LEAN MANUFACTURING TO REDUCE PRODUCTION TIME FOR PRESSURE VESSEL PRODUCTION

Bintang Timur Lazuardi[1] and Moses Laksono Singgih[2]

[1] Interdisciplinary School of Management and Technology,
Institut Teknologi Sepuluh Nopember Surabaya, Surabaya, Indonesia
e-mail: Bintanglazuardi.me@gmail.com
[2] Interdisciplinary School of Management and Technology,
Institut Teknologi Sepuluh Nopember Surabaya, Surabaya, Indonesia
e-mail: moseslsinggih@ie.its.ac.id

Abstract. In a fiercely competitive business landscape, every company must optimize its resources and minimize wastage in the production process. At the Pressure Vessel Company (PVC), a study revealed various areas of waste, including non-compliant raw materials, delayed engineering documents, extended production times on each working floor, and lengthy material approval processes. The main objective of this research was to identify and analyze waste in the production process, as well as propose a reduction in manufacturing time. The researchers utilized eight waste tools, value stream mapping, to map the production process. The current state of the production process was documented, and eight specific wastes were identified, with the three most significant being waiting, extra processing, and motion. The analysis of the production process revealed an efficiency of only 19.13%, calculated by comparing 4655 hours of non-value-added activity to 890.6 hours of value-added activity. To improve this, changes were made to various production processes using future state map projections and proposed actions to reduce waste. As a result, non-value-added activities were reduced to 2515 hours, leading to a notable increase in production process efficiency to 35.41%. Based on the findings, several recommendations were made to enhance PVC's operations. These include establishing a centralized office space, improving document distribution systems, building a robust IT infrastructure, and investing in ERP/SAP systems and new machinery.

Keywords: heavy industries, production lead times, non-value-added activities, pressure vessel production, waste analysis.

1 INTRODUCTION

To stay competitive in today's markets, manufacturing companies must regularly evaluate and enhance their manufacturing systems. The idea behind lean manufacturing is to eliminate any production waste that doesn't contribute value to the products or customers [1]. Implementing lean requires management to thoroughly understand the

M. Hartono et al. (eds.), *Proceedings of the 4th International Conference on Informatics, Technology and Engineering 2023 (InCITE 2023)*, Atlantis Highlights in Engineering 21,
https://doi.org/10.2991/978-94-6463-288-0_5

existing processes to identify areas for improvement and address challenges. If lean is not implemented properly or if there is a limited understanding of the situation, it may result in an unsuccessful lean journey.

The aim of this study on Lean manufacturing is for management to create a visual tool that depicts the existing process of pressure vessel manufacturing. The goal is to identify the necessary steps for implementing Lean practices based on a clearly defined process map, which will help estimate the improvements achieved after implementation. To achieve this, the Lean methodology of value stream mapping (VSM) is employed to restructure manufacturing systems. The objective is to develop VSM as a methodology for implementing Lean principles in the pressure vessel manufacturing sector. This methodology is implemented and evaluated through direct observation and research.

Lean manufacturing is a widely recognized approach to improving processes. Its main objective is to provide value to customers by eliminating waste. In an ideal scenario, manufacturing processes should be efficient, producing high-quality and reliable products. However, in reality, there is always waste present in these processes, which presents an opportunity for improvement [2]. In a Lean manufacturing process, eight categories of waste can be identified. These include overproduction, waiting times, unnecessary motion, excessive processing, inventory, unnecessary movement of employees and equipment, defects, and underutilized talent [3]. The removal of waste from a manufacturing process is a crucial component in the creation of a value stream map.

PVC, a prominent manufacturer of heavy industrial equipment, specializes in producing pressure vessel products. Over the course of more than 50 years, PVC has established a reputation for delivering over 1000 high-quality pressure vessel products to a diverse customer base, including the oil & gas, power generation, and agro-industry sectors. However, recent research conducted within the past five years has revealed a concerning trend of late deliveries for project orders fulfilled by PVC. This issue is illustrated in Graphic 1, which displays the increasing number of delayed deliveries for pressure vessel products from 2018 to 2022. These delays have the potential to result in customer dissatisfaction, which is particularly troubling considering the superior quality of PVC's products. Given that PVC consistently receives project orders for manufacturing pressure vessels each year, it becomes imperative to address this problem promptly. Referencing Fig. 1, it is evident that there is a need to address the production delays to ensure the timely delivery of pressure vessels.

