Lean Production for Reducing Wastes in Convex Lens Production Process

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Abstracts: This research aimed to investigate the waste generated during the production of traditional convex lens. The study proposed a method to eliminate such waste by utilizing value stream mapping (VSM) as a tool for data collection and waste identification throughout the entire production process. Through the analysis of data using VSM, three specific types of waste were identified. These included losses resulting from ineffective utilization of the oven machine during the polymerization process, inefficiencies in personnel performance, and inappropriate working procedures. To address these waste issues, the task employed the work study method to optimize machine utilization, develop efficient work processes for personnel, and improve inappropriate procedures to enhance overall efficiency. The ECRS method was utilized to improve the process of waste elimination. The research findings demonstrated substantial reductions in waste within the production process. Specifically, the total throughput time decreased from 661.07 minutes to 480.68 minutes, representing a reduction of 27.29%. Furthermore, the total production lead time decreased from 1.20 days to 0.94 days, indicating a reduction of 21.67%. In terms of personnel, the workforce decreased from 42 employees per shift to 29 employees, reflecting a decrease of 30.95%. Finally, the number of oven machinery units required for all three shifts decreased from 3 ovens to 2 ovens, resulting in a reduction of 33.33%.

Keywords: Lean production, Waste Reduction, Value stream mapping, Lead time, Convex lens.

1. INTRODUCTION

The eyewear lens production industry is a growing sector driven by economic expansion. The manufacturing of eyewear lenses is essential for ensuring quality and everyday living, as they are considered essential commodities. However, market demand for eyewear lenses may decline due to economic and societal factors, as well as the social and educational standards of the population. Proper eye care contributes to overall well-being, making the eyewear lens production industry a significant component in addressing visual impairments and even limitations in reading and learning, which extend beyond the realm of education and encompass consumer perception.

The case study company operates in the manufacturing and distribution of various types of eyewear lenses, including prescription lenses, sunglasses, tinted lenses, and lenses with specific characteristics. In this research, the focus is on studying the production process of extended vision lenses, as it has been observed that this specific lens type involves complex manufacturing procedures and high production volumes. In these intricate processes, significant waste is often incurred. Therefore, reducing waste and effectively managing production activities are crucial elements that contribute to an organization's competitive advantage.

While many organizations have implemented improvements in their product and service production processes following the principles of Lean Manufacturing, it has been observed that these efforts are sometimes insufficient as Kaizen only provides partial development. Hence, there has been a growing adoption of Value Stream Mapping as a means of addressing this gap. Value Stream Mapping offers a comprehensive view of the entire production process, from product creation to delivery, allowing for a deeper understanding of waste within the process and facilitating the formulation of strategies to eliminate such waste [1-3]. Additionally, it enables cost reduction in production and efficient product delivery to customers, ultimately enhancing customer satisfaction and competitive performance within the business. The research aims to identify the causes of waste and study strategies to reduce the cycle time in the value stream of convex or long-distance lens production.

2. LITERATURE REVIEWS

2.1. Lean Manufacturing

Lean Manufacturing is a systematic approach that aims to identify and eliminate waste or non-value-added activities within the flow of value in a process. It relies on a pull system that responds to customer demand, ensuring a continuous, smooth flow and ongoing improvement to create value for the system [4-5]. The concept of Lean Manufacturing, also known as Lean, originates from the foundational Lean thinking, which gained recognition in the 1980s from the management system of Toyota, a Japanese automobile manufacturer, referred to as the "Toyota Production System" (TPS) and "Muda," or waste in operations [6].

Lean Manufacturing is based on three fundamental principles, which are as follows:

1. Create Value: The primary focus is on creating value for customers. Organizations need to analyze and understand what customers truly want and define the value that can be delivered to them. This involves identifying and addressing customer pain points or problems, providing solutions that meet their needs, and aligning business objectives with customer value.

2. Eliminate Waste: Lean Manufacturing aims to reduce various types of waste by eliminating unnecessary activities. This includes eliminating excessive time utilization, excessive resource consumption, and unnecessary costs.

