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Research Article

Manufacturing Lead Time Using the Value Stream Mapping (VSM) Approach in the Oyster Mushroom Baglog Production Process

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Abstract : This research focuses on fulfilling demand by reducing the Manufacturing Lead Time (MLT) value at small and medium enterprises (SMEs) of Ungaran mushrooms, which produce baglog for growing oyster mushrooms. This research consists of several stages to optimize the production process for making baglogs in the Ungaran mushroom house, where there is a delay in meeting demand. The first stage of our method is value stream mapping (VSM). This method aims to map the entire process of making a baglog from start to finish. Based on the VSM results, the baglog material mixing process has processes that need improvement. After finding which processes need improvement, the second stage is brainstorming using a fishbone diagram to get the root of the problem in the mixing process. The next stage is looking for root cause analysis of issues in the mixing process. Based on the brainstorming and root cause analysis process, the design and mixing of baglog material tools were improved. Based on the results of the implementation of this tool, it was found that the baglog mixing process time decreased by 58.99 % and the MLT value for the entire baglog production process decreased from 1529,516 minutes to 1405,616 minutes, which is the same as the MLT decrease from 28 days to 26 days.

Keywords : Value stream mapping, oyster baglog production, lean manufacturing.

1 Introduction

Oyster mushrooms are horticultural plants that can be used as food. Its nutritional content is superior to other mushroom types because it contains good nutrients such as vegetable protein without cholesterol. As an alternative food source, oyster mushrooms can help prevent heart disease and hypertension [1]. Based on data from the Indonesian Ministry of Agriculture, total mushroom consumption in Indonesia reached 39 tons. However, the level of mushroom production in Indonesia has yet to achieve this target. In 2019, Indonesia only managed to produce 33 tons of mushrooms. From these data, it can concluded that the level of mushroom consumption in Indonesia exceeds the production level. From 2018 to 2020, mushroom production in Semarang Regency experienced a decline. One of Indonesia's small and medium enterprises (SMEs) engaged in mushroom cultivation is "Ungaran Mushroom". The main focus of this company is the cultivation and production of oyster mushroom baglog.

Baglog is a planting medium for oyster mushrooms in the form of a tubular container measuring approximately 15cm x 30cm, generally made from plastic materials such as polypropylene (PP), polyethylene (PE), or polyvinyl chloride (PVC) [2]. The production level that Mushroom Production in Ungaran Mushroom SMEs can achieve is only around 150 baglogs per day, or in one month, it can only produce 3900 baglogs. However, every month, the average demand for oyster mushroom baglog reaches 5000-8000 pcs. This situation indicates that Ungaran Mushroom SMEs need more time to meet demand. Delays in fulfilling this demand impact the buildup of production quantities, resulting in overtime in the production process. The use of overtime certainly causes production costs to increase compared to production during regular working hours. Today's industry employs lean manufacturing to reduce production time and enhance the production lines of companies experiencing waste [3], [4]. Therefore, using the value stream mapping method, we took a system to identify waste in the oyster mushroom baglog production process.

The utilization of overtime poses supplementary difficulties, chief among them being a rise in production expenses in contrast to standard working hours. The Ungaran Mushroom SME's financial sustainability is impacted by this cost increase, which also calls into question the overall efficacy of its operations. Upon realizing that a systematic approach is required to tackle these obstacles, the research shifts its focus to lean manufacturing principles. There needs to be an apparent discrepancy between the market demand and production capacity, which causes delays in order fulfilment and eventually affects output numbers.

Ungaran Mushroom SMEs must increase output over time to meet the growing demand. Although it helps meet urgent needs over time, it also raises production costs, which impacts the SME's overall operational effectiveness and financial sustainability.

Lean manufacturing is a common tactic in reaction to the problems plaguing the industrial landscape. The main goals of lean manufacturing are reduced waste, improved output effectiveness, and process optimization. Ungaran Mushroom SMEs want to shorten lead times and simplify production procedures using lean manufacturing ideas. Value Stream Mapping (VSM) is this study's critical lean manufacturing methodology. Waste, bottlenecks, and inefficiencies in the production system can be found using the VSM approach. The study aims to identify areas for optimization and improvement by mapping the whole value stream, from the delivery of raw materials to the finished product [3], [5]. Ungaran Mushroom SMEs hopes to match production capacity with market demand, improve overall efficiency, and guarantee long-term sustainability in the cutthroat mushroom sector by strategically implementing lean manufacturing ideas and techniques. A systematic approach is required due to the complex relationship between production capacity, market demand, and operational issues in the oyster mushroom cultivation business. Using Value Stream Mapping with lean manufacturing concepts presents Ungaran Mushroom SMEs with a viable way to fix and decrease inefficiencies.

After mapping the process using VSM, the analysis step is critical for initiating improvements to the mapped process. The analysis stage may use Fishbone diagrams and root cause analysis to find potential areas for improvement by the lean manufacturing concepts outlined earlier. Similarly, fishbone diagrams, known as Ishikawa or cause-and-effect diagrams, are handy for root cause analysis. These diagrams aid in the breakdown of complicated problems into their root causes, allowing for more targeted interventions and process changes. Fishbone diagrams provide a structured framework for identifying potential root causes across various dimensions, including people, processes, and equipment. Root cause analysis is a fundamental quality management method that seeks to discover the root causes of problems or faults [6]. Organizations can improve overall efficiency and prevent recurrence by systematically exploring the fundamental reasons deeper.

Optimizing manufacturing lead time has emerged as a pivotal challenge in the industry's dynamic landscape in recent years. Implementing Lean Manufacturing has been recognized as a potent strategy to address this complexity. Notable works such as "Lean Thinking in Manufacturing" Emphasize the importance of implementing lean manufacturing practices and tools to minimize waste and enhance production lead time [7]–[11]. By doing so, manufacturing companies can achieve the desired product with affordable cost and quality, which is essential for their success in the global market [12]. Panigrahi et al. (2023) have contributed valuable insights for manufacturing companies in Oman and other countries that want to implement Lean Manufacturing practices. The study also shows that companies should consider the benefits and risks of each Lean Manufacturing practice before implementing it; a discernible research gap persists, particularly in customizing Lean Manufacturing to confront lead time challenges specific to certain industries [13]–[17].

Several studies have also confirmed the use of value stream mapping, which is used to reduce waste in the production process [18]–[21]. For example, research by Suhardi et al. It uses VSM to reduce waste in Indonesia's garment industry production process. Based on the results of VSM mapping carried out in the garment industry production process, it was found that there was an increase in production process time of 3 minutes and an increase in line efficiency of 6.17%İThis research has been good at mapping waste that occurs in the production section of the garment industry and can reduce non-added value to increase the productivity of the production process in the garment industry. This has also been confirmed by several studies using value streams to map waste and reduce it to increase productivity on a production line [21]–[24].

