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RESEARCH ARTICLE

VALUE STREAM MAPPING IMPLEMENTATION IN A SMALL AND MEDIUM AGRO-BASED INDUSTRY

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ABSTRACT – This study explores the implementation of Lean Manufacturing Systems at a small and medium-sized enterprise (SME) in the agro-industrial sector to identify and eliminate potential waste. The study analyzes current operational inefficiencies and proposes effective Lean solutions. Data on the company's production processes were collected and analyzed to pinpoint sources of waste. Using Tecnomatix Plant Simulation software, models of the current and improved future states were developed. These models provided a detailed visualization of the process flow, identifying key areas where Lean interventions could yield significant improvements. The effectiveness of these Lean initiatives was further analyzed using Value Stream Mapping (VSM), which facilitated a comparative analysis of process performance before and after implementing Lean improvements. The results demonstrated substantial enhancements in operational efficiency, which is 20.7%, doubled the profits, and improved customer satisfaction. This study not only underscores the feasibility of applying Lean principles in SME but also provides a robust framework for other similar enterprises to follow. The findings and recommendations presented in this study offer SME a strategic approach to achieving sustainable operational improvements and competitive advantage in their respective markets.

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1.0 INTRODUCTION

Small and Medium-sized Enterprises (SMEs) are critical to stimulating economic growth, promoting innovation, and creating jobs in the fast-paced world of modern business [1]. SMEs frequently need help optimizing their operating procedures to compete in the global market. There is increasing interest in applying Lean Manufacturing principles to small and medium-sized enterprises due to the need for effective resource utilization, waste reduction, and continual improvement [2]. Based on the well-known Toyota Production System, lean manufacturing is a systematic approach to waste reduction, workflow optimization, and increased operational effectiveness [3]. Even while lean concepts are frequently used in large-scale businesses, further research is still needed to determine how SMEs may implement these concepts. Due to their distinct characteristics, such as their more nimble organizational structures, resource limitations, and flexibility, SMEs present both possibilities and challenges when implementing lean [4].

A thorough, comprehensive literature review identified 12 Lean Manufacturing tools that likely affect sustainability most [5]. Numerous earlier studies stated that after identifying and repeatedly proving the tool's impact on one, two, or three aspects of sustainability, it becomes the critical factor in selecting these 12 tools [6]. Lean implementation is mostly driven by employee empowerment and involvement. Organizations may harness their workforce's collective knowledge and creativity by offering training, fostering an environment of accountability, and recognizing the experience of frontline workers. Throughout the organization, this cooperative approach promotes a sense of ownership and dedication to the Lean concepts [7]. According to Elkhairi, maintaining momentum and sustaining lean techniques over time might not be straightforward [8]. It can fade if the implementation's initial enthusiasm is not continuously encouraged and nurtured. Leadership commitment and employee participation at all levels are essential to fostering a culture of continual improvement [9], [10]. This study aims to gain a deeper understanding of how Lean Manufacturing practices impact the operational efficacy of small and medium-sized enterprises. This research aims to provide significant insights into the practicality, benefits, and possible obstacles related to the implementation of Lean Manufacturing in this sector by examining the problems encountered by SMEs and applying Lean ideas to their unique situation.

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2.0 METHODS AND MATERIAL

The flowchart, as shown in Figure 1, illustrates a comprehensive process for developing and evaluating Lean Manufacturing implementation in SME.

