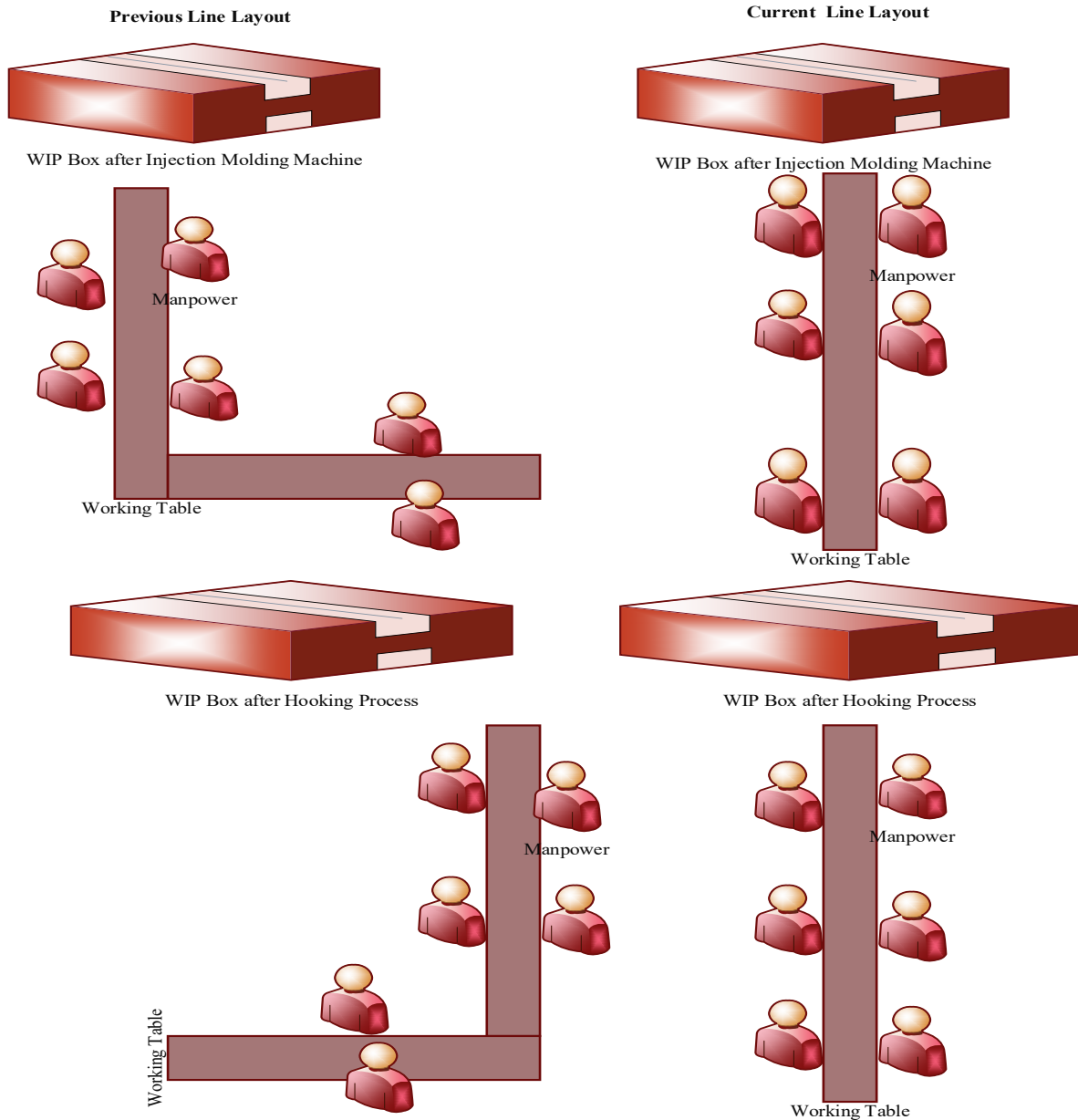


Figure 7. Previous and Current Layouts

6. Conclusion

This case study illustrates the application of some lean manufacturing tools in the plastic process industry. Through this study the authors have demonstrated use of VSM in the hanger production process. Through applying VSM, hidden waste and non-value adding activity have been identified that used to affect the productivity of hangers. Quantitative analysis showed that many of the lean tools have extended impacts related to the reducing of waiting time and waste. Through the use of VSM, the result of a change (reduction of waiting time) has been assessed. A positive change was viewed through the implementation of these tools as there was substantial gap between the standard operation procedure and the previously practiced culture. Maintaining this recommended procedure and maintain them will be a key factor for the company to further increase their efficiency and reduce operational cost.

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