Solving waste reduction problems from the lean manufacturing concept cannot be separated from using tools related to continuous improvement. The VSM method is generally followed by several other methods to support solving manufacturing lead time problems. The follow-up method after VSM that is often used is the analysis method using fishbone diagrams and root cause analysis. This method helps to brainstorm the causes of problems to obtain the root of the problem that will be corrected; many of the studies that use this method to solve problems include [25], [26]. Implementing fishbone analysis to find the root of the problem is quite effective. This is illustrated by related research using fishbone analysis to determine all causes of tank leaks [27]. This research has succeeded in describing the overall causes of the entire tank to enter the following analysis stage. This is also in line with the research above, all of which have successfully described the causes of problems using fishbone diagrams [25], [27]. From the discussion of the issues from other research related to lean manufacturing and root cause analysis, we offer a combination of the VSM method and root cause analysis to solve the problems of the Ungaran Mushroom SMEs.

This study seeks to bridge this gap by actively identifying critical factors that can be seamlessly integrated into the Lean framework, enhancing the effectiveness of minimizing lead time. While existing literature provides a foundation, the proposed research seeks innovation by exploring novel avenues to improve the efficacy of Lean Manufacturing in lead time management. It will specifically focus on integrating emerging technologies, leveraging advanced data analytics, and implementing more streamlined strategies for supply chain management. Envisioning these elements introduces a new dimension to Lean Manufacturing, pushing its boundaries and ensuring a more nuanced and tailored approach to lead time reduction.

The objectives of this research encompass a thorough assessment of the impact of integrating new technologies, identifying critical factors influencing lead time, and evaluating the effectiveness of supply chain management strategies in supporting Lean approaches. Through these objectives, the study aspires to contribute to the academic discourse on Lean Manufacturing and offer practical insights for industry practitioners seeking to enhance their lead time management strategies. Ultimately, this research provides a comprehensive understanding of how Lean Manufacturing, when strategically customised and integrated with cutting-edge technologies, can significantly minimize manufacturing lead time in a rapidly evolving industrial landscape.

2 Experimental Methods

2.1 Manufacturing Lead Time

Manufacturing lead time (MLT) is the total amount of time required to process a product, including machine setup time, from the stage of raw materials to the finished product [28], [29]. The following formula is used in the oyster mushroom baglog production process to determine manufacturing lead time:

$$MLT = \sum_{i=1} (T_{suji} + (\frac{Q}{Q_i}.T_{cji}) + T_{noji}) \tag{1}$$

j = product
i = workstation
T_c = setup time for operation
Q = quantity/number of products
Q_i = product output in one operation
T_{no} = non-operation time

2.2 Value Stream Mapping (VSM)

Value stream is a complete series of actions that include activities that add value (value added) and those that do not add value (non-value added), which are needed to deliver products through the main process, namely the production flow from raw materials to finished products, to finished products. It reaches the hands of consumers [30]. The manufacturing industry uses value stream mapping to identify waste in the production flow. Once we identify the source of waste, we need to make improvements to eliminate it. The goal of VSM is to carry out mapping focusing on the entire production flow to find system waste and avoid "traps" where optimization at one workstation can sacrifice the overall production flow optimization. The application of VSM is also quoted from process improvement research. Data was obtained before and after the application of VSM to measure the effectiveness of the lean-kaizen concept. Several tangible and intangible benefits from implementing lean were observed in eliminating defects and rework and increased productivity and product quality. Stadnicka and Litwin (2019) apply the integration of VSM with value stream analysis (VSA) and system dynamics analysis (SDA) [3]. The results of this research are in the form of data to develop human resources for the production line. This research shows that VSM is a flexible tool for combining other methods and improvements

The calculation to measure process efficiency in manufacturing can be using the formula [8], [19]:

$$PCE = \frac{VAT}{PLT} \tag{2}$$

PCE = Process Cycle Efficiency inline production
VAT = Total Value Added time
PLT = Total Production lead time

2.3 Fishbone Diagram And Root Cause Analysis

Fishbone diagrams are a tool to help identify factors that have the potential to influence problems. Based on research conducted by, a fishbone diagram is a cause-and-effect diagram generally influenced by various factors such as materials, machines, humans, methods, and the environment. In this research, the factors that affect the problem of delays in fulfilling demand are machine, environmental, and method factors. Specifically, the fishbone diagram is often used to conduct cause-and-effect analysis, identifying complex causal interactions for specific problems or events. In defect analysis research on fishing boat manufacturing processes, fishbone diagrams have played a role in identifying defects in human factors, machines, materials, and methods that produce recommendations for Improvement. Apart from that, researchers in China also apply fishbone diagrams in research [31]. This research demonstrates that fishbone diagrams are a tool one can use to identify problems in a case.

A systematic, step-by-step technique based on research is used in root cause analysis, a continuous improvement methodology, to determine the causes of unfavourable events or issues. Step-by-step demonstrates that this strategy requires a systematic process to be implemented. Furthermore, research implies that doing so requires preparation, time, and effort. As a result, one must research every aspect of the undesirable circumstance to identify the issue's primary cause [32]. Root cause analysis is the primary method used in research [33] to pinpoint the source of a case's problem. 3x5 why's is one of the methodologies employed in this study.

2.4 Data Collection and Processing

Used primary and secondary data collection to collect data in this research. Preliminary data was collected by directly observing the oyster mushroom baglog production process. Meanwhile, we obtained secondary data from previous research references. We processed the collected data by calculating manufacturing lead time, takt time, value stream mapping, fishbone diagrams, and root cause analysis. Following the data processing, we analyzed this research to propose conclusions. The VSM method yielded results in production process improvements to reduce manufacturing lead time. Figure 1 below illustrates the research process flow.

2.4.1 Initiation Stage

This stage is the initial stage to obtain data from the Ungaran mushroom community by observing, mapping and measuring the process time of each baglog making station. At this stage, the times that have added value and those that do not are also measured. A literature study was also carried out to obtain a comprehensive tool for solving problems in the Ungaran Mushroom MSMEs.

2.4.2 Calculation Stages

This research begins with calculating the manufacturing lead time at each oyster mushroom baglog production workstation. Manufacturing lead time is the total time needed to process a product from raw materials to finished products, including non-operational time such as machine setup time. The manufacturing lead time calculation is done by adding up the production cycle time at each workstation with the machine setup time and non-operation time at the workstation. Apart from calculating manufacturing lead time, takt time calculations are also carried out to calculate the level of available working time relative to customer demand. If production in the current cycle time is higher than the takt time, there will be a production shortage, so customer demand will not be met.

2.4.3 Current State Value Stream Mapping

Current state value stream mapping is carried out after MLT and takt time calculations. Namely, this was in the form of the condition of the production process at Ungaran Mushroom SMEs before repairs were carried out. VSM mapping is carried out in detail, starting from incoming customer demand, which is then received by management and forwarded to the head of production. After that, the head of production plans production (production planning) and procurement of raw materials, then maps the oyster mushroom baglog production process until product delivery arrives for consumers. In VSM mapping, the data displayed is the number of product demands that must be met, product cycle time at each workstation, setup time, non-operation time/transportation time, number of operators, and inventory levels at each workstation. Time in VSM is divided into 2, namely value-added time (processes that provide added value to the product) and non-value-added time (processes that do not offer added value), for example, waiting time or transportation of goods.

