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ORIGINAL ARTICLE

Enhanced Value Stream Mapping for Streamlining Supply Chains in The Furniture Manufacturing Industry

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ABSTRACT – This study aims to analyze and optimize the supply chain processes of a furniture fabrication company by leveraging Value Stream Mapping (VSM) and simulation software. The current production system is meticulously modeled to identify inefficiencies and bottlenecks, enabling targeted improvements. Using Tecnomatix, both Current State and Future State Mappings are developed to enhance operational efficiency, minimize waste, and streamline workflows. The study commences with comprehensive data collection, followed by a detailed analysis of the Current State Mapping, revealing key inefficiencies such as excessive movement, prolonged waiting periods, and a lack of standardized work procedures. Based on these findings, a Future State Mapping is designed to optimize production flow. Among the alternatives evaluated, Scenario 2 emerges as the most effective, incorporating Kaizen principles in the measurement and cutting process across three workstations. This scenario achieves the highest output of seven units per shift, outperforming other scenarios while maintaining five operators and reducing the number of workstations from 13 to 10. Additionally, Scenario 2 exhibits the lowest lead time, ensuring a seamless production flow with minimized idle time. Scenario 1 effectively reduced waiting time by merging workstations, while Scenario 2, incorporating Kaizen, led to a 40% increase in output while maintaining the same workforce Although waiting and total processing times show slight increases, they remain within acceptable working limits. By implementing these strategic improvements, this study successfully reduces waste, enhances productivity, and promotes sustainable manufacturing practices, ultimately benefiting the industry and the broader economy.

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1.0 INTRODUCTION

Value Stream Mapping (VSM) is a sophisticated lean management tool designed to visualize, analyze, and optimize the flow of materials and information across manufacturing processes. When applied to the intricate supply chains of the manufacturing process industry, VSM emerges as an indispensable instrument for identifying inefficiencies, reducing waste, and enhancing overall performance. As a widely adopted lean management technique, VSM simplifies the analysis of value streams, enabling organizations to pinpoint areas for improvement and drive operational excellence [1]. The modern supply chain is a complex network of interconnected entities, including suppliers, manufacturers, distributors, and consumers. This interconnectedness plays a critical role in facilitating the flow of materials, information, and value across various stages of production and distribution. However, as manufacturing organizations expand to meet the demands of global markets and evolving customer expectations, supply chain operations have grown increasingly complex and scaled. This complexity introduces new challenges in process optimization and performance improvement, necessitating advanced tools like VSM to navigate these intricacies effectively [2].

In today's interconnected and interdependent manufacturing sector, lean principles have long been employed to enhance production efficiency, eliminate waste, and maximize value [3]. However, applying VSM in this context presents unique challenges and opportunities. Manufacturing organizations often operate within multiple supply chains, sourcing raw materials, components, and finished products from diverse suppliers [4]. Managing these supply chains requires navigating intricate supplier networks, coordinating production schedules, and synchronizing distribution channels to meet varying customer demands while maintaining cost-effectiveness and agility [5]. VSM addresses these challenges by providing a structured approach to reducing non-value-added steps, streamlining processes, and aligning operations with strategic goals [6]. One of the key strengths of VSM lies in its ability to visualize the current state of production processes and serve as a blueprint for designing the desired future state. By mapping out activities within the production process, organizations can identify bottlenecks, redundancies, and inefficiencies, paving the way for targeted improvements [7]. This is particularly critical in the manufacturing industry, where companies face mounting pressures to achieve cost-

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effectiveness, reduce lead times, and enhance production system quality. Balancing these competing priorities requires systematically integrating inspection processes and other value-added activities into the process chain [8].

This study employs theoretical analysis, face-to-face research, and real-life case studies to explore the dynamics of managing multiple supply chains. It aims to identify the key drivers of inefficiency and waste, offering tailored VSM-based strategies for process optimization and performance improvement [9]. By examining the interconnected relationships and dependencies among supply chain entities such as suppliers, manufacturers, and distributors, the research seeks to develop a comprehensive framework for synchronizing production flows, reducing lead times, and enhancing overall supply chain performance [10]. Through this approach, the study will provide actionable insights for manufacturing organizations striving to thrive in an increasingly complex and competitive global landscape.