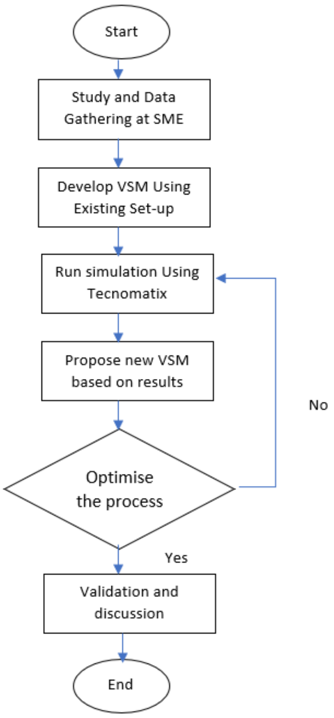

Figure 1. Research Flowchart

The process begins with a comprehensive literature review to understand Lean Manufacturing principles, challenges faced by SMEs, and existing solutions. This foundational step provides context and identifies gaps that the study aims to address. Next, suitable SMEs are selected based on company size, industry sector, and willingness to participate, ensuring the research focuses on relevant and representative companies. Detailed data collection involving recording current production processes and identifying sources of waste through interviews, observations, and company records. If data collection is incomplete, efforts are revisited to ensure thoroughness. Using Tecnomatix Plant Simulation software, a model of the current production layout is developed, providing a visual and analytical representation of existing workflows and highlighting inefficiencies. The simulation of this current layout is then run to establish baseline performance metrics such as cycle times, inventory levels, and throughput rates.

The data from this simulation is translated into a Value Stream Map (VSM), a visual tool that helps identify and analyze material and information flow, pinpointing waste and value-added areas which justify why a simulation is required. Analyzing this VSM reveals key areas for improvement, leading to the proposal of specific Lean improvements like Just-In-Time (JIT) production, reducing batch sizes, improving workflow layouts, and enhancing quality control processes. A new production layout incorporating these improvements is developed and simulated using Tecnomatix Plant Simulation software. The resulting data is used to create a new VSM for the improved production flow, visualizing the changes and their effect on process efficiency. The results are then evaluated to see if the improvements meet the desired objectives. If the results are satisfactory, the findings are validated through discussion and review with stakeholders, ensuring the proposed solutions are feasible and sustainable. If not, the improvement proposals are revisited and adjusted as necessary.

Finally, the research findings are summarized, highlighting the effectiveness of Lean Manufacturing System implementation in reducing waste and improving efficiency in SMEs. Recommendations for future study and practical applications are provided, emphasizing the importance of continuous improvement and the potential for ongoing Lean initiatives to sustain operational excellence in SMEs. This structured methodology offers a comprehensive framework for SMEs to implement Lean Manufacturing Systems effectively, leveraging simulation tools and VSM to drive continuous improvement and competitive advantage.

It could be necessary to compile data about the current state of the process before implementing Lean in the company. Below information is necessary:

1. Processing times, including cycle and changeover times, for every process.
2. Historical data on throughput, errors, and rework rate will be gathered. Charts can then be used to display the data and pinpoint areas that require improvement.

3. Bottlenecks can be detected by surveys and interviews with the five direct members (workers) regarding production line process issues.
4. Gathering machine data on output rate, equipment condition, frequent malfunctions, and machine breakdown.
5. Process flow, floor layout design, and tools utilized.

Understanding the working hours, shift, and break schedule for workers is crucial. This data will help to ensure that the workers are operating at their most productive and that the production process is optimized. The next critical stage in implementing Lean Manufacturing is a thorough analysis and simulation using Value Stream Mapping (VSM) with the help of Tecnomatix software, which comes after the data collection from company X, which specializes in agriculture-based products. The gathered data covers various production-related topics and is thoroughly investigated and entered into the Tecnomatix program, a practical simulation tool that enables a dynamic and visual visualization of the complete production system. Here is how the method will be done:

i. Data analysis for current state : Identify inefficiencies, bottlenecks, and wasteful areas by methodically analysing the data gathered.
ii. Simulation for current state : Utilising Tecnomatix to simulate the current process.
iii. Propose Improvement : Collect information from the existing process and propose improvement.
iv. Simulation for future state : Model and evaluate the new improvement applied.
v. Assessment: Evaluate the outcomes of the simulations for the new process and the current process to assess their respective impacts on overall system performance.

3.0 RESULTS AND DISCUSSION

Gathering data is fundamental to each experimental study, providing a framework for thorough analysis and reliable conclusions. Time studies, observations, interviews, and related documents have all been used to collect data. The information gathered was used to assess the present production line and pinpoint possible areas for enhancement.

Table 1. General Data of Production

No	Information of Production	Data
1	Working hour	8 hours
2	Break time	1 hours
3	Production demand	2,000 kg/day
4	Number of workstations	5 workstations
5	Number of workers	5 workers

Table 2. Processing Time of Workstations

Workstation	Processing Time (minute)
Mixing	4
Extruding and Cutting	9
Baking	20
Drying	20
Packing	5

General information about company X is shown in Table 1, whereas the processing time for each workstation is stated in Table 2.