3. Continuous Improvement: Lean Manufacturing strives to continuously improve and enhance processes. This involves seeking opportunities for improvement, implementing changes, and striving for ongoing progress and optimization.

These three principles form the basis of the five components of Lean Manufacturing [7-8]:

1. Identify Value: Organizations need to understand their business goals and the value they want to deliver to customers before focusing on waste reduction. By analyzing and identifying customer needs and pain points, organizations can determine what products or services will fulfill those needs and provide value.

2. Map the Value Stream: This step involves planning and mapping the workflow and production processes according to the defined value. It includes defining the steps, responsibilities, materials, resources, and sources required for the process. By analyzing the value stream, organizations can identify and eliminate any unnecessary steps or waste, using the concept of "Muda" or the eight types of waste defined in the Toyota Production System.

3. Create Flow: After understanding the workflow and identifying areas for improvement, the focus is on creating a seamless flow of operations without any bottlenecks or disruptions. Detailed task breakdown and addressing work-related challenges contribute to achieving a smooth and efficient workflow.

4. Establish Pull System: This step involves establishing a pull system, which is a work system that responds to actual demand. The goal is to create a responsive and efficient system that minimizes waste. This system ensures that production occurs only when there is a demand or order, avoiding overproduction and excessive inventory. It involves pulling resources as needed to fulfill specific customer requirements.

5. Seek Perfection: The final principle emphasizes the continuous pursuit of perfection or continuous improvement. Organizations should strive for ongoing enhancements, seek feedback, and refine processes to achieve operational excellence.

Lean Manufacturing aims to reduce waste and optimize operations by focusing on value creation, streamlining workflows, and continuously improving processes. By implementing the principles and following the basic principles of Lean, organizations can achieve increased efficiency, productivity, and customer satisfaction while minimizing waste and unnecessary costs [9-11].

2.2. Value Steam Mapping

Value Stream Mapping (VSM) is a vital tool for initiating process analysis and is widely recognized as a best practice and the latest trend in process improvement [12]. It is an excellent method of visual management. Value Stream Thinking helps gain an overall understanding of the process from a customer's perspective and focuses on improving resource and information flow throughout the entire supply chain [13-14]. By identifying necessary activities for waste elimination, VSM enables the identification of value-added activities and non-value-added activities. It uses information from the analysis of the current state to define the future state, with documents illustrating the desired state after improvement [15-17]. There is a number of common icons used in value stream maps, but icons can also be customized to best serve a value stream map. Icons help distinguish different elements of a product line from another. For example, different arrows should be used to distinguish between product and information movement. The Figure-1 below contains commonly used icons in Value Stream Mapping [18].

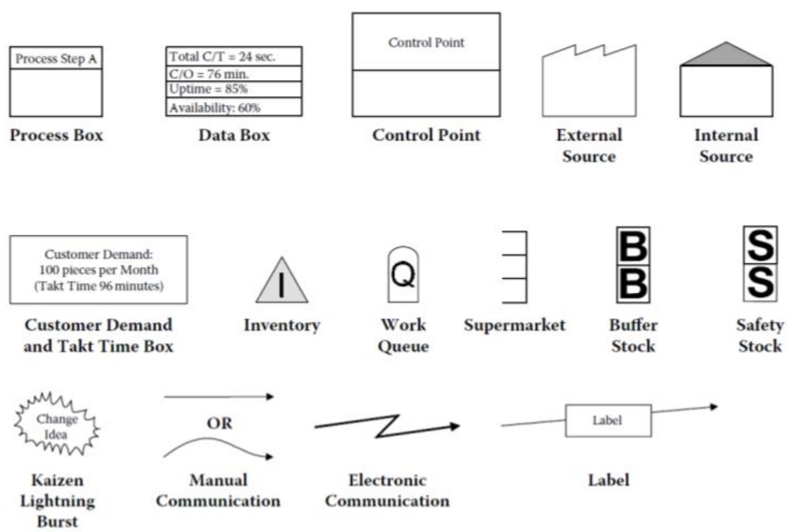

Figure 1. Standard Icons used in VSM.