2.4.4 Analysis and Improvements

After completing the current state value stream mapping, waste identification analysis was carried out along the oyster mushroom baglog production line using a fishbone diagram and the 5 why tools. Fishbone is used to brainstorm all potential causes of waste in the production line, while the 5 why the method is used to identify the root causes of waste sources in a production process. In this stage, an analysis is carried out in the form of 5 why questions (why) this waste can occur five times until the root of the problem is found. Apart from the above techniques, the root cause analysis (RCA) technique is used to get the root cause of the problem. The stage in determining the root of the problem using RCA is to take data on the factors causing the problem from the fishbone diagram that was created previously. Next, identify the root causes of the factors that have been discovered previously. After finding the root cause of the problem, improvements are made through recommendations and implementation to prevent the problem from recurring. After getting to the root of the problem, the next stage is to design improvements using lean manufacturing tools. The improvements focus on reducing waste so that manufacturing lead times can be reduced and consumer demand can be met.

2.4.5 Future Value Stream Mapping

This stage is carried out by mapping and measuring again after improving the processing time for each oyster mushroom baglog production station. This stage will provide information on the effects of improvements that have been made, whether there are changes in terms of waste or overall manufacturing lead time.

2.4.6 Conclusion

The conclusion from the results of the analysis of improving the production process to reduce manufacturing lead time using the VSM method approach at Ungaran Mushroom SMEs will be a proposal for enhancing the oyster mushroom baglog production process so that it can meet customer demand promptly.

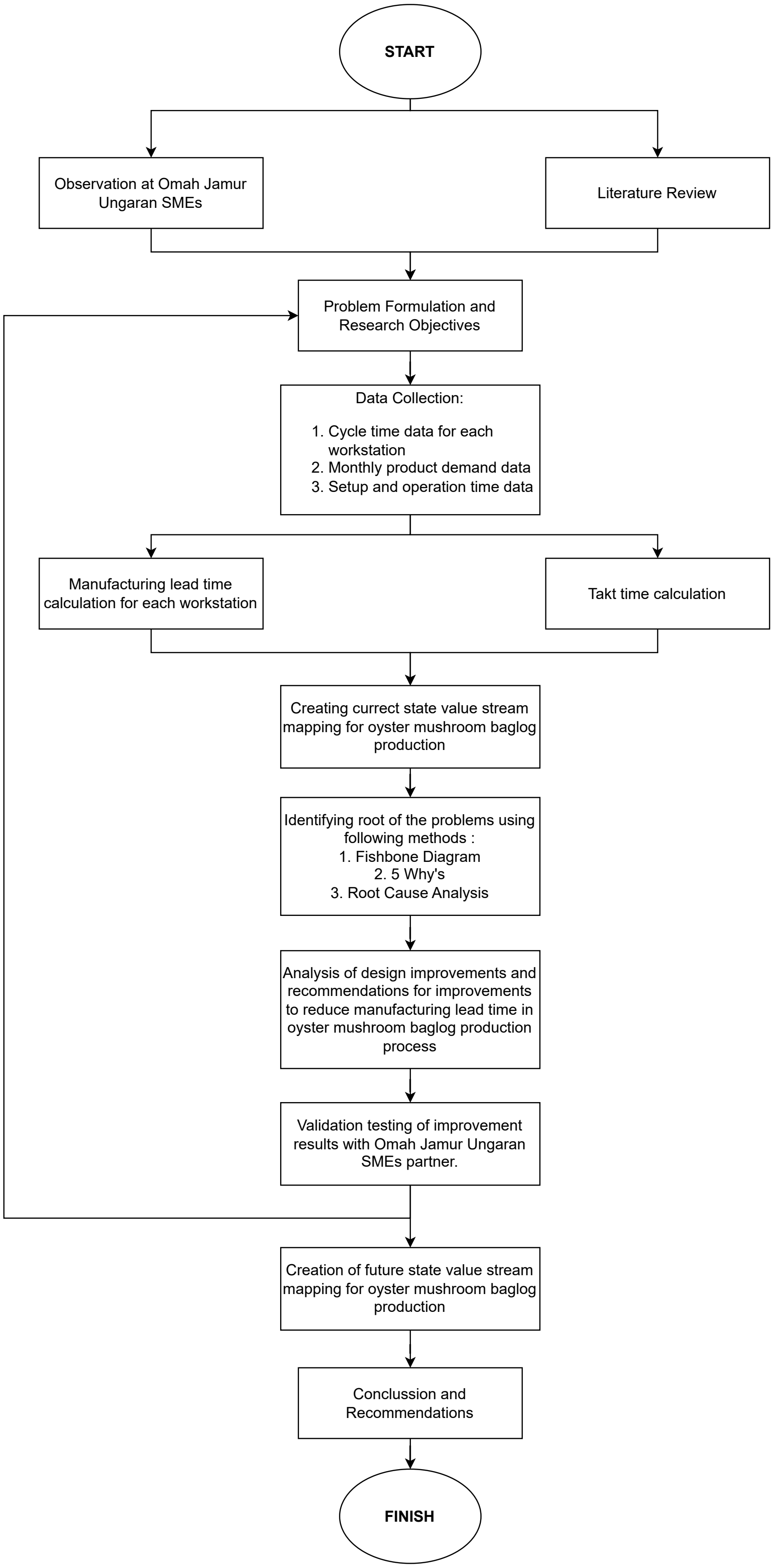

Figure 1: The flow of the research

3 Results and Discussion

3.1 Results

3.1.1 Manufacturing Lead Time Calculation

Manufacturing lead time is the time needed to produce a product. Manufacturing lead time consists of a workstation's production cycle time, setup time, and non-operation time. This research carried out manufacturing lead time calculations daily to meet the average demand at 6462 baglog pcs. Analysis of manufacturing lead time at the oyster mushroom baglog mixing station uses the following formula:

$$MLT = (T_{suji} + (\frac{Q}{Q_i}.T_{cji}) + T_{noji}) = (36 + (\frac{350}{38}.4,526) + 6) = 71,766 \ \ min \tag{3}$$

Meanwhile, see the table below to find the MLT value at each workstation.

Table 1: Manufacturing Lead Time Each Work Station

Manufacturing Lead Time (Minutes)							
Mixing	Sifting	Packaging	Pressing	Providing Cover	Sterilization	Seeding	Total
71,776	39,818	80,901	56,682	103,858	880,744	295,736	1529,516

Table 1 shows the total daily manufacturing lead time for the oyster mushroom baglog production process, which is 1529.516 minutes. If accumulated over one month, that is 26 effective working days. The monthly manufacturing lead time for producing 6462 baglogs was 39575.73 minutes or 28 days. The delay in the formed manufacturing lead time was two days compared to the effective work time.