METHODOLOGY

This study adopts a structured approach to analyze and optimize the manufacturing process of a furniture company producing Block Board, Aluminium, and Plywood (Figure 1). The research begins with selecting a relevant manufacturing company, identifying its supply chain and production processes, and formulating a problem statement with well-defined research objectives. The initial phase involves identifying key process elements, including entities, activities, and resources, to map material and information flows effectively. These relationships are documented using flowcharts, VSM, and process descriptions to ensure clarity and accuracy.

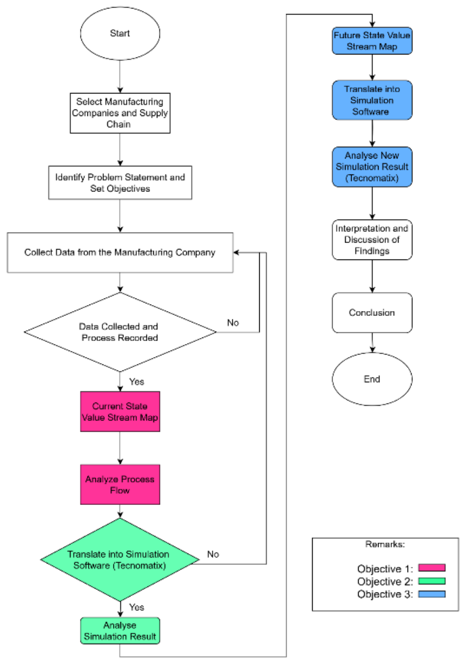

Figure 1. Methodology Flowchart

Following this, data collection is conducted to capture production workflows, material movement, and operational metrics specific to Block Board, Aluminium, and Plywood manufacturing. This data is processed into a Current State Value Stream Map (CSVSM), highlighting bottlenecks, delays, and waste inefficiencies. The current state is modeled in Tecnomatix Plant Simulation to assess further process efficiency, where a digital twin of the production system is created. The simulation results provide insights into existing inefficiencies and areas requiring improvement. Based on these findings, a Future State Value Stream Map (FSVSM) is developed, integrating Lean methodologies such as Kaizen, Kanban, and Heijunka to optimize resource allocation, reduce waste, and enhance productivity.

The FSVSM is then simulated in Tecnomatix to evaluate its impact on process efficiency. Key performance indicators (KPIs) such as throughput, lead time, and resource utilization are assessed to measure improvement. The results from the future state simulation are compared with the current state to quantify improvements. Tecnomatix visualization tools, such as performance charts and bottleneck analysis, are used to gain deeper insights into idle times, overutilized resources, and inefficiencies. Tecnomatix was chosen because it offers a comprehensive Lean Manufacturing, VSM, and digital twin modeling solution. It is superior to ARENA and FlexSim for supply chain and production system optimization. Its Product Lifecycle Management (PLM) integration, advanced 3D simulation, and bottleneck analysis capabilities make it the best fit for analyzing furniture manufacturing workflows. Findings are then interpreted, leading to data-driven recommendations for process optimization. By integrating VSM, Lean methodologies, and simulation-based optimization, this study provides a systematic framework for enhancing manufacturing efficiency and sustainability in the furniture industry.

RESULTS AND DISCUSSION

The collected data will be systematically analyzed and categorized to provide a comprehensive overview of the current state within the study's scope. This structured approach ensures a clear understanding of existing processes, inefficiencies, and performance trends. Any statistically significant correlations or emerging patterns will also be identified, serving as valuable insights for guiding future improvements and optimization efforts. During this phase, workers are interviewed about their experiences on the production line to aid in identifying key challenges and inefficiencies. A comprehensive list of processes is documented during the site visit, ensuring that all relevant aspects are considered. To facilitate improvement efforts, it is crucial to gather detailed information and statistical data on the current state of the production process. Figure 2, illustrates the current plant layout, detailing the entire process flow from supplier input to final product delivery to customers.