3. METHOD

3.1. A Case Study Process

The selection of case study products was based on comprehensive data gathered by the researchers regarding the production and export of various types of eyeglass lenses. This data collection effort spanned a period of four months, specifically from June to September. Subsequently, a meticulous analysis of the collected data was conducted to identify the most suitable case study product, which ultimately focused on convex eyeglass lens. This selection was driven by several factors, including the lens' high production capacity and the complexity associated with their manufacturing steps, which led to subpar production performance relative to the desired targets.

3.2. Production Process of Convex Lens

The traditional production process for manufacturing long-distance eyeglass lens consisted of ten distinct steps, as visually represented in Figure 2.

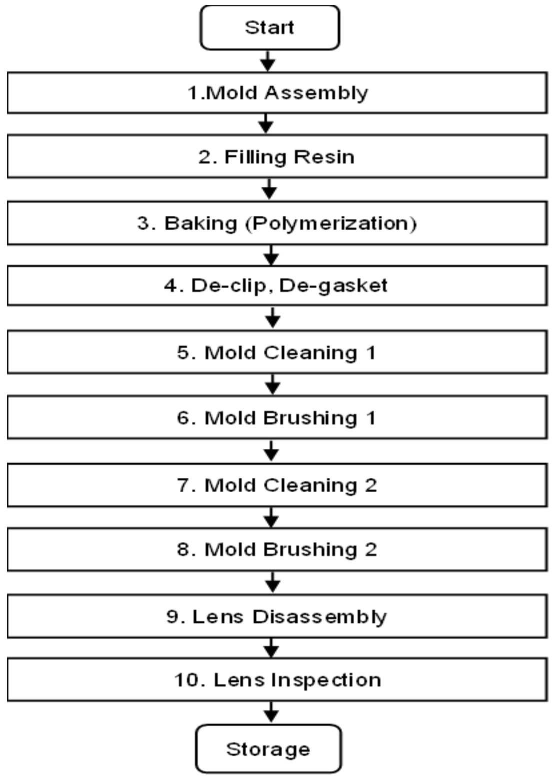

Figure 2. Convex Lens Production Process.

3.3. Problem Identification

Especially Through a comprehensive survey and in-depth discussions with the production department's supervisor, it was identified that the production of convex eyeglass lenses using the traditional manufacturing process faced challenges in achieving the desired production outcomes. Specifically, the process exhibited complexity and excessive resource utilization, leading to suboptimal production performance. Furthermore, there were issues related to meeting customer delivery deadlines, resulting in the inability to deliver completed products within the specified timeframes. Consequently, these observations formed the basis for defining the research problem, which aimed to investigate the sources of waste within the production process and explore improvement opportunities to reduce inefficiencies within this production line.

3.4. Research and Data Collection Tools

Various tools were employed to facilitate the research activities. Firstly, data was collected from the actual production site and subjected to preliminary analysis. This analysis primarily relied on in-depth interviews and the study of real-time operational data. The gathered information was subsequently analyzed to provide a foundation for further research. The research activities encompassed several components, including an investigation into the production steps and details of convex eyeglass lens manufacturing, the use of a Check Sheet to document observations, the application of Value Stream Mapping (VSM) to analyze waste, the utilization of the ECRS (Eliminate, Combine, Rearrange, Simplify) principle for waste reduction, an overall efficiency analysis, and the exploration of relevant industrial engineering techniques.

3.5. Future Production System Design

To enhance overall efficiency, the research team collaborated with the production unit to design a new system that aimed to eliminate waste within the production process. The Lean system concept was employed to improve the overall efficiency of the production process. Innovative designs were implemented to automate certain production steps, reducing the need for manual labor. The newly developed system was then evaluated and implemented for practical use. In this stage, a comparison was made between the time required for each production step, the overall production lead time, and the overall efficiency, highlighting the impact on production time and the subsequent reduction in production costs.

4. RESULTS

4.1. Current Stat Value Stream Mapping

The research team conducted an extensive analysis of the overall production process, starting from production planning, communication and coordination, raw material preparation, process execution, and culminating in the delivery of finished products to customers. The team also conducted time observations for each sub-activity within the ten main production steps. Based on these observations, a Current State Value Stream Mapping (VSM) was created, as illustrated in Figure 3.