3.1.2 Takt Time Calculation

Takt time is a process cycle time designed to match customer demand. The following is the calculation of the takt time for oyster mushroom baglog production by considering a working time of 26 days and a month's demand of 6462 pcs of oyster mushroom baglog:

$$Takttime = \frac{AT}{D} = \frac{37440 minutes}{6462 pcs} = 5,794 \ minutes/pcs \tag{4}$$

The calculations based on Table 2 indicate that the required takt time to achieve is 5,794 minutes per piece, whereas the current production capacity can only reach 6,124 minutes per piece. This means that the processing time to produce one baglog product in its current condition is 0.33 minutes higher than the target or the equivalent of 5.696 % higher than the predetermined target. We can conclude that the Ungaran Mushroom MSMEs' current production capacity will result in delays in meeting demand.

Table 2: Comparison Takt Time for demand 6264 pcs

Calculation	Current Condition	Target
Actual Time (minutes)	39575,732	37440
Takt Time (minutes/pcs)	6,124	5,794

3.1.3 Current State Value Stream Mapping

Value stream mapping is a lean manufacturing tool illustrating the material and information flow throughout a company's production process. Value stream mapping currently distinguishes between production process activities that contribute value (value added) and those that do not (non-value added). The value stream mapping in the oyster mushroom baglog production process is shown in Figure 2 below. Table 3 supports the explanation from Figure 2.

Table 3: Description Current State Value Stream Mapping

Process (P)	Process Name	Qty Operator	Cycle Time (sec)	Non-Added Value/NVA(minutes)	Value Added/VA(minutes)
P1	Mixing	1	271,550	42,000	29,776
P2	Sifting	1	121,460	26,500	13,318
P3	Packaging	1	11,020	35,000	45,901
P4	Pressing	1	9,040	19,000	37,682
P5	Providing Cover	1	19,890	21,000	82,858
P6	Sterilization	1	28826,800	80,000	800,744
P7	Seeding	1	60,180	45,000	250,736
Total		7	29319,940	268,500	1261,015

The current state of value stream mapping results has revealed 1261,016 minutes of value-added time and 268,5 minutes of non-value-added time in the production process. Afterwards, we conducted process cycle efficiency (PCE) measurements to assess the efficiency level of the production process for baglog oyster mushrooms. The following represents the PCE value.

$$PCE = \frac{TotalValueAddedTime}{TotalManufacturingLeadTime} = \frac{1261,016}{1529,516} = 82,45\% \tag{5}$$

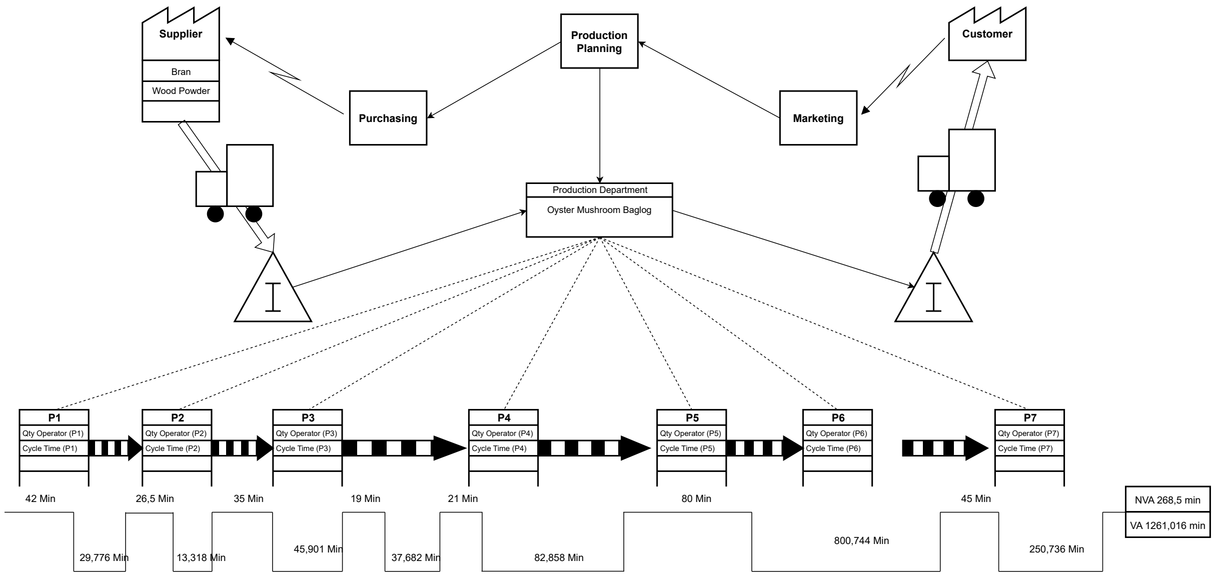

Figure 2: Current State Value Stream Mapping

From these calculations, the PCE results obtained from the oyster mushroom baglog production process currently have a process efficiency level of 82,45 %

3.1.4 Identify Problems Using Fishbone Diagrams

Fishbone diagrams are a tool to help identify factors that have the potential to influence problems. Fishbone diagrams identified three factors affecting the oyster mushroom baglog production process: machine, method, and environmental factors. Figure 3 shows the results of the fishbone analysis diagram of the oyster mushroom baglog production process:

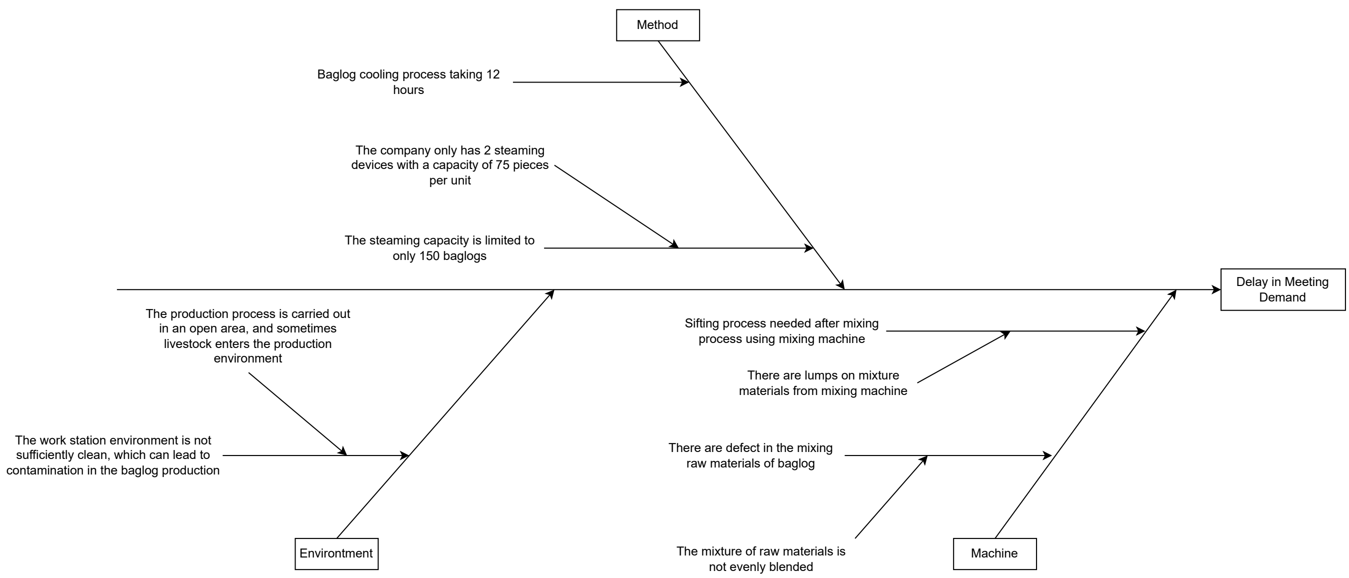

Figure 3: Fishbone Diagram

Based on the results of the fishbone diagram above, problems were found in each factor as follows:

- Machine factor: The results of mixing baglog raw materials using a mixing machine are currently experiencing clumping, so it requires overprocessing activities in the form of a sieving process.
- Method factor: The steaming equipment's capacity is limited to 150 bags of oyster mushrooms.
- Environmental factors: The production floor needs to be cleaner because the space is open, and livestock often enter the production area.