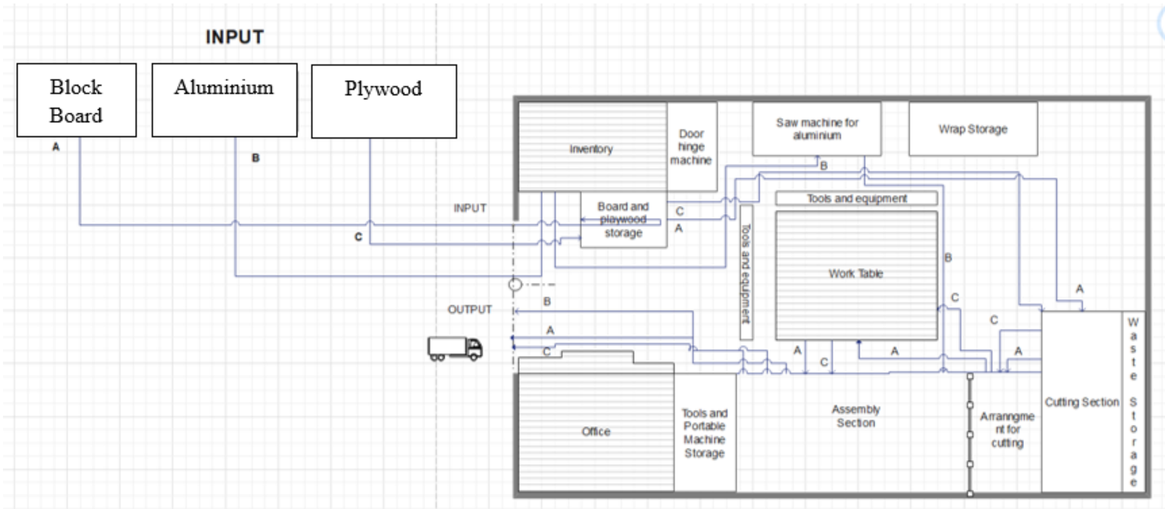

Figure 2. Plant layout

Table 1.

Category	Data Collected	Purpose
Processing Time	Takt time, cycle time, changeover time	Assess process efficiency and identify delays.
Production Performance Metrics	Throughput, defect rates, rework rates (historical data)	Identify trends, inefficiencies, and areas for quality improvement.
Operator Insights	Interviews and surveys with 5 direct production line members across 13 workstations	Detect process difficulties, bottlenecks, and worker challenges.
Machine Performance Data	Production speed, equipment status, frequent failures, changeover time (CO)	Evaluate machine reliability and identify maintenance needs.
Process Flow & Layout	Workflow documentation, equipment usage, factory layout	Optimize spatial arrangements and streamline process flow.
Workforce and Shift Patterns	Working shifts, total working hours, break times	Improve labour efficiency and optimize workforce scheduling.

Table 1. Data for Actual State

The production line consists of 13 workstations, each playing a crucial role in the manufacturing process. By strategically allocating tasks and optimizing resource distribution across these workstations, the objective is to enhance operational efficiency, minimize delays, and improve overall productivity. The key data points are collected, as shown in Table 1.

CURRENT STATE MAP

The state map plays a crucial role in evaluating the efficiency, productivity, and overall effectiveness of manufacturing processes within the industry. Figure 3, presents the CSVSM for Block Board, detailing the sequence and arrangement of its five key processes. This visual representation provides valuable insights into the spatial organization, material flow, inventory movement, and operational activities within the supply chain. After calculation, the total value-added time for the block board is 198 minutes. In comparison, the non-value-added (NVA) time amounts to 1,446 minutes, highlighting significant process optimization and waste reduction opportunities.