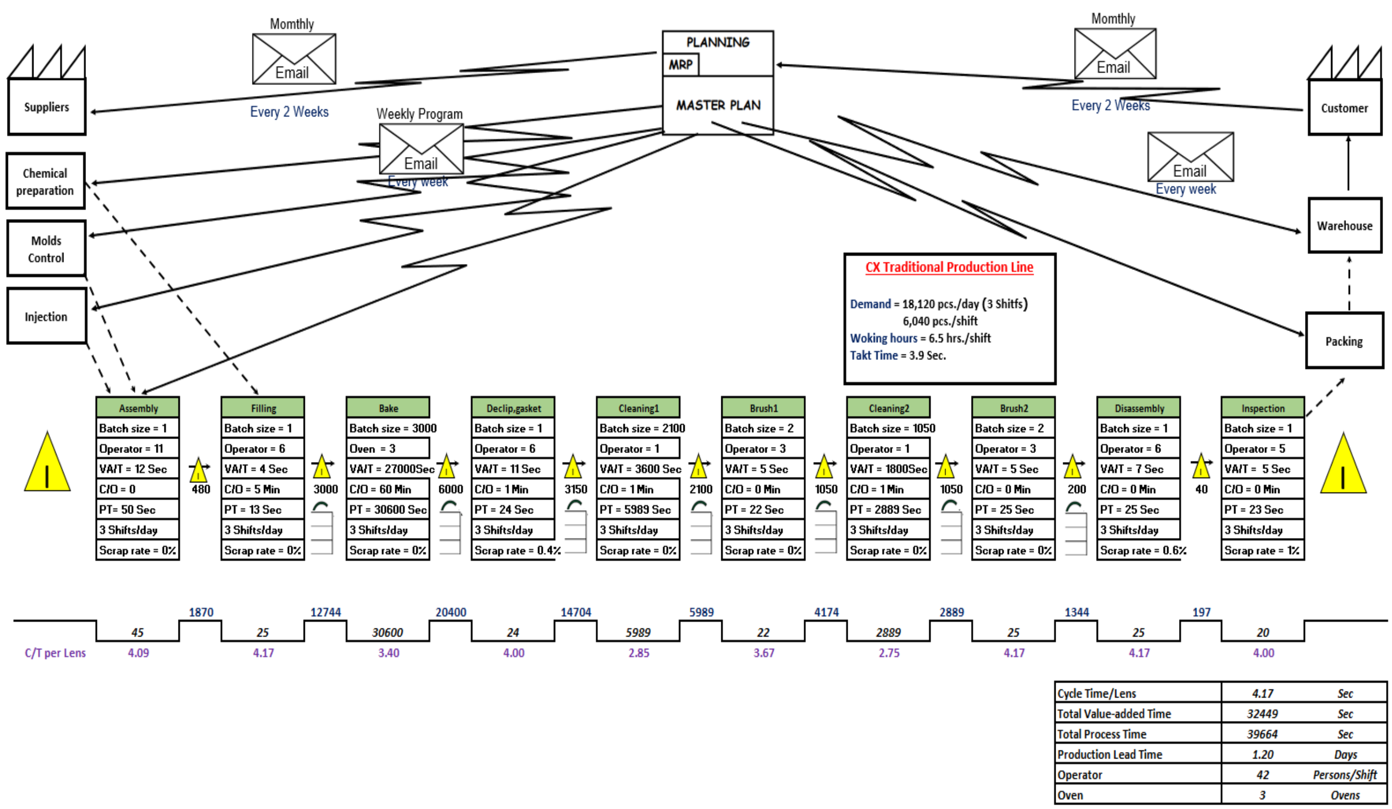

Figure 3. Current State VSM of Lens Production Process.