Simulation of Current State

Company X comprises five workstations: mixing, extruding and cutting, baking, drying, and packing. Given the high production demand of 2,000 kg per day and the operational working time of 8 hours a day, it is essential to identify and reduce the bottlenecks in production to ensure a compelling performance. Tecnomatix Plant Simulation software simulates a thorough production line model, enabling product flow analysis via each section. This model assisted in locating possible bottlenecks and testing various scenarios to determine the best course of action for increasing production efficiency. Figure 2 below shows the layout production area of the pellet from the Tecnomatix software. A dedicated worker is at each of the five workstations in the production area. This production sequence will be continuous for 8 hours a day.

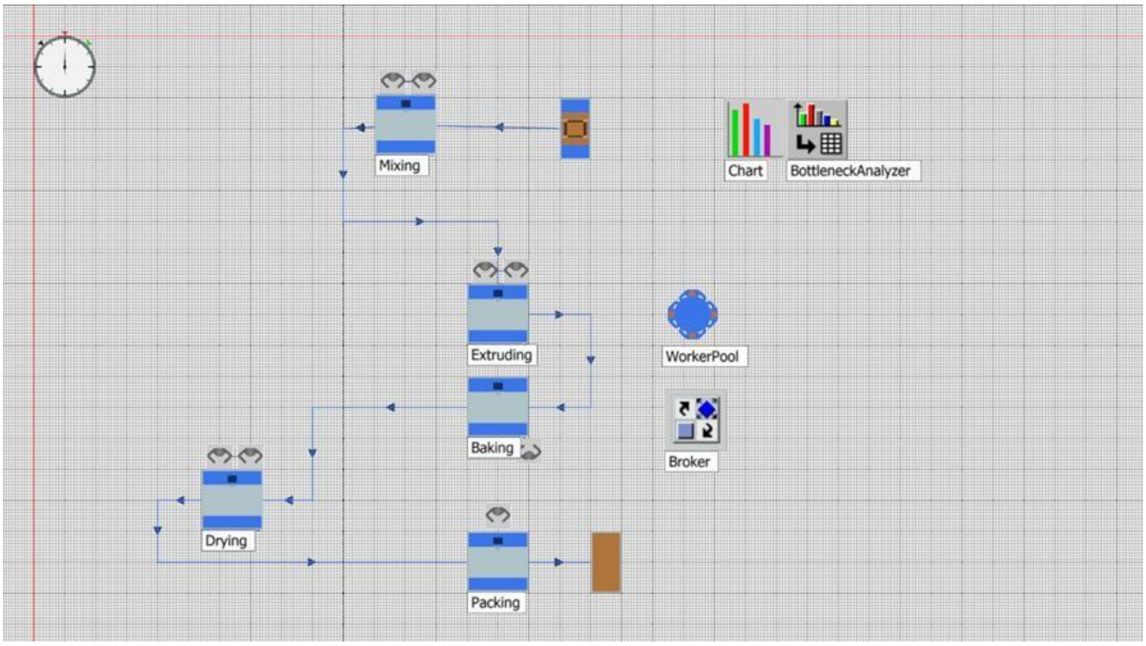

Figure 2 Current Production Layout

Figure 3 shows the graph percentage of the workstation's resource statistics and the workstation's value while working. In the graph, the green bar represents that the workstation is working, grey for waiting, and yellow indicates that the workstation is blocked.