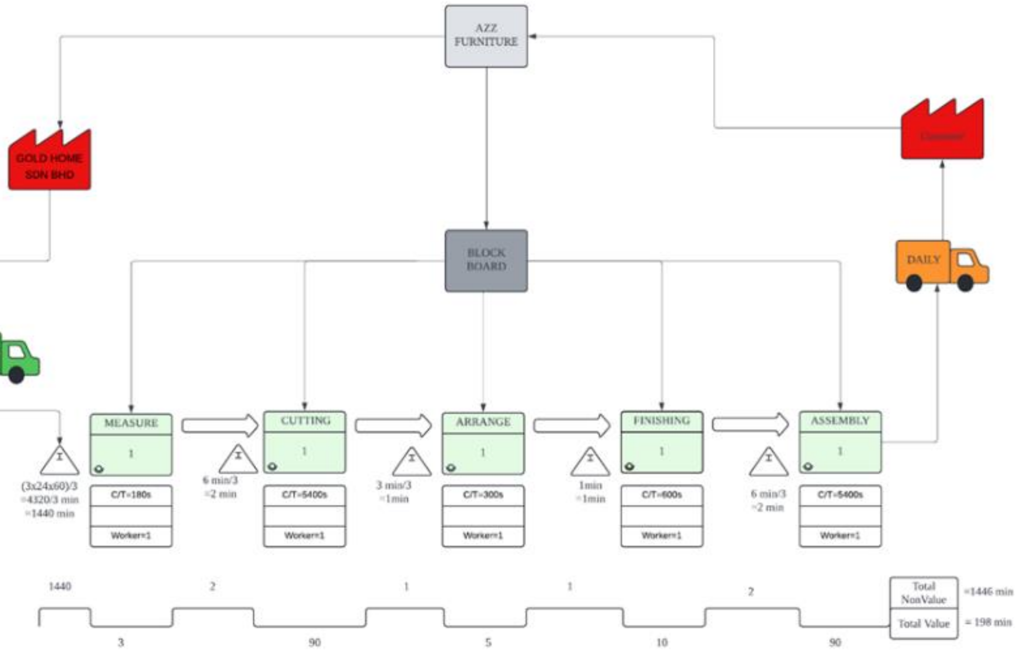

Figure 3. VSM for Block Board

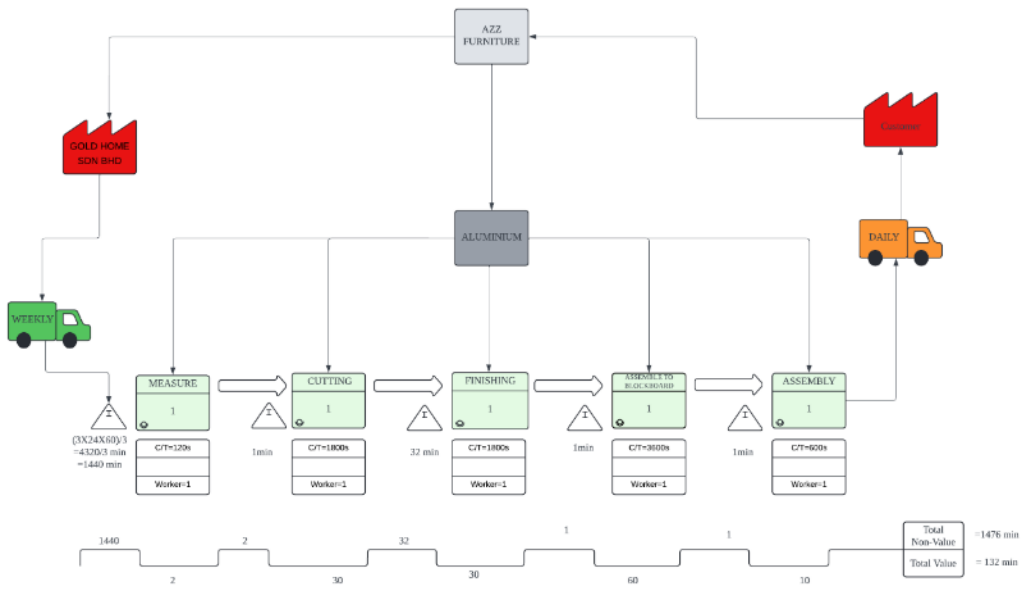

Figure 4. VSM for Aluminium

Figure 4, illustrates a production line featuring a linear arrangement of five workstations dedicated to processing Aluminium. This layout, commonly referred to as a "straight-line" or "in-line" configuration, positions workstations sequentially along a single path. This design facilitates the smooth flow of resources and products from one workstation to the next, ensuring a streamlined progression through the production process. In this setup, the total time recorded for the aluminium processing encompassing both VA and NVA activities is 1,472 minutes. Within this total, the VA time, which directly contributes to the transformation of the material, accounts for 132 minutes. This highlights a significant disparity between VA and NVA activities, underscoring the potential for process optimization to reduce inefficiencies and enhance overall productivity.