From Figure 3, it illustrates the flow of information, known as Information Flow, which entails the transmission of data from the production planning process to the relevant processes, including raw material suppliers, raw material preparation units, production units, packaging units, storage units, and ultimately to customers. As for the workflow, it depicts the production process of eyeglass lenses, specifically for convex lenses, starting from the raw material acquisition process, including chemical solutions, molds, and seals, and passing through all 10 steps until the completed work is delivered to customers, namely the packaging units, storage units, and customer delivery in sequential order. When considering the process box, a data table with seven components can be identified, namely batch size, operator count per process, value-added time (VA/T), changeover time (C/O), process time (P/T), shift/day count, and scrap rate. In the lower part of the value stream diagram, the timeline segment is represented by a line that indicates the timing aspects. On the bottom right corner of the value stream diagram, there is a summary box that presents the duration that occurs, including cycle time per lens, total value-added time, production lead time, operator count, and number of oven machines. If the system has been improved, these values should be lower, with a focus on reducing wasted time due to waiting or non-value-added activities. By calculating the time required for the production process of convex eyeglass lenses in the current conventional production line using time measurements in each activity, it is found that the average production time per lens (cycle time) is 4.17 seconds, which is higher than the customer's desired time (takt time) of 3.9 seconds. Bottlenecks occur in the process, preventing the work from being produced as planned. The total value-added time in the process is 32,449 seconds (540.82 minutes), the total production process time is 39,664 seconds (661.07 minutes), and the total lead time is 1.20 days. The operator count per shift is 42, and the number of oven machines in all three shifts is three ovens.

4.2. Wastes in Production Line

The analysis of work processes from the 10 production processes was conducted to identify activities that generate value and non-value-added activities that result in waste in the process using the principle of value analysis. The activities were classified into value-added activities (VA) and non-value-added activities (NVA). Among these activities, there were three types of waste: inefficiency in utilizing the lens oven machines due to incomplete efficiency, which falls under the category of knowledge waste and utilization. This was presented as a proposal to reduce the time for lens baking and setup time for the ovens, aiming to reduce the number of ovens. It was a way to increase machine efficiency from the production unit team but had not yet been improved. Inadequate work performance of the personnel falls under the category of excessive motion, involving unnecessary movement and improper work methods. Lack of assistance tools for easier work, such as a station for removing clips and seals from molds, should be improved to facilitate and simplify the work. Lastly, inappropriate work processes fall under the category of extra processing, where excessive processes can be avoided. By organizing the process to be more appropriate and reducing non-value-added activities, such as in the cleaning process, where the personnel had free time while the machine was running, it was found that one person could work with two lens cleaning machines by rearranging the work sequence. Additionally, the first and second mold edge brushing stations could increase the number of brushing pieces from two to three in one work cycle to reduce the working time, resulting in a reduced number of operators from six to three persons.

4.2.1. Improvement of Lens Baking Process

The lens baking process, polymerization, in the oven is a time-consuming operation, with each baking cycle taking up to 450 minutes. Three ovens are utilized concurrently in a rotating shift pattern. To address inefficiencies and reduce waste in this process, the researchers employed the ECRS (Eliminate, Combine, Rearrange, Simplify) principle for analysis. Through surveys, brainstorming sessions, and process analysis with the production team, it was concluded that there is waste in the baking process. Specifically, completed lenses were left in the oven for an additional 120 minutes, which could be reduced without compromising the quality of the lenses. Consequently, the baking time in the oven was adjusted from 450 minutes to 330 minutes per oven. Furthermore, an analysis of the setup time for lens baking was conducted, identifying the unnecessary activity of keeping the oven open while waiting for the lens. This activity had a duration of 45 minutes, which was deemed unnecessary. Consequently, the setup time for lens baking was reduced from 60 minutes to 15 minutes, resulting in a time reduction of 45 minutes. As a result of these improvements, the total baking process time was reduced from the original 510 minutes to 345 minutes. Subsequently, the researcher created a Gantt Chart to visualize the revised oven utilization and setup time, which revealed that the use of ovens in a rotating shift pattern could be reduced from three ovens to two ovens, resulting in a reduction of one oven, as depicted in Figure 4.