Table 4: Solution And Target RCA

Factor	Solution	Detail	Targets
Machine	The mixing machine design uses a stirrer propeller	Make a design for a mixing machine with a stirrer propeller according to the capacity of Mushroom Production Ungaran MSMEs	Get a baglog mixture that is even and without lumps, so it doesn't require a sifting process
Environment	Someone immediately places the results of the mixing baglog into the packaging.	Create a mixing machine design to enter the mixing results into baglog plastic packaging.	An unclean baglog production environment does not contaminate the result of a baglog mixture.
Method	Addition of a steaming tool	Proposing the addition of an oyster mushroom baglog steamer to increase steaming capacity	Increase the steaming capacity of oyster mushroom baglog

3.1.5 Root Cause Analysis

The root cause analysis (RCA) process, a research-based, structured, 'step-by-step' method for determining the causes of unfavourable circumstances or issues, is developed from continuous improvement [22]. The outcomes of the root cause investigation into Ungaran Mushroom SME's demand fulfilment delays are as follows at figure 4.

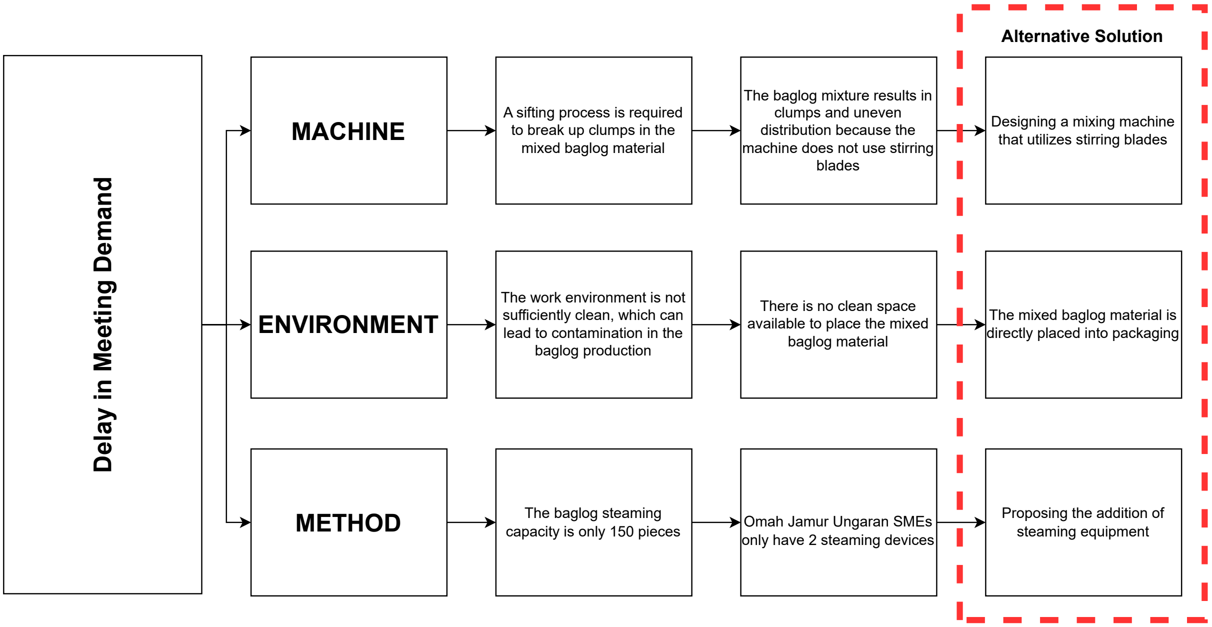

Figure 4: Root Cause Analysis for Improvements

From the results of the RCA analysis, we identified alternative solutions for each factor that influenced the problem of delays in fulfilling demand. Details of the solutions and targets to be achieved from each alternative solution created can be seen in Table 4 below.

3.1.6 Improvements

Improvements were made based on the results of determining the root of the problem of delays in fulfilling demand. The following is the preparation of corrective actions to reduce manufacturing lead time for oyster mushroom baglog production:

- The lumpy baglog mixture resulting from the mixing process using a mixing machine currently requires an updated stirrer design using a stirrer propeller, and hoping that good mixed results can eliminate overprocessing in the process of sifting the baglog mixture.
- An unclean environment can cause contamination of the baglog. Therefore, pouring the resulting baglog mixture on the production floor is unnecessary. The improvement design involves implementing a filling tank in the mixing machine to enable the direct placement of resulting raw materials into baglog packaging.
- The proposal to add steaming equipment aims to increase the capacity of steaming oyster mushroom baglog in one process at a time. However, Ungaran Mushroom SMEs have been unable to implement this proposal due to high operating costs.

The improvement that Ungaran Mushroom SMEs Production can implement is manufacturing a mixer to overcome the problem of fulfilling the demand for baglogs. We will explore the tool's design and manufacturing process in our other research. After creating an alternative design for a baglog production mixer, the next stage involves manufacturing a mixer to blend ingredients for baglog production. Further research will discuss the outcomes of the baglog raw material mixer design (figure 5).

Figure 5: Mixer Machine Baglog

3.2 Discussion

Ungaran Mushroom SMEs have achieved results based on the implemented improvements. Comparison of production waiting times after implementing improvements can be seen in table 5 below.

The future state value stream mapping illustrates the flow conditions of the oyster mushroom baglog production process after we have implemented improvements shown in Figure 6. Table 6 supports the explanation from Figure 6.