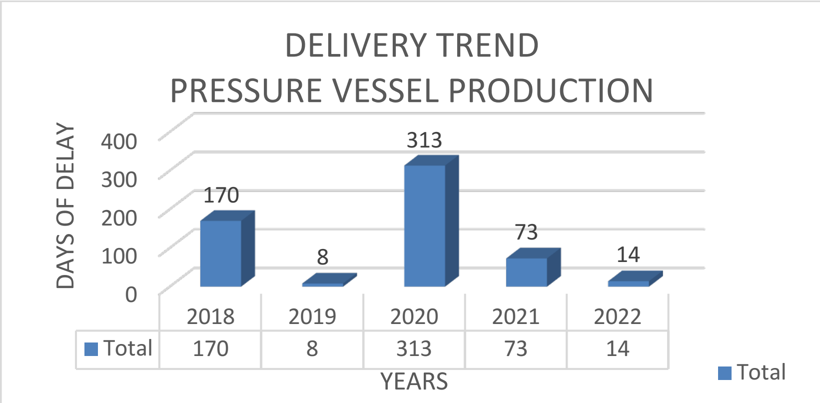

Fig. 1. Delay (days) of pressure vessel production.

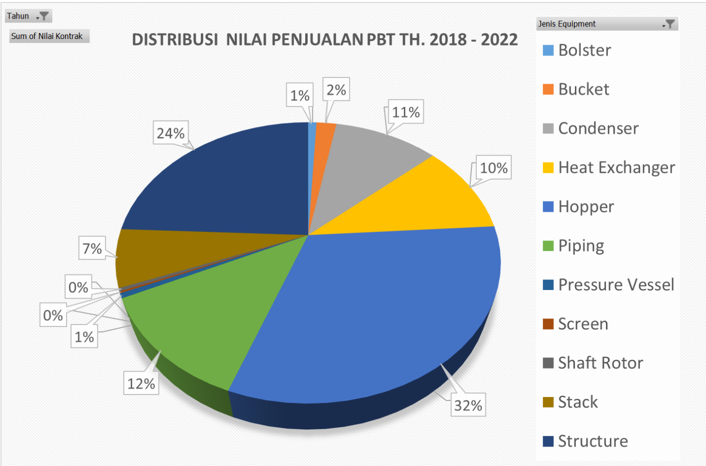

Fig. 2. Pressure vessel is the superior product in a company called Pressure Vessel Company (PVC), which has contributed 32% of sales of PVC.

To effectively implement value stream mapping (VSM) in pressure vessel manufacturing, a systematic approach is necessary. The primary goal of this study is to minimize the lead time in the production of pressure vessels by utilizing value stream mapping. By examining the manufacturing process, several inefficiencies are identified and targeted for improvement.

2 LITERATURE REVIEW

Value stream mapping (VSM) is a visual representation that encompasses the flow of both materials and information within the manufacturing process. It provides a comprehensive view of all the steps involved in the production process. A value stream refers to all the activities, whether they add value (Value Added - VA) or do not add value (Non-Value Added - NVA), that are required to bring a product through the entire process, starting from the raw materials stage and culminating in the delivery to the customer [5]. The primary objective of value stream mapping (VSM) is to achieve waste elimination, lead time reduction, and cost reduction once inefficiencies have been identified [10]. VSM offers a comprehensive visual representation that illustrates the interconnected flow of information and materials within a process [6]. Value stream mapping (VSM) is a versatile tool that goes beyond focusing on a single process. Instead, it provides a holistic view of the entire production process, making it a potent and valuable tool [11].

To create a value stream map (VSM), a standardized set of icons, as demonstrated in Rother and Shook's work, is used for visualization [5]. To facilitate enhancements in the production process, a visual representation known as the current state map is created, providing a snapshot of the existing workflow and practices [6]. The future state map represents an idealized depiction of how tasks and processes can be carried out in an optimized manner, reflecting a vision of how things should ideally be done [12].

Before creating the future state map, it is essential to have a good understanding of the fundamental calculations involved in future state mapping.