4.2.2. Improvement of Mold Cleaning Process

In the mold cleaning process, after removing the clips and seals, the molds attached to the lenses are cleaned by immersing them in a chemical solution in a cleaning tank before being scrubbed. The cleaning process is divided into two stages: the first cleaning cycle consists of cleaning 2,100 molds, and the second cycle involves cleaning 1,050 molds. The team analyzed the work relationship between the operators and the cleaning machines for the first and second cleaning cycles. It was observed that two operators were controlling the first cleaning machine, while one operator was assigned to the second cleaning machine. The analysis revealed that the waiting time for the machine's operation could be reduced by reassigning one operator from the original ratio of one operator per one machine to one operator per two machines. Thus, the operator ratio for the first cleaning machine reduced from one operator to one machine to one operator to two machines, as shown in Table 1.

Table 1. Man-machine Chart for Cleaning Process 1 and 2.

	Operator 1	time (sec.)	mark	Cleaning M/C 1	time (sec.)	Mark	Cleaning M/C 2	time (sec.)	Mar k
1.	Move parts to M/C 1	272		Idle	517		Idle	892	
2.	Load parts to a tub no.1 (M/C 1)	245							
3.	Move parts to M/C 2	250		Tub no. 1 working	900				
4.	Load parts to a tub no.1 (M/C 2)	125							
5.	Idle	525					Tub no. 1 working	900	
6.	Load parts to a tub no. 2 (M/C 1)	247		Idle	247				
7.	Idle	128		Tub no. 2 working	900	Idle			
8.	Load parts to a tub no. 2 (M/C 2)	128					Idle	128	
9.	Idle	644					Tub no. 2 working	900	
10.	Load part to a tub no.3 (M/C 1)	243		Idle	243				
11.	Idle	13		Tub no. 3 working	900				
12.	Unload parts from a tub no. 2 (M/C 2)	132					Idle	676	
13.	Move parts from M/C 2 to Brushing 2	169							
14.	Move parts to waiting area of M/C2	250							
15.	Load parts to a tub no. 1 (M/C 2)	125							
16.	Idle	211					Tub no. 1 working	900	
17.	Unload parts from a tub no. 3 (M/C 1)	243		Idle	243				
18.	Idle	446		Tub no. 4 working	900				
19.	Load parts to a tub no. 2 (M/C 2)	128					Idle	128	
20.	Idle	326					Tub no. 2 working	900	
21.	Unload parts form a tub no. 4 (M/C 1)	251		Idle	875				
22.	Move parts from M/C 1 to Brushing 1	323							
23.	Unload parts from a tub no. 2 (M/C 2)	132					Idle	301	
24.	Move parts from M/C 2 to Brushing 2	169							
	Total working time	3,182		Total working time	3,600		Total working time	3,600	
	Total idle time	2,543		Total idle time	2,125		Total idle time	2,125	
	Total time	5,725		Total time	5,725		Total time	5,725	
	% Utilization	55.58%		% Utilization	62.88%		% Utilization	62.88%	