Table 5: Comparison MLT After Improvements

Workstations	Before (Minutes)	After (Minutes)
Mixing	71,776	29,429
Sifting	39,818	0
Packaging	80,901	39,167
Pressing	56,682	56,682
Providing Cover	103,858	103,858
Sterilization	880,744	880,744
Seeding	295,736	295,736
Total	1529,516	1405,616

Table 6: Description Future State Value Stream Mapping

Process (P)	Process Name	Qty Operator	Cycle Time (sec)	Non-Added Value/NVA(minutes)	Value Added/VA(minutes)
P1	Mixing	1	271,550	20,000	9,429
P2	Packaging	1	7,000	10,000	29,167
P3	Pressing	1	9,040	19,000	37,682
P4	Providing Cover	1	19,890	21,000	82,858
P5	Sterilization	1	28826,800	80,000	800,744
P6	Seeding	1	60,180	45,000	250,736
Total		6	29194,460	195,000	1210,616

There is an increase in PCE in future state value stream mapping. The following is the PCE calculation after implementing improvements to the oyster mushroom baglog production process:

$$PCE = \frac{TotalValueAddedTime}{TotalManufacturingLeadTime} = \frac{1210,616}{1405,616} = 86,13\% \tag{6}$$

Table 7 shows a recapitulation of improvements that have been made at the sieving station for the baglog production process. Decrease in the percentage of activities worth NVA from 17,55% to 13,87 % . The production results can reach the target takt time of 5,627 minutes/pcs. PCE increased from 82,45% to 86,13% . There was a reduction in manufacturing lead time for the oyster mushroom baglog production process per day from 1529,516 minutes to 1405,616 minutes. There was also a reduction in the total manufacturing lead time for the baglog production process per month from 28 days to 26 days.

Based on the results of the calculations and analysis of the value stream mapping, the lean manufacturing approach enhances the efficiency of processes within the company, as concluded. This research finding is consistent with several previous studies addressing similar topics. Researchers and practitioners have developed various frameworks for implementing lean, which can enhance the company's benefits by reducing occurring waste [20], [33], [34].

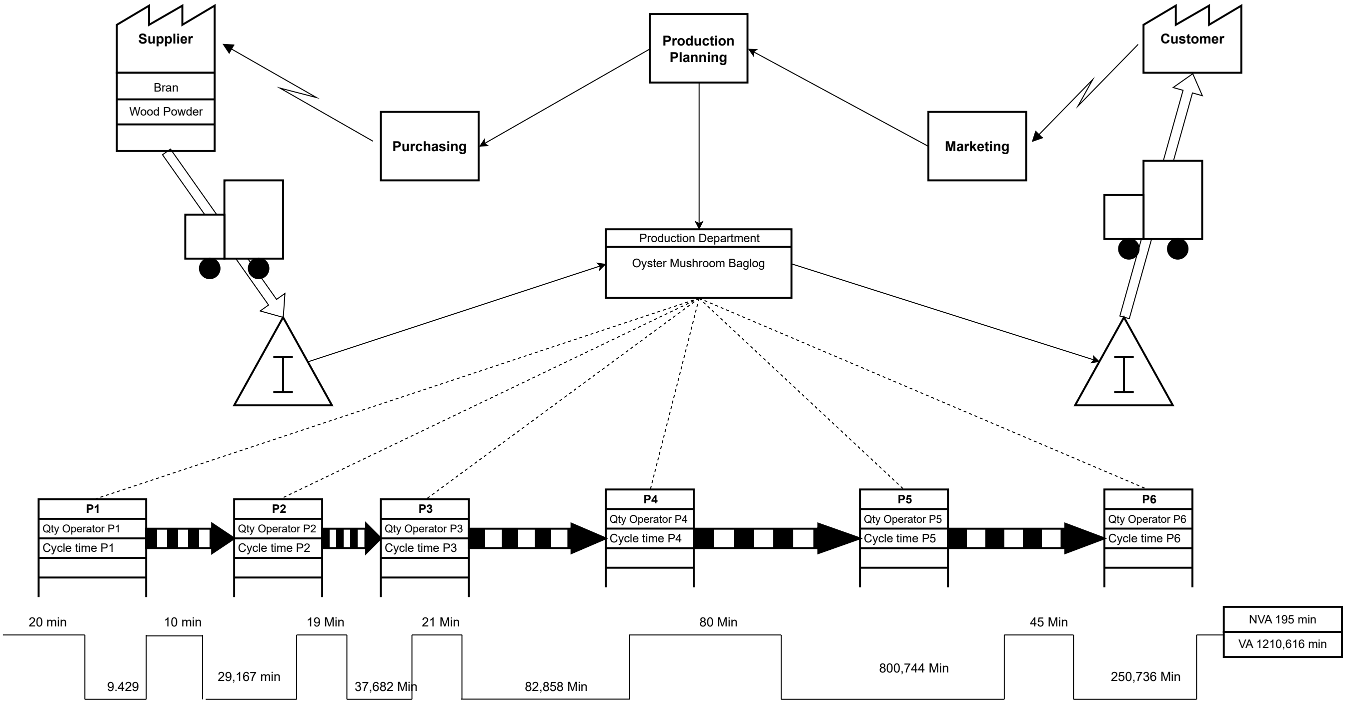

Figure 6: Future State Value Stream Mapping

Table 7: Comparison Results

Comparison	Before	After
Station	7	6
NVA	17,55%	13,87%
Takt Time	6,124 minutes/pcs	5,627 minutes/pcs
PCE	82,45%	86,13%
MLT	1529,516 minutes	1405,616 minutes
Total MLT	28 days	26 days

The research findings are thoroughly analyzed and interpreted in the discussion part, which also situates them within the larger framework of previously published works and industry standards. The Value Stream Mapping (VSM) method assesses how well the implemented improvements reduced Manufacturing Lead Time (MLT) in the oyster mushroom baglog production process. The study aimed to investigate the influence of extended MLT on demand fulfilment delays at UMKM Mushroom Production Ungaran, which affects the timely delivery of oyster mushroom baglogs to customers. To satisfy the average monthly demand of 6462 baglogs, the production process's identified MLT was 39575,73 minutes, or 28 days, longer than the intended 26 days. VSM, one of the lean manufacturing principles, was used to find and remove waste.

Many academics have stressed the importance of lead time minimization in lean manufacturing to improve operational efficiency [7]. The concepts of Lean Thinking, as promoted by Womack and Jones, emphasize how crucial it is to eliminate waste to produce value effectively. This is consistent with the primary goal of the current study, which is to lower MLT by optimizing the oyster mushroom baglog production process. The proposed research addresses a particular issue in the oyster mushroom baglog producing industry, adding to the body of information already in existence. Although Lean Manufacturing strategies have been extensively studied in a variety of industries [8], [11], [33], the customization of lean methodologies to address the particular issues associated with mushroom cultivation still needs to be discovered. To pinpoint the main causes of manufacturing process delays, the study used techniques including Fish-bone Diagrams and Root Cause Analysis. The investigation uncovered capacity limitations in the steaming process, inadequate environmental cleanliness, and machine-related problems. These results align with research using fish-bone diagrams to effectively identify and examine variables affecting different production processes.

In addition, the research conducted Root Cause Analysis using the 3x5 whys technique to determine the underlying causes of delays in meeting demand methodically. This methodological strategy aligns with earlier studies that stress the significance of using systematic analysis to identify the root causes of unfavourable events [32]. The suggested fixes, which address environmental issues and involve improving the mixing process by revamping the mixing machine and adding an infill tank, show how lean principles may be used in real-world situations. These answers align with academic suggestions that support the use of lean tools to improve process efficiency [13], [16], [35], [36]. When the recommended changes were subsequently implemented, MLT significantly decreased, demonstrating the effectiveness of the lean solutions. The findings show that the number of workstations sifting has reduced, the Process Cycle Efficiency (PCE) has increased by 3,68% and the MLT has decreased by 3213,718 minutes (2 days). This lead time reduction aligns with the larger lean manufacturing objective of reducing non-value-added processes.