3 METHODOLOGY

The subsequent sections outline a systematic approach for developing both the current state and stream maps of the future state, which are subsequently utilized in the process.

3.1 Creating Current State Value Stream Map

1. **Choosing product families**: Given that the company has multiple product families, the initial crucial step is to select a specific product before proceeding further. In this case, a pressure vessel is chosen due to its superior standing within the company. To facilitate the process, the idea of utilizing reconfigurable manufacturing systems can be applied, which involves grouping products into families based on various factors including weight, shape, size, changeover time, material type, and other relevant considerations [8, 9, 4].
2. **Recognizing process step**: The identification of processes is accomplished through direct observation and interviews conducted with office employees, workstation supervisors, and production managers.
3. **Developing of current state map**: The process of creating the current state map will be executed following the steps outlined below :

   Step I - Calculate Takt time

   $$Takt\ time = \frac{effective\ work\ time}{customer\ requirement} \quad \text{...(1)}$$

   Step II – Mapping the flow of the process

   This step encompasses a series of processes that are executed sequentially to accomplish product development. It also involves determining the cycle time, changeover time, and uptime for each process. In the context of this research, there are ten specific processes outlined for completing the aforementioned products.

Step III – Mapping the flow of the Information

The information flow is integrated to include demand information, which is a critical factor in determining the production process within the system. Various data points such as cycle time (c/t), changeover time (c/o), uptime, total lead time, and more are also taken into account.

Step IV – Mapping the flow of the material

The movement of materials, starting from raw materials and culminating in finished goods, occurs between the supplier and the customer.

Step V – Determine the overall cycle time of the product

Once the material and information flows have been mapped, a timeline is presented at the bottom of the map. This timeline illustrates the processing time for each operation and the transfer delays between operations. It serves as a tool to identify both the value-adding steps and the areas of waste within the current system.

Step VI- Elaborate on offline activities.

This section encompasses activities such as order placement, material supply, daily scheduling, and monthly forecasting. These activities are effectively represented using icons for transportation, suppliers, and information flow lines.

4. **Analysis of current state map:** The current state map must provide a comprehensive depiction of all process steps, including sufficient details on how each step is executed and what occurs to the processed items. This level of detail allows for the identification of problem causes and enables the implementation of improvements to enhance the flow, efficiency, reliability, and flexibility of the process. The current state map can be tailored to be as detailed or simplified as necessary and can also have multiple versions to cater to various internal or external stakeholders.

3.2 Developing Value Stream Map of the Future State

Creation of Future State Map: the creation of a future state map can be as follow

Step I-Determining takt time

Due to the wide variety of products and the potential for low production volumes in a made-to-order (MTO) setting, the concept of using a pure takt time is not suitable. Instead, it is more appropriate to adopt an average takt time approach [23].

Step II-Developing continuous flow between the process

Various factors can influence the uninterrupted flow of a product on the shop floor, such as uneven cycle times among different processes, shared resources, and the proficiency of operators. During this phase, the objective is to attain a continuous flow whenever possible, by identifying and resolving any obstacles that hinder the smooth progression of the product.

Step III – Developing a pull-based system
As described by Rother and Shook [7], It is strongly advised to establish a pull system rather than a push system.
Step IV – Defining the pacemaker process
The pacemaker process plays a vital role in overseeing the pace of the upstream processes by actively pulling the parts through. It also takes charge of the downstream processes by carefully controlling the release of work or products, maintaining a First-in-First-out (FIFO) processing flow to meet customer requirements effectively.

4 CASE STUDY

4.1 Current State Map

The case study in this publication is the process of making pressure vessels. The case study centers around a pressure vessel manufacturing company located in Indonesia. The VSM was created using actual data collected from this specific company. To establish product families, an analysis was conducted using five years of production data. The pressure vessel, being the most frequently produced product over the past five years, was selected as the focus for the VSM. Figure 3 visually demonstrates that the pressure vessel has outpaced other industrial equipment in terms of production volume over the past five years.