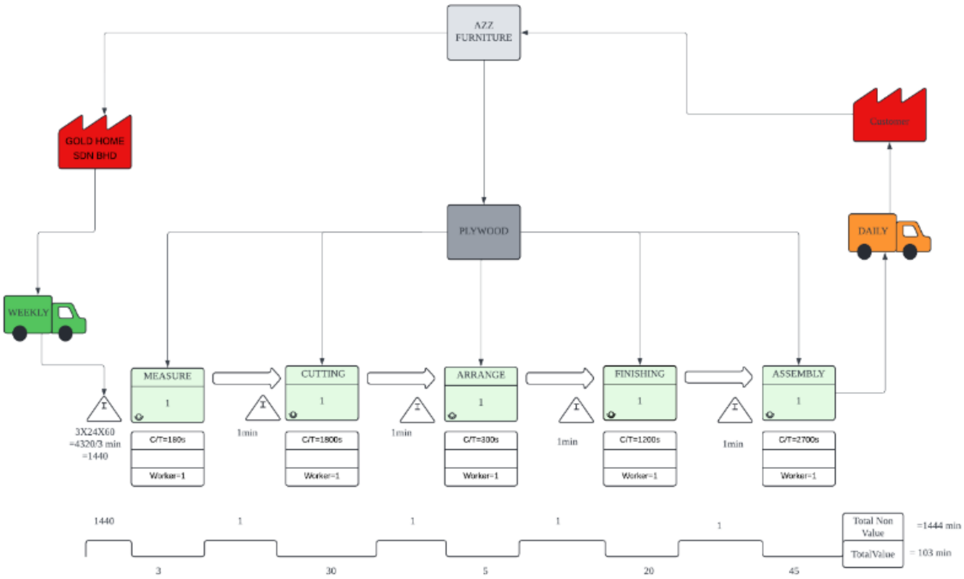

Figure 5. VSM for Plywood

Figure 5, presents the current state map for Plywood manufacturing, the VSM highlighting both VA and NVA activities. The process involves five main steps: measuring, cutting, arranging, finishing, and assembly, with each step assigned to a single worker. The total value-added time is 103 minutes, representing the actual transformation of plywood into the final product. However, the process is significantly hindered by non-value-added time, totaling 1,444 minutes, primarily due to waiting, inventory holding, and transportation delays between steps. The most extended processing times occur in the cutting (30 min) and assembly (45 min) stages, indicating critical areas for improvement. The high NVA time suggests inefficiencies that could be reduced through lean manufacturing strategies, such as minimizing waiting times, improving workflow synchronization, and optimizing material handling to enhance overall production efficiency.

Simulation of Current State

The plant is comprised of three primary supply chains: the Block Board process area, the Aluminium process area, and the Plywood process area. With a high production demand of five sets of TV racks and an operational structure limited to one 8-hour shift, it is essential to identify and address bottlenecks in the system to ensure optimal and efficient performance.