Mark : Work Independent Work together Idle

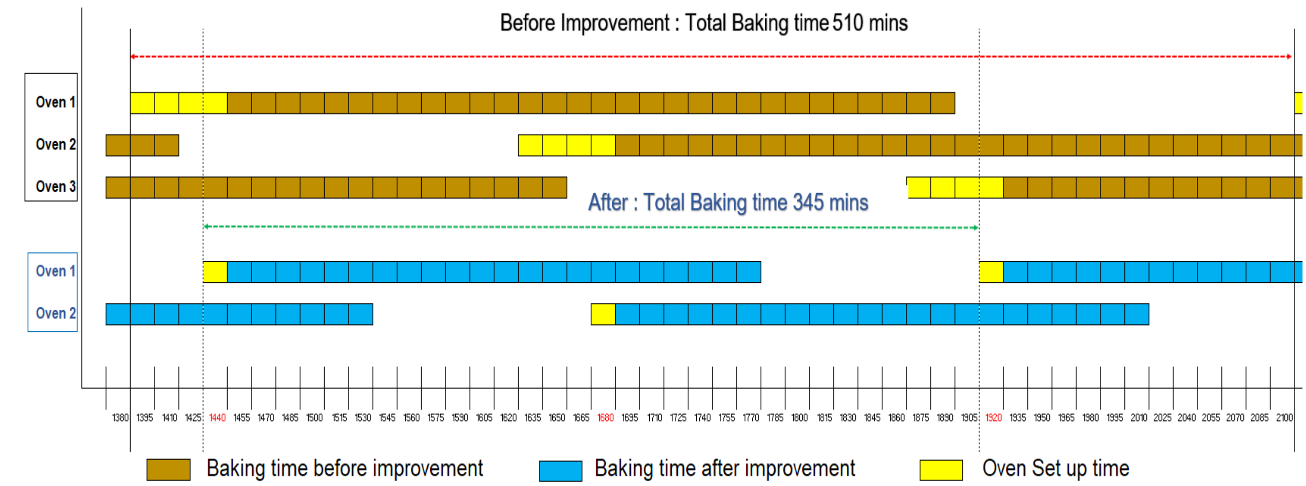

Figure 4. Oven Baking Plan before and after Improvement.

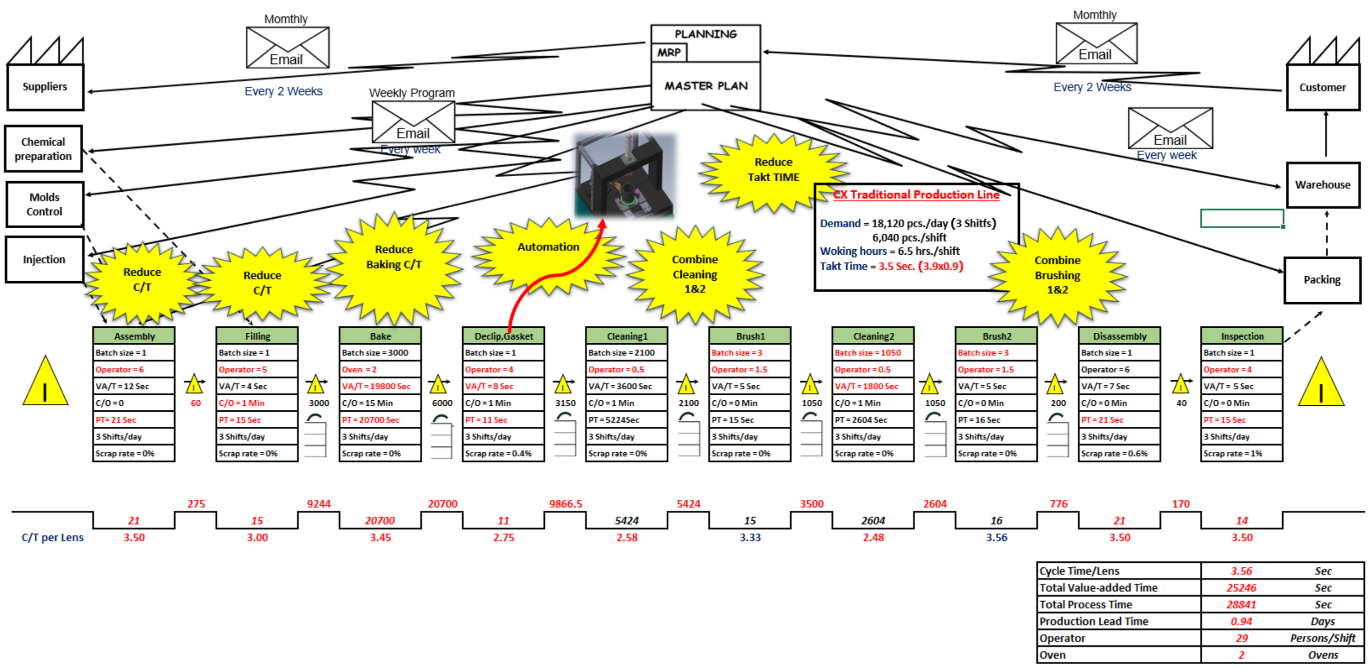

Figure 5. Future state VSM of Lens Production Process.