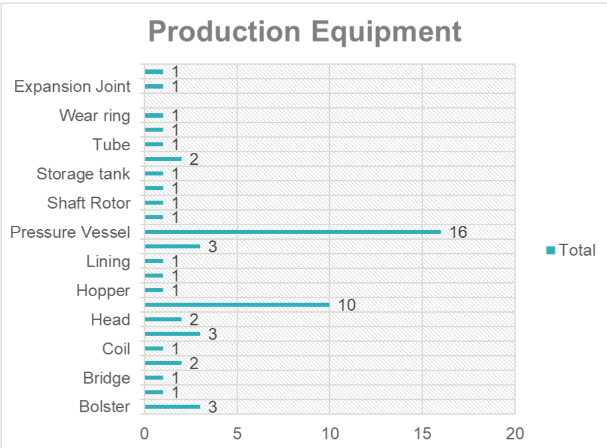

Fig. 3. Frequent products to be produced.

After the product is chosen the mapping using a value stream map can be carried out. The process of production of pressure vessels is shown in Fig. 4.

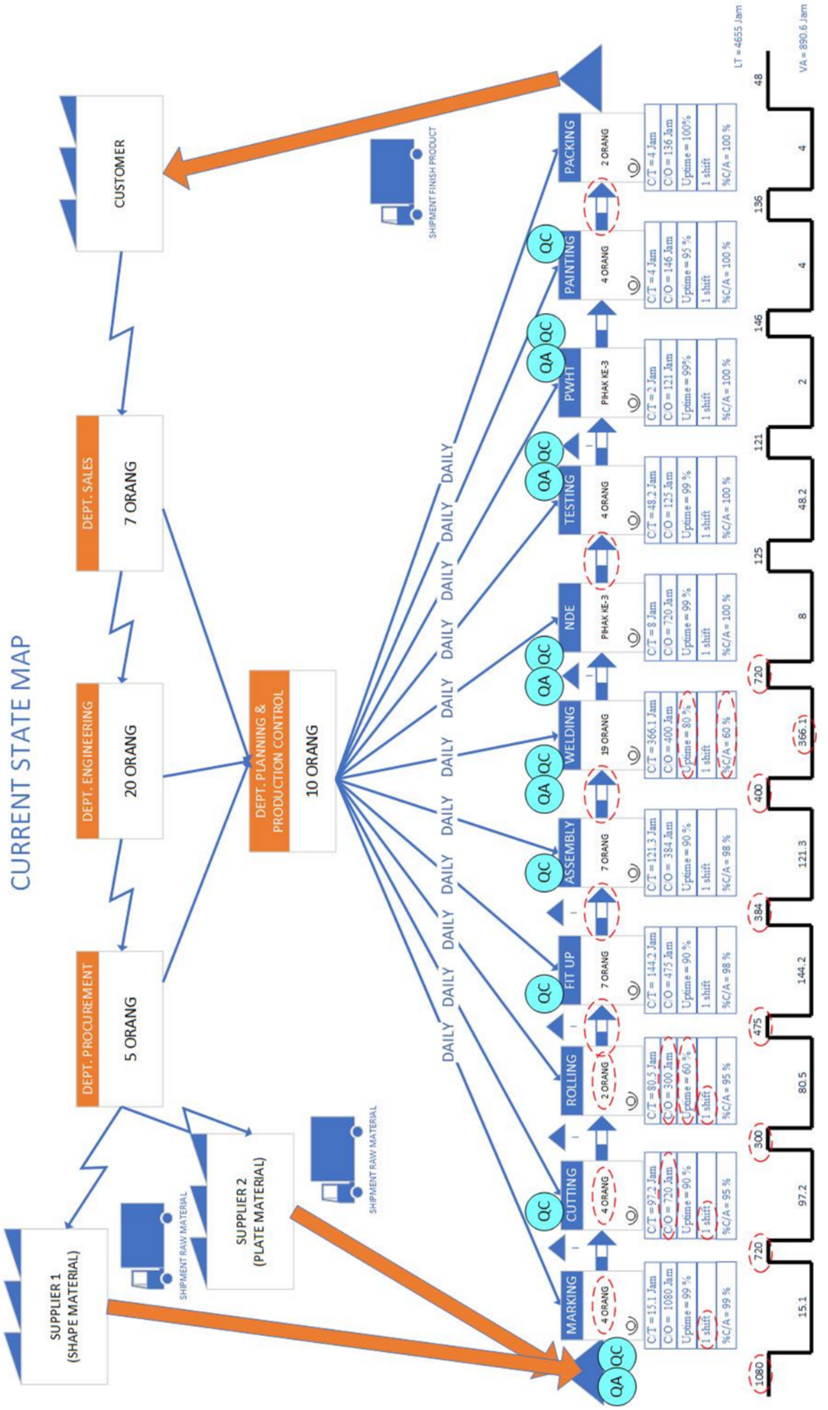

Fig. 4. Current state map of pressure vessel production

The value stream commences in the upper right corner when a customer contacts the sales department to communicate their requirements. Following the customer's order placement, the sales department forwards the details to the engineering department, initiating the process of creating drawings, bills of quantity, cutting plans, and other necessary documents. Concurrently, production preparations are also initiated. Those documents particularly bills of quantity generated for the procurement department. Then the procurement department starts to source, negotiate & finalize the purchase of materials. Then after the material arrives in the shop the production begins. The following observations from the current VSM could be made :

1. Lead time material on the shop has the longest lead time among all the processes (1080 hours).
2. Availability of roll machine is only 60%.
3. The welding process has the longest cycle time (366.1 hours) among all processes.
4. The availability of welding machines is the lowest (80%) among all processes.
5. The completion & accuracy result of welding is the lowest among all processes (60 %).
6. The efficiency of the manufacturing process as per the current state VSM is VA/LT = 890.6 hours/4655 hours = 19.13 %

In value stream mapping (VSM), the cycle time is measured in hours. The current lead time, as recorded in the VSM, is 4655 hours. Within the current VSM, the fit-up process serves as the pacemaker process, overseeing and regulating the pace of operations upstream.

In the future VSM some improvement plans to be made the future. Some improvements are as follows:

1. Reduce lead time material by cutting the approval process for purchase material by implementing one roof approval.
2. Increase available shift time from 1 shit to 2 shifts for marking, cutting, and rolling since these processes are the pacemaker.
3. Investment in roll machine so there will 2 workstations can be used.
4. Repair & replace the welding machine to increase the availability of the welding machine.
5. Training of QC personnel, increasing safety & ergonomy of the work environment, place the right person based on what type of welding to be carried out.
6. Using a pull system starting from fit-up, assembly, welding, and packing process, will help a lot to reduce waiting time and processing based on batch production/work order number.