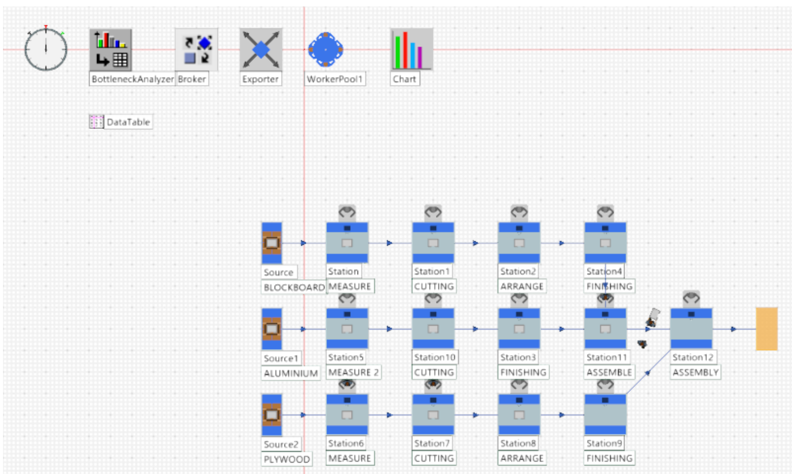

Figure 6. Overall production process

Figure 6 illustrates each area's critical role in the production process. The Block Board process area is the starting point, where parts typically take the most time in the supply chain. Ensuring smooth operation in this area is vital to prevent delays downstream. The second area is the Aluminium process area, where a crucial task involves assembling Aluminium parts with the Block Board. The flow route for this process must be accurately mapped and closely monitored for efficiency. Finally, the Plywood process area, though having a lower processing time compared to the other areas, still requires analysis to address any imbalances and achieve optimal processing time. By utilizing Tecnomatix simulation software, a detailed assembly line model can be developed to analyze the flow of parts through each process area. This model will help identify potential bottlenecks and test various scenarios to determine the most effective solutions for improving production performance. As outlined above, the assembly line is divided into three departments, each with its own simulation model. Since both entity arrival and service times are probabilistic rather than deterministic, it is necessary to determine the statistical distribution function to understand the data patterns. To obtain the statistical distribution, the Tecnomatix Bottleneck Analyzer is utilized, with the resulting data distribution function.

Table 2. Simulation Result of Current State

Output	6
Number of Operator	5
Number of Workstations	13
Lead Time	4:54:04
VA Time	1:02:43
Waiting Time	2:23:44
Total Time	7:57.51

Table 2, presents the key findings from the current state of the manufacturing system. The current state simulation's throughput is six, with five operators and 13 workstations. The lead time for this system is 4 hours, 54 minutes, and 4 seconds, which is considerably long. This extended lead time could be attributed to several factors, such as product complexity, the number of workstations, or excessive waiting time between operations. The current lead time is significantly higher than expected, posing a potential barrier for the production line to meet its targets. In this state, the value-added (VA) time is just 1 hour, 2 minutes, and 43 seconds, a much smaller figure than the total time. This indicates a considerable amount of wasted time in the production process.

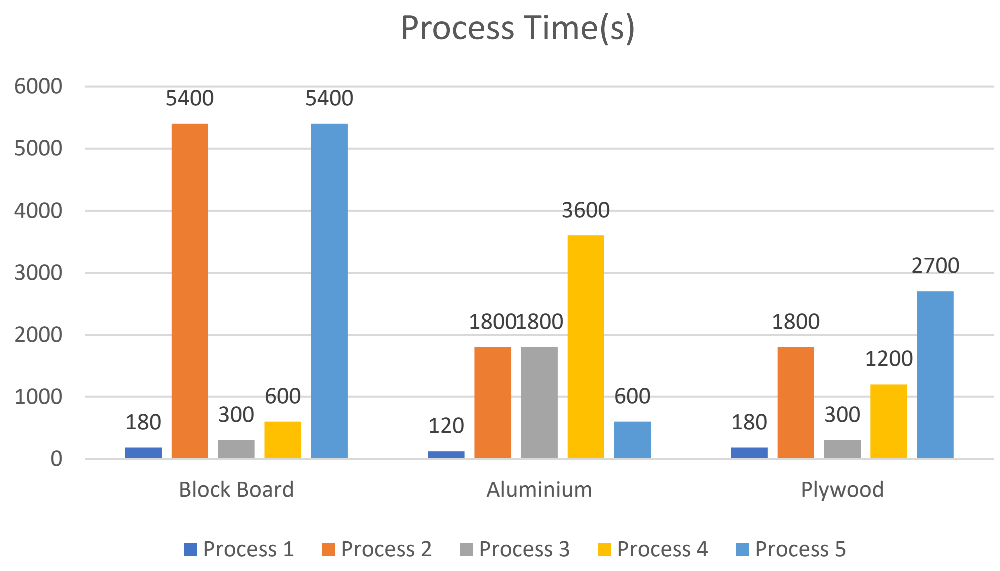

Figure 7. Process time

Figure 7, presents the processing time analysis, which shows the cycle time recorded by the production for TV Rack. The bar chart presents the processing time (in seconds) for three materials, Block Board, Aluminium, and Plywood, across five distinct processes. For Block Board, Process 2 and Process 5 take the longest time, at 5,400 seconds, while the other processes are significantly shorter, with Process 1 being the shortest at 180 seconds. This suggests that Process 2 and Process 5 may require optimization to improve efficiency. For Aluminium, the most extended process is Process 4 at 3,600 seconds, while Process 1 is the shortest at 120 seconds. Process 2 and Process 3 take 1,800 seconds, indicating that they contribute significantly to the overall processing time. Process 5, at 600 seconds, is relatively shorter but still notable.