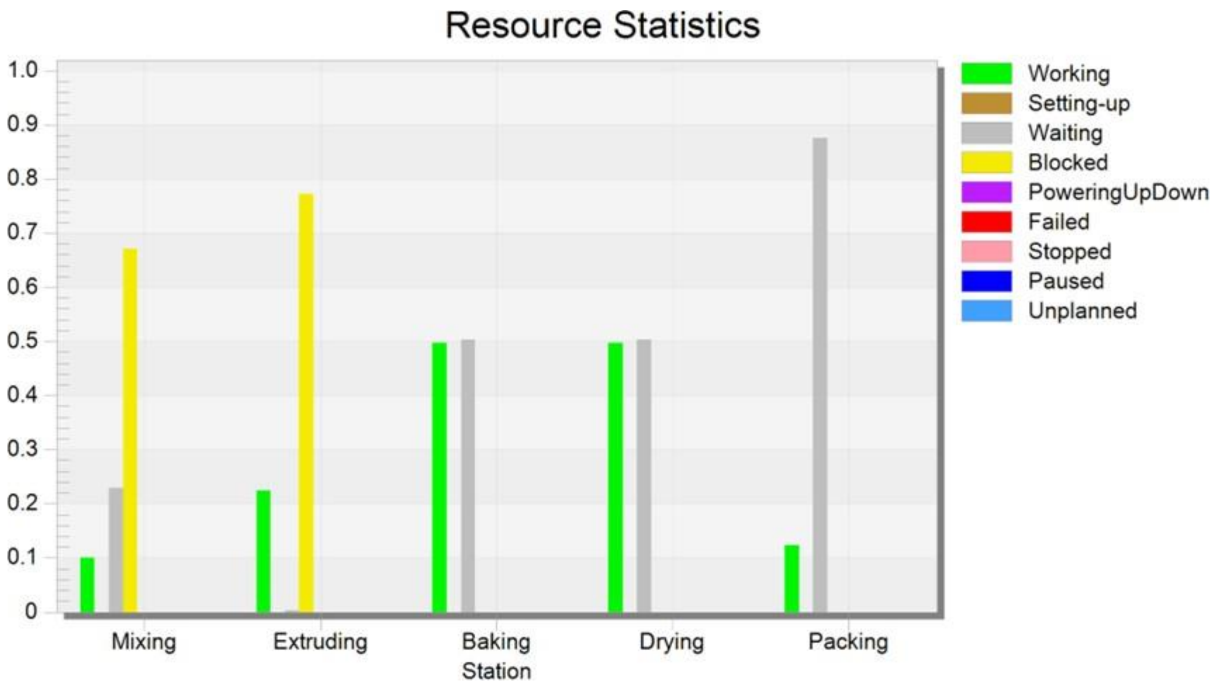

Figure 3 Graph of Resource Statistics for Current Layout.

Based on the simulation output, value stream mapping for the current state can be developed to analyze which areas need improvement to increase the company's productivity. Figure 4 shows the current state VSM of the Company X.