When comparing the before and after situations, it was evident that the enhanced production process had a favourable effect on many necessary performance measures. The optimization of the baglog mixing process is shown in the decrease in the number of sieving workstations, which enhances operational efficiency. The value-added time to total lead time ratio has improved overall, as seen by the rise in PCE from 82,45% to 86,13%The revised mixing machine has addressed the root causes found in the Fishbone Diagram and Root Cause Analysis with a stirrer propeller and the addition of a steaming tool. The new designs are intended to improve the overall cleanliness of the production environment, provide an even baglog mixture, and remove pointless processes.

The research results significantly contribute to the wider discussion on lean manufacturing, especially for small and medium-sized businesses (SMEs) that grow mushrooms. Lean approaches are adaptable and effective when customized to handle industry-specific difficulties, as demonstrated by Mushroom Production Ungaran's implementation of lean principles.

4 Conclusions

The results of manufacturing lead time calculations for the baglog production process, totalling 39575,73 minutes or 28 days, have proven the delay in fulfilling one month's demand. The demand, which should met within an adequate working time of 26 days, highlighted the need for Improvement. The root cause analysis identified issues such as lumps in the raw material mixture leading to overprocessing through a sieving process, unhygienic environmental factors contributing to potential contamination, and limited steaming capacity causing delays. To address these challenges, the researchers developed an improvement plan involving redesigning the mixing machine with a stirrer propeller to ensure an even mixture without lumps. The mixing machine design also incorporated an infill tank, facilitating the direct placement of mixed raw materials into baglog packaging, eliminating the need for pouring onto the production floor. Implementation of these improvements resulted in reduced workstations, a 3,68% increase in Process Cycle Efficiency (PCE), attainment of the takt time target of 5,627 minutes/pcs, and a decrease in total manufacturing lead time to meet the average monthly demand of 6,462 pcs baglog from 28 days to 26 days.

Acknowledgments

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Authors' Contributions

All authors contributed to writing this journal according to their experts and fields.

Competing Interests

This research team and I declare no conflict of interest in implementing this research.

References

[1] M. Hultberg, T. Prade, H. Bodin, A. Vidakovic, and H. Asp, "Adding benefit to wetlands – Valorization of harvested common reed through mushroom production," *Science of The Total Environment*, vol. 637-638, pp. 1395–1399, Oct. 2018. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0048969718317418

[2] W. A. Wan Mahari, W. Peng, W. L. Nam, H. Yang, X. Y. Lee, Y. K. Lee, R. K. Liew, N. L. Ma, A. Mohammad, C. Sonne, Q. Van Le, P. L. Show, W.-H. Chen, and S. S. Lam, "A review on valorization of oyster mushroom and waste generated in the mushroom cultivation industry," *Journal of Hazardous Materials*, vol. 400, p. 123156, Dec. 2020. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0304389420311456

[3] D. Stadnicka and P. Litwin, "Value stream mapping and system dynamics integration for manufacturing line modelling and analysis," *International Journal of Production Economics*, vol. 208, pp. 400–411, Feb. 2019. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0925527318304894

[4] A. Erceg, "Lean manufacturing application in the frozen goods industry," *Journal of ekonomi*, vol. 4, no. 2, pp. 57–62, 2022. [Online]. Available: https://dergipark.org.tr/en/pub/ekonomi/issue/70173/1182631

[5] S. Kumar, A. K. Dhingra, and B. Singh, "Process improvement through Lean-Kaizen using value stream map: a case study in India," *Int J Adv Manuf Technol*, vol. 96, no. 5-8, pp. 2687–2698, May 2018. [Online]. Available: http://link.springer.com/10.1007/s00170-018-1684-8

[6] D. D. Shinde, S. Ahirrao, and R. Prasad, "Fishbone Diagram: Application to Identify the Root Causes of Student–Staff Problems in Technical Education," *Wireless Pers Commun*, vol. 100, no. 2, pp. 653–664, May 2018. [Online]. Available: http://link.springer.com/10.1007/s11277-018-5344-y

[7] J. P. Womack and D. T. Jones, "Lean Thinking—Banish Waste and Create Wealth in your Corporation," *J Oper Res Soc*, vol. 48, no. 11, pp. 1148–1148, Dec. 1997. [Online]. Available: https://www.nature.com/doifinder/10.1038/sj.jors.2600967

[8] S. G. Gebeyehu, M. Abebe, and A. Gochel, "Production lead time improvement through lean manufacturing," *Cogent Engineering*, vol. 9, no. 1, p. 2034255, Dec. 2022. [Online]. Available: https://www.tandfonline.com/doi/full/10.1080/23311916.2022.2034255

[9] R. Hardcopf, G. J. Liu, and R. Shah, "Lean production and operational performance: The influence of organizational culture," *International Journal of Production Economics*, vol. 235, p. 108060, May 2021. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0925527321000360

[10] S. Gupta and S. K. Jain, "A literature review of lean manufacturing," *International Journal of Management Science and Engineering Management*, vol. 8, no. 4, pp. 241–249, Nov. 2013. [Online]. Available: https://www.tandfonline.com/doi/full/10.1080/17509653.2013.825074

[11] R. Sharma, M. Kasher, L. Zhang, N. Mani, and B. Lai, "Application of Lean Manufacturing Principles in Optimizing Factory Production," in *2018 IEEE MIT Undergraduate Research Technology Conference (URTC)*. Cambridge, MA, USA: IEEE, Oct. 2018, pp. 1–4. [Online]. Available: https://ieeexplore.ieee.org/document/9244796/

[12] S. Yaşar, M. YEŞİLYURT, O. GÜNAYDIN, E. Levent, and T. KÜÇÜKÖMEROĞLU, "Dövme kalıplarında aşınma mekanizmaları," *El-Cezeri*, vol. 8, no. 1, pp. 202–219. [Online]. Available: https://dergipark.org.tr/en/pub/ecjse/article/819457

[13] S. Panigrahi, K. K. Al Ghafri, W. R. Al Alyani, M. W. Ali Khan, T. Al Madhagy, and A. Khan, "Lean manufacturing practices for operational and business performance: A PLS-SEM modeling analysis," *International Journal of Engineering Business Management*, vol. 15, p. 184797902211478, Jan. 2023. [Online]. Available: http://journals.sagepub.com/doi/10.1177/18479790221147864

[14] F. Abu, H. Gholami, M. Z. Mat Saman, N. Zakuan, and D. Streimikiene, "The implementation of lean manufacturing in the furniture industry: A review and analysis on the motives, barriers, challenges, and the applications," *Journal of Cleaner Production*, vol. 234, pp. 660–680, Oct. 2019. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0959652619322449