For Plywood, Process 5 has the highest processing time at 2,700 seconds, followed by Process 2 at 1,800 seconds and Process 4 at 1,200 seconds. Process 1 remains the shortest at 180 seconds, similar to Block Board. Overall, Process 1 consistently takes the least time across all materials, while Processes 2, 4, and 5 are the longest, depending on the material. Block Board's Process 2 and Process 5, Aluminium's Process 4, and Plywood's Process 5 are critical areas for process improvement. Optimizing these processes could lead to significant time savings and increased efficiency. In order to improve the performance of the production line, various scenarios are developed based on the factors outlined above and their respective influences.

SCENARIO 1 – MERGE MEASURE AND CUTTING WORKSTATION

The processing time analysis, as in Figure 7, reveals that the Process Measure (Process 1) and Cutting operations (Process 2) can be merged, as they have low cycle times and are located near each other. Even after combining these workstations, the cycle time remains lower than the desired takt time. While other processes have similarly low cycle times, their differing task requirements prevent them from being merged. By combining workstations, production could lower operating costs. This approach could lead to savings through reduced equipment redundancy, minor space requirements, and improved procedures, ultimately decreasing labor and material costs.

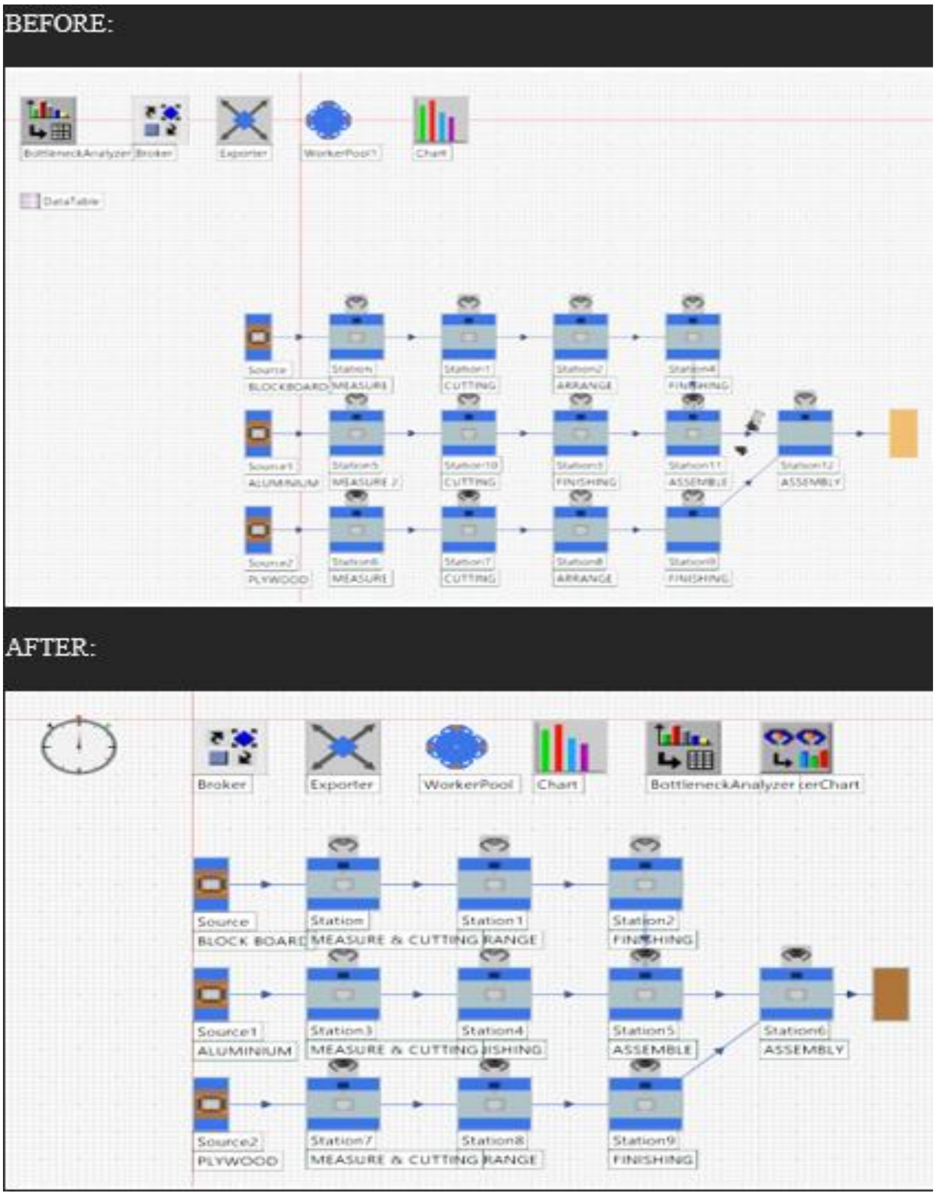

Figure 8. Before and after merged Process 1 and Process 2 Workstations

Figure 8 shows that the output for Scenario 1 does not exceed the current state of 6 TV racks produced per shift, maintaining the same output as the actual result. The number of operators remains unchanged, but the number of workstations has been reduced from 13 to 10. Notably, lead time and waiting time have decreased compared to the current state, with the highest lead time and waiting time. After implementing the workstation merge in Scenario 1, the lead time is reduced to 4 hours, 18 minutes, and 58 seconds, while the waiting time drops to 1 hour, 59 minutes, and 91 seconds. This represents a reduction from the current state, which had a lead time of 4 hours, 54 minutes, and 4 seconds and a waiting time of 2 hours, 23 minutes, and 44 seconds. Scenario 1 also features a lower value-added time of 55 minutes compared to the current state. Finally, Scenario 1 has the lowest total time, at 7 hours, 15 minutes, and 39 seconds, making it the most efficient option among the alternatives.

Scenario 2 – Implementation of Kaizen at Measuring Process