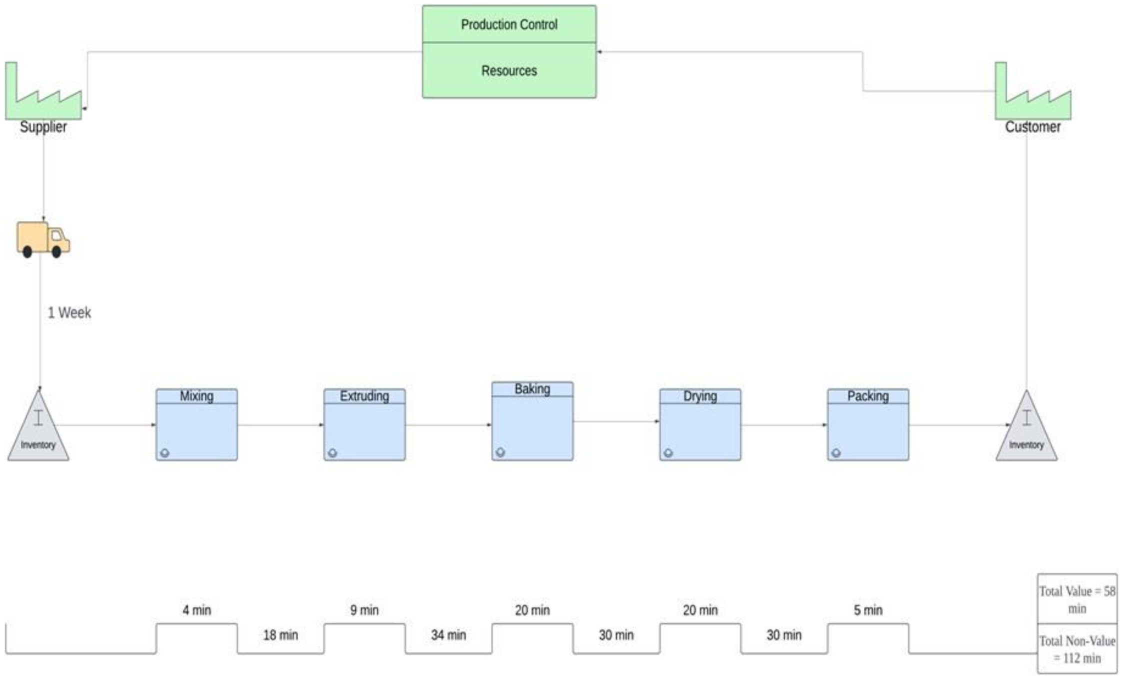

Figure 4 Value Stream Mapping of Current State

Simulation of Future State

To decrease the percentage of blocked workstations in production, the suggestion of adding additional machines or workstations has been considered. This additional machine will not burden the SMEs because the additional machine will not greatly cost the SMEs and give more advantage to the SMEs to expand their businesses. The machine that needs to be added is only a 3-layer oven and one additional drying place. Also, the worker assigned to each workstation needs to be adjusted to eliminate unnecessary movement. The future plant layout shows that the workers who are currently assigned to the baking process will only operate the oven machine and will not do additional work and movement to the drying process as shown in Figure 5. This will streamline their tasks and make their roles more efficient and valuable.

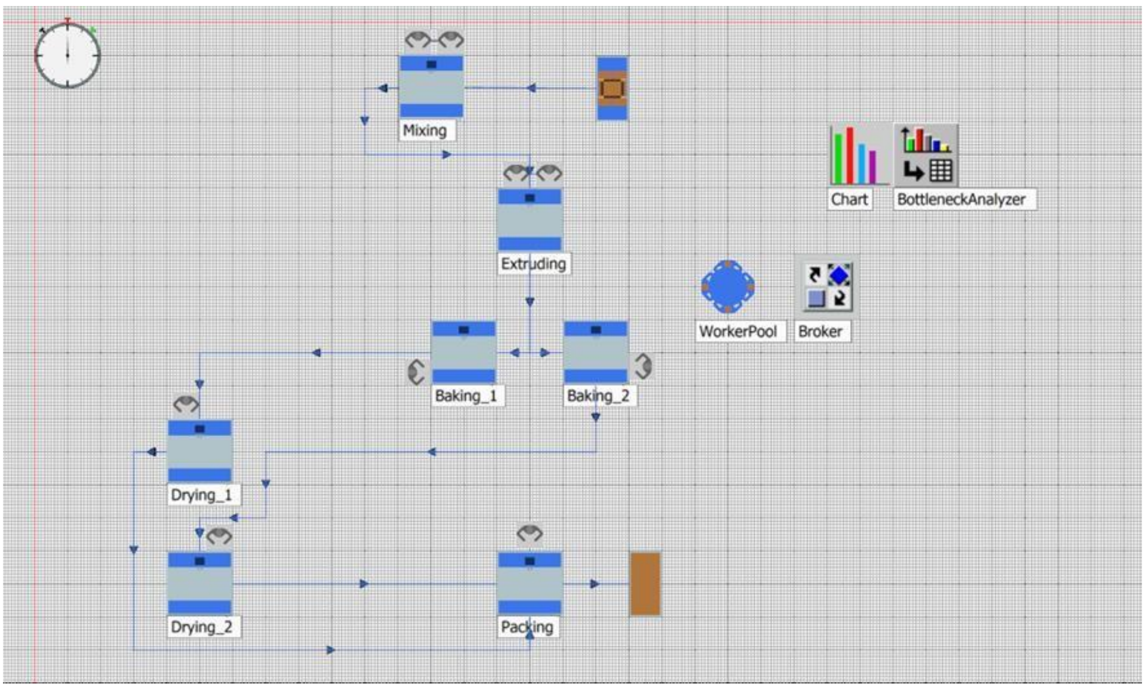

Figure 5 Future Production Layout

The process also applies to the Drying process, in which one worker will be assigned to do the work. The sequence of the new production layout will also change. After the Extruding process is completed, the following process will be Baking 1, and no operation will happen in Baking 2. After the Extruding completes, the pellet will go to Baking 2 for the following process. The same applies to Drying, in which Baking 1 finishes the task; the pellet will go to Drying 1 while Baking 2 will go to Drying 2. The whole process will be continuous for 8 hours a day. Even though the block will still occur, the percentage of being blocked has been reduced significantly, and the percentage of working workstations has increased positively.