[15] D. E. Ufua, T. Papadopoulos, and G. Midgley, "Systemic Lean Intervention: Enhancing Lean with Community Operational Research," *European Journal of Operational Research*, vol. 268, no. 3, pp. 1134–1148, Aug. 2018. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0377221717307166

[16] N. Kumar, S. Shahzeb Hasan, K. Srivastava, R. Akhtar, R. Kumar Yadav, and V. K. Choubey, "Lean manufacturing techniques and its implementation: A review," *Materials Today: Proceedings*, vol. 64, pp. 1188–1192, 2022. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S2214785322018284

[17] Ö. DEMİRCİ and T. GÜNDÜZ, "Combined application proposal of value stream mapping (vsm) and methods time measurement universal analysis system (mtm-uas) methods in textile industry," *Endüstri Mühendisliği*, vol. 31, no. 2, pp. 234–250, 2020. [Online]. Available: https://dergipark.org.tr/en/pub/endustrimuhendisligi/issue/56362/728061

[18] B. Suhardi, M. Hermas Putri K.S, and W. A. Jauhari, "Implementation of value stream mapping to reduce waste in a textile products industry," *Cogent Engineering*, vol. 7, no. 1, p. 1842148, Jan. 2020. [Online]. Available: https://www.tandfonline.com/doi/full/10.1080/23311916.2020.1842148

[19] M. A. Sayid Mia, M. Nur-E-Alam, and M. K. Uddin, "Court Shoe Production Line: Improvement of Process Cycle Efficiency by Using Lean Tools," *LFJ*, vol. 17, no. 3, pp. 135–146, Sep. 2017. [Online]. Available: http://revistapielarieincaltaminte.ro/revistapielarieincaltaminteresurse/en/fisiere/full/vol17-nr3/article$3_vol17_issue3.pdf$

[20] J. Singh and H. Singh, "Application of lean manufacturing in automotive manufacturing unit," *IJLSS*, vol. 11, no. 1, pp. 171–210, Jan. 2020. [Online]. Available: https://www.emerald.com/insight/content/doi/10.1108/IJLSS-06-2018-0060/full/html

[21] S. Patel, D. Mistry, and M. Shah, "A process improvement methodology for effective implementation of value stream mapping integrated with foreman delay survey," *Innov. Infrastruct. Solut.*, vol. 6, no. 3, p. 137, Sep. 2021. [Online]. Available: https://link.springer.com/10.1007/s41062-021-00512-1

[22] G. D. Koltun, S. Feldmann, D. Schutz, and B. Vogel-Heuser, "Model-document coupling in aPS engineering: Challenges and requirements engineering use case," in *2017 IEEE International Conference on Industrial Technology (ICIT)*. Toronto, ON: IEEE, Mar. 2017, pp. 1177–1182. [Online]. Available: http://ieeexplore.ieee.org/document/7915529/

[23] D. E. Ufua, A. S. Ibidunni, M. O. Akinbode, C. G. Adeniji, and B. E. Kehinde, "Value stream mapping, a tool for optimum implementation of systemic lean intervention: a case study of a livestock commercial farm in Nigeria," *IJSOM*, vol. 39, no. 3, p. 399, 2021. [Online]. Available: http://www.inderscience.com/link.php?id=116123

[24] C. Valmohammadi and A. A. Dadashnejad, "Value stream mapping implementation: an operational view," *IJPQM*, vol. 32, no. 3, p. 307, 2021. [Online]. Available: http://www.inderscience.com/link.php?id=113612

[25] J. Lin, X. Fang, Y. Zhang, and Y. Lian, "Application of Plan-Do-Check-Action cycle and fishbone diagram analysis in optimizing surgical procedures to improve satisfaction degree of doctor-nurse-patient," *Ann Eye Sci*, vol. 5, pp. 2–2, Mar. 2020. [Online]. Available: http://aes.amegroups.com/article/view/5060/html

[26] V. Girish, "Identifying the Perspectives of Domestic Tourists Visiting Puducherry of India During theCOVID-19 Pandemic: A Fishbone Diagram Analysis," *Tourism (Zagreb, Online)*, vol. 70, no. 1, pp. 127–130, Dec. 2021. [Online]. Available: https://hrcak.srce.hr/267981

[27] T. Luo, C. Wu, and L. Duan, "Fishbone diagram and risk matrix analysis method and its application in safety assessment of natural gas spherical tank," *Journal of Cleaner Production*, vol. 174, pp. 296–304, Feb. 2018. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0959652617326410

[28] M. Groover and G. Jayaprakash, *Automation, Production Systems, and Computer-integrated Manufacturing*, ser. Always learning. Pearson Education Limited, 2015. [Online]. Available: https://books.google.co.id/books?id=t2fXoAEACAAJ

[29] B. Fahimnia, L. H. S. Luong, B. Motevallian, R. M. Marian, and M. M. Esmaeil, "Analyzing & Formulation of Product Lead Time," 2008.

[30] R. Sundar, A. Balaji, and R. S. Kumar, "A Review on Lean Manufacturing Implementation Techniques," *Procedia Engineering*, vol. 97, pp. 1875–1885, 2014. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S1877705814034092

[31] Guangdong University of Science & Technology, Dongguan, China and J. Qiu, "Construction and Empirical Analysis of Environmental Cost Early-warning Model for Manufacturing Enterprises Based on Fishbone Diagram," *FMR*, vol. 3, no. 3, Jul. 2019. [Online]. Available: http://www.isaacpub.org/images/PaperPDF/FMR$_100062_2019051410441567231.pdf$

[32] R. Sweis, A. Moarefi, M. H. Amiri, S. Moarefi, and R. Saleh, "Causes of delay in Iranian oil and gas projects: a root cause analysis," *IJESM*, vol. 13, no. 3, pp. 630–650, Sep. 2019. [Online]. Available: https://www.emerald.com/insight/content/doi/10.1108/IJESM-04-2018-0014/full/html

[33] G. Yadav, S. Luthra, D. Huisingh, S. K. Mangla, B. E. Narkhede, and Y. Liu, "Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies," *Journal of Cleaner Production*, vol. 245, p. 118726, Feb. 2020. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0959652619335966

[34] I. Leksic, N. Stefanic, and I. Veza, "The impact of using different lean manufacturing tools on waste reduction," *Adv produc engineer manag*, vol. 15, no. 1, pp. 81–92, Mar. 2020. [Online]. Available: http://apem-journal.org/Archives/2020/Abstract-APEM15-$1_081 - 092.html$

[35] E. Lamani, A. Ahmad, and M. B. Ahmad, "Lean manufacturing implementation to reduce waste on weighing scale assembly line," *International Journal of Emerging Trends in Engineering Research*, vol. 8, no. 1, pp. 1–2, 2020.

[36] J. Du, Y. Xue, V. Sugumaran, M. Hu, and P. Dong, "Improved biogeography-based optimization algorithm for lean production scheduling of prefabricated components," *ECAM*, vol. 30, no. 4, pp. 1601–1635, May 2023. [Online]. Available: https://www.emerald.com/insight/content/doi/10.1108/ECAM-04-2021-0311/full/html