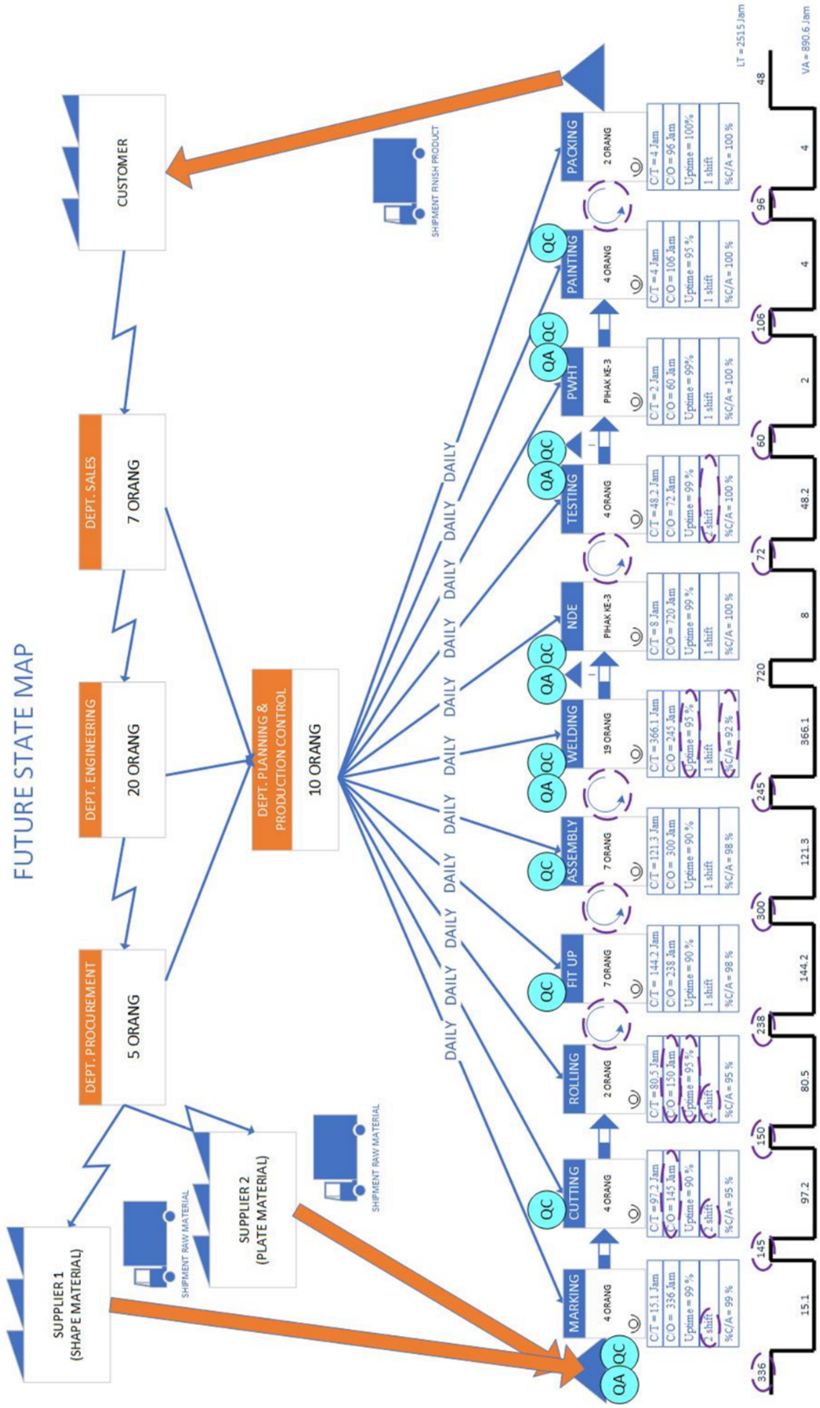

Fig. 5. Future state map of pressure vessel production

In the future state value stream map (VSM), the lead time is projected to decrease significantly from 4655 hours to 2515 hours. Additionally, the future state VSM demonstrates enhanced efficiency, improving from 19.13% to 35.41%.

4.2 Discussion

The manuscript discusses several recommendations to improve the efficiency and productivity of the manufacturing process. The proposed changes include reducing lead time by implementing a streamlined approval process, increasing available shift time, investing in additional machinery, repairing or replacing equipment, training personnel, and implementing a pull system.

The authors suggest that implementing a one-roof approval process for purchasing materials can significantly reduce lead time. This change eliminates the need for multiple approvals and streamlines the procurement process. While this recommendation can improve efficiency, it may require adjustments to the existing system and stakeholder buy-in.

Another recommendation is to increase the available shift time from one shift to two shifts for marking, cutting, and rolling processes. By maximizing resource utilization and minimizing idle time, this change aims to increase overall productivity

Recommendation:

1. Implementing a one-roof approval process for purchasing materials can significantly reduce lead time. By eliminating the need for multiple approvals, the procurement process becomes more streamlined and efficient.
2. Increasing the available shift time from one shift to two shifts for marking, cutting, and rolling can lead to increased productivity. This change allows for continuous operations, maximizing the utilization of resources and reducing idle time.
3. Investing in an additional roll machine and having two workstations can enhance production capacity. This helps meet demand and prevents bottlenecks in the manufacturing process.
4. Repairing and replacing the welding machine will increase its availability, reducing downtime and ensuring smooth operations. This improves overall productivity and minimizes delays caused by equipment issues.
5. Training the QC personnel and enhancing safety and ergonomics in the work environment is crucial for maintaining quality standards and preventing accidents. Placing the right person for specific welding tasks improves efficiency and reduces errors.
6. Implementing a pull system throughout the production process, starting from fit-up, assembly, welding, and packing, can significantly reduce waiting time. By aligning production with demand and focusing on batch production or work order numbers, the workflow becomes more efficient.