4.2.3. Improvement of Mold Brushing Process

The first and second mold edge polishing processes involve similar work steps and require a total of six operators, with three operators stationed at each work station. In each round of mold edge brushing, two molds are polished. The time required for the first mold edge brushing is 22 seconds, while the second mold edge brushing takes 25 seconds. Through analysis, it was found that the inspection activity for the molds could be reduced by 3 seconds, and the pre-polishing air blowing process could be reduced by 4 seconds. Additionally, further analysis revealed that the number of molds brushed in each round could be increased from two molds to three molds, resulting in an average brushing time per mold reduced from 4.17 seconds to 3.56 seconds. Consequently, the number of operators for the first and second mold edge brushing processes could be reduced from six to three operators.

4.3. Develop Future State Value Stream Mapping

After analyzing the waste and identifying guidelines to reduce waste in the production process of covex eyeglass lenses in the original manufacturing process, a further analysis was conducted to propose waste reduction strategies in non-value-added activities, leading to improvement and modification in each production process. This resulted in the creation of a Future-state Value Stream Map (VSM) by reducing the number of steps from the original 94 steps to 72 steps, a reduction of 22 steps. Additionally, the average cycle time per lens production decreased from 4.17 seconds to 3.56 seconds prior to the improvement.

The total accumulated time in the value-creating processes before improvement was 32,449 seconds (540.82 minutes), which reduced to 25,246 seconds (420.77 minutes) after improvement. The total production process time before improvement was 39,664 seconds (661.07 minutes), which decreased to 28,841 seconds (480.68 minutes). The lead time for the entire process before improvement was 1.20 days, which decreased to 0.94 days. The number of employees per shift before improvement was 42, which reduced to 29 operators. Furthermore, the number of lens baking ovens used in all three shifts in the original rotating production process decreased from 3 ovens to 2 ovens.

By reducing non-value-added activities in the production process of long-focus eyeglass lenses in the original manufacturing process of the case study company, it has resulted in cost reduction, time savings, and increased productivity for the company. The Future State VSM, represented in Figure 5, illustrates these improvements.

5. CONCLUSIONS

This This research study focused on the application of value stream mapping to reduce waste in the production process. The case study examined the production process of convex lens eyewear in a specific company. The objectives of the case study were to investigate the waste in the production process of convex lens eyewear in the original production process of the case study company and propose improvement measures to eliminate waste and enhance the production line.

The research began by studying the original production process of convex lens, starting from the initial stages until the final stages. Through the analysis of waste using value stream mapping, three categories of waste were identified. Firstly, there was waste resulting from the inefficient utilization of lens oven machines, which fell under the category of waiting waste. This waste was addressed by proposing time reduction in lens baking and oven setup to decrease the number of oven machines used, thereby increasing the machine utilization efficiency based on the recommendations from the production team.

Secondly, there was waste arising from operators not working at full capacity, categorized as motion and waiting wastes. It was observed that there were unnecessary movements, improper work methods, lack of ergonomic tools, and inadequate work processes. To address these wastes, the proposed measures included analyzing the workflow to improve machine utilization efficiency, designing work processes to enable employees to work at full capacity, and optimizing inefficient work processes to enhance efficiency.

Lastly, there was waste categorized as "Extra Processing." This waste resulted from unnecessary processing steps that could be avoided. The proposed measures included designing more suitable processes, eliminating non-value-added activities, and improving efficiency accordingly. The improvement measures were implemented in sequence, following the principles of ECRS (Eliminate, Combine, Rearrange, Simplify), which were found to effectively reduce waste in the production process.

As a result of the research, the total process time, including all stages, was reduced from the original 661.07 minutes to 480.68 minutes, representing a 27.29% reduction. The total production lead time was reduced from 1.20 days to 0.94 days, indicating a 21.67% reduction. The number of employees per shift decreased from 42 to 29, resulting in a 30.95% reduction. Additionally, the number of lens oven machines used in three shifts was reduced from 3 to 2, representing a 33.33% reduction. These improvements enabled the company to meet the planned production schedule and deliver products to customers on time. Moreover, the value stream mapping demonstrated a balanced production line, leading to enhanced efficiency and productivity.

6. ACKNOWLEDGEMENT

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