Figure 6 shows the graph percentage of resources statistics of the workstation for the future layout after it has been improved. In the graph, the green bar for mixing and extruding increases significantly, and the yellow bar shows it has decreased after the improvement. The graph also shows values for the additional workstation.

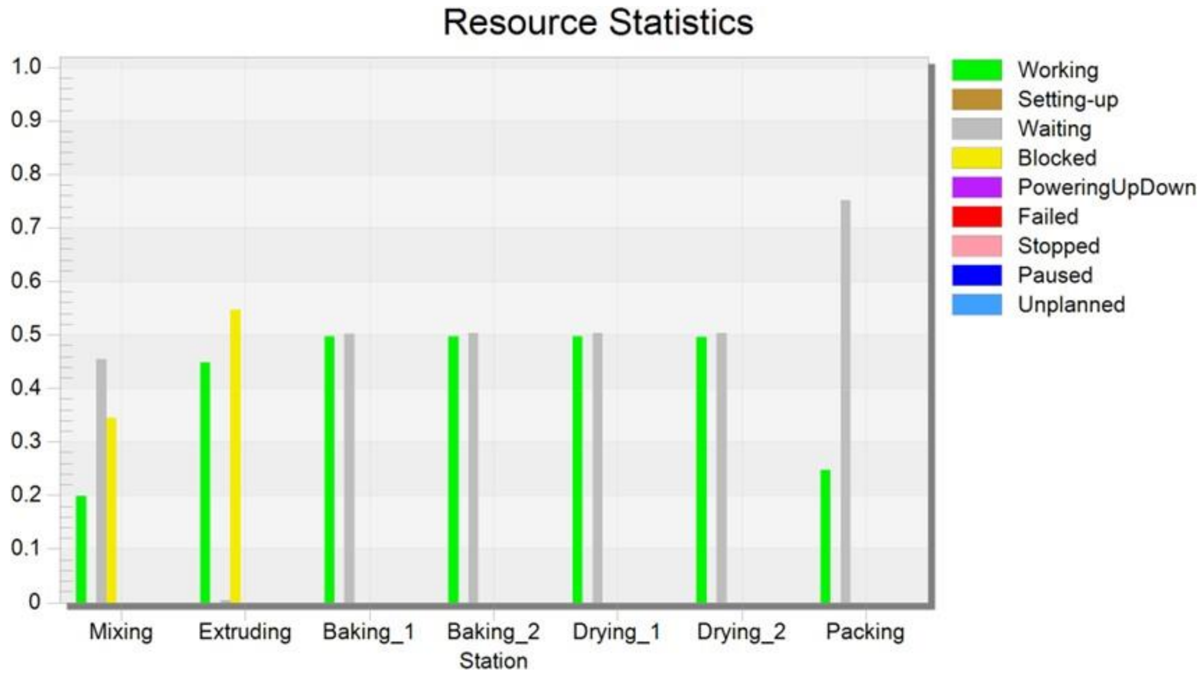

Figure 6 Graph of Resource Statistic for Future Layout

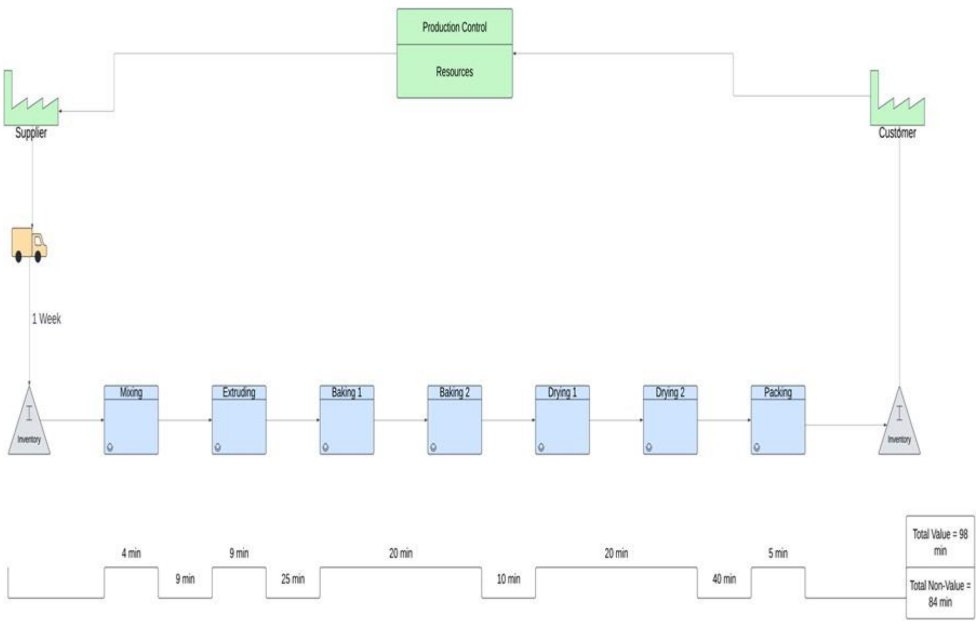

Figure 7 Value Stream Mapping of Future State

Figure 7 shows the future state VSM of the SMEs based on the simulation output. Value stream mapping for future states analyzes how much improvement affects company productivity with the additional Baking and Drying machines.

Efficiency and Cost Analysis

Calculating the efficiency of a production line involves comparing the actual output to the potential maximum output, given the resources and time available, as shown in Table 3. The net production time is the total time available for production, excluding planned downtime, and the maximum production rate is the rate at which the production line can produce units under ideal conditions. The results demonstrated substantial enhancements in operational efficiency, which is 20.7%, by using the existing operating time and improved waiting time in between stations as the non-value-added activities.

Table 3 Comparison of current and future VSM

Data	Current VSM	Future VSM
Operating Time	8 hours/day (480 minutes)	8 hours/day (480 minutes)
Maximum Production Rate	5 units/hour	10 units/hour
Actual Output	29 units/day	70 units/day
Effective Capacity	8 hours × 5 units/hour = 40 units/day	8 hours × 10 units/hour = 80 units/day
Efficiency (%)	72.5	87.5
Efficiency Improved (%)	-	20.7

The estimation for cost is that if the company plans to buy another 3-layer oven, it will likely cost about RM50,000, and the cost to order another drying plate is about RM10,000, which is a total of RM50,000.