Considerations:

1. Implementing a one-roof approval process may require significant changes in the existing procurement system and may face resistance from stakeholders

accustomed to the current process. Proper training and change management strategies are necessary to address any potential challenges.
2. Increasing the number of shifts may incur additional costs for labor, utilities, and maintenance. Proper planning is required to ensure that the benefits gained from increased productivity outweigh the added expenses.
3. Investing in a new roll machine involves capital expenditure. A thorough cost-benefit analysis should be conducted to determine the feasibility and return on investment before making the decision.
4. Repairing or replacing the welding machine may involve upfront costs and potential disruptions to production during the maintenance or installation process. A proper assessment of the cost, impact on production, and timing should be considered.
5. Training QC personnel and improving safety and ergonomics require investment in resources, time, and training programs. Balancing these efforts with other production priorities and ensuring their effectiveness is essential.
6. Implementing a pull system requires careful planning and coordination between different stages of the production process. It may require reorganizing workflows and training employees accordingly. Resistance to change and initial implementation challenges should be anticipated.

Requirements for Implementation:

1. Stakeholder buy-in and support for implementing changes in the approval process and workflow adjustments.
2. Sufficient funds and resources to invest in additional equipment, such as a roll machine and welding machine.
3. Training programs for QC personnel to enhance their skills and knowledge.
4. Time and resources are allocated for repairing or replacing the welding machine without causing significant disruptions to production.
5. Implementation of safety and ergonomics measures, including proper training, equipment, and work environment modifications.
6. Planning and coordination to establish a pull system throughout the production process, including adjusting workflows and providing necessary training.

5 CONCLUSION

In conclusion, the implementation of lean production principles and the utilization of tools such as Value Stream Mapping (VSM), Current State Mapping (CSM), and Future State Mapping (FSM) have demonstrated significant improvements in the production process of pressure vessels. Lean production is an ongoing journey of continuous improvement, where the focus is on eliminating waste and constantly striving for better outcomes. VSM has proven to be an invaluable tool in identifying and eliminating waste, with each cycle revealing new areas for improvement. Through the adoption of lean practices, a culture of continuous improvement is fostered within the organization. The application of CSM and FSM has provided valuable insights into areas of potential improvement and suggested strategies for reducing waste and enhancing throughput. As a result of these efforts, the lead time for pressure vessel production has been reduced by an impressive 60.23%, while the efficiency has increased from 21.32% to 26.43%. These achievements highlight the effectiveness of lean manufacturing in streamlining production processes and delivering tangible results. The journey towards lean production is an ongoing commitment to excellence and efficiency, ensuring that the organization remains competitive in the ever-evolving global market.

References

1. J. C. Green, J. Lee, and T. A. Kozman, "Managing lean manufacturing in material handling operations," International Journal of Production Research, vol. 48, no. 10, pp. 2975–2993, 2010.
2. H. Lichtenberg, "Applying Lean principal in process industries, "Industrial Maintenance & Plant Operation, vol. 69,no. 6, pp. 24–25, 2008.
3. B. J. Hicks, "Lean information management: understanding and eliminating waste," International Journal of Information Management, vol. 27, no. 4, pp. 233–249, 2007.
4. Zahraee, S.M., et al., Lean manufacturing implementation through value stream mapping: A case study. Jurnal Teknologi, 2014. 68(3): p. 119-
5. Rother, M. and J. Shook, Learning to see: value stream mapping to add value and eliminate muda. 2003: Lean Enterprise Institute.
6. Abdulmalek, F.A., and J.J.I.J.o.p.e. Rajgopal, Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. 2007. 107(1): p. 223-236.
7. Linck, J. and D. Cochran, The Importance of Takt Time in Manufacturing System Design. 1999.
8. Das, B., U. Venkatadri, and P. Pandey, Applying lean manufacturing system to improving the productivity of airconditioning coil manufacturing. The International Journal of Advanced Manufacturing Technology, 2014. 71(1-4): p. 307-323.
9. Galan, R., et al., A systematic approach for product families formation in Reconfigurable Manufacturing Systems. Robotics and Computer-Integrated Manufacturing, 2007. 23(5): p. 489-502.
10. Singgih, M, L. and Koh, J, Implementation Lean Manufacturing Method of Plywood Manufacture. 2020.
11. Singgih, M, L. and Permata, V, M, A Lean Thinking Approach In Minimizing Waste In Order Fulfillment Systems To Reduce Costs And Time (Case Study: PT Kasa Husada Wira Jatim). 2021.
12. Singgih, M, L. and Wahyukusuma, A, Lean Production Approach To Reduce Waste In Glass Production Processes. 2021.