Table 4. Comparison Profit Between Current and Future Company X Production

Income Data	Current VSM (RM)	Future VSM (RM)
Income per week [5 days]	19,200	38,400
Income per month [4 weeks]	76,800	153,600
30% from profit	23,040	46,080
Total profit per year [12 months]	276,480	552,960

Table 4 shows the output revenue for the current set-up, and the estimation after improvement has been applied. The profit obtained is doubled by spending only RM50,000, and the cost for upgrading will be recovered within just one month of operation.

4.0 CONCLUSION AND RECOMMENDATION

In conclusion, this study has successfully achieved its objectives by demonstrating the significant potential of Lean Manufacturing Systems to enhance operational efficiency, reduce waste, and improve productivity in small and medium-sized enterprises (SMEs). The study meticulously examined SMEs' unique challenges and opportunities when adopting Lean principles, focusing on modeling the current and future states using Tecnomatix Plant Simulation software. The resulting data were interpreted to create Value Stream Mapping (VSM), enabling a detailed effectiveness analysis before and after applied improvements. The study analyzed existing processes using Tecnomatix Plant Simulation software, identifying fundamental inefficiencies and bottlenecks. The current state simulation offered a detailed understanding of the operational baseline, while the future state model illustrated significant optimization potential by incorporating Lean methodologies. The effectiveness of these interventions was rigorously analyzed through VSM, which allowed for a clear comparison of process performance before and after improvements. The results showed substantial enhancements in process efficiency of 20.7 %, reduced production costs, increased both profits and customer satisfaction, proving the integration of VSM with simulation data to be a powerful approach for visualizing and quantifying the benefits of Lean practices.

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