Figure 7 illustrates the process time analysis, highlighting that the Cutting process (Process 2) has one of the highest cycle times. This cycle time is approaching the required takt time to meet the customer demand of five units per shift. The first proposed improvement aims to reduce the cycle time of processes nearing the takt time limit. The Measure and Cutting process has the longest operator cycle time due to the additional effort required to align the marked part properly. Misalignment complicates the cutting process, reducing efficiency. The primary issue is that the marked part and cutter point are not in a straight line, making precise cuts difficult. The root cause of this misalignment is a crowded workstation layout, lacking designated spaces for tools and materials. This disorganization stems from the absence of standardization and inadequate workplace maintenance, leading to inefficiencies.

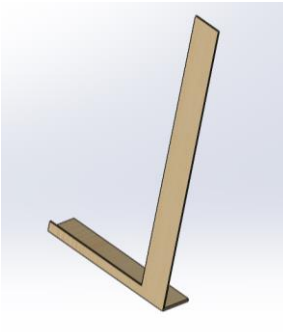

Figure 9. Ruler Jig Design

To address the issue of longer cycle time, a ruler jig (Figure 9) is proposed to ensure accurate measurement and cutting. The jig offers several benefits: it enables precise marking along a straight line and is easy to set up using the panel’s edge surface. Reducing misalignment decreases the risk of defective products and material waste, minimizing potential market claims. After implementing the ruler jig across the supply chain, processing times are expected to decrease by up to 13 minutes.

Results Analysis

The proposed alternative simulation model enables a more precise comparison, offering more profound insights into the different alternatives, as presented in Table 7.

Table 7. Workstation Performance Comparison

Parameter	Actual	Scenario 1	Scenario 2
Output	5	6	7
Number of Operators	5	5	5
Number of Workstations	13	10	10
Lead Time	4:54:04	4:18:58	4:17:91
Value-Added (VA) Time	1:02:43	0:55:00	0:55:00
Waiting Time	2:23:44	1:59:91	2:15:91
Total Time	7:57:51	7:15:39	7:42:52

Based on the comparative analysis between the current state and the two improvement scenarios, there are significant enhancements in output, processing time, and work efficiency, as shown in Figure 10. In the current state, the output is only five units. However, with the implementation of Merge Workstation (Scenario 1)**,** the output increases to 6 units, while the Kaizen at Measure & Cutting Process (Scenario 2) successfully boosts the output to 7 units. This indicates that the Kaizen approach is more effective in increasing production capacity. Regarding processing time, Lead Time in the current state is 4 hours 54 minutes, but it is reduced to 4 hours 18 minutes in Scenario 1 and 4 hours 17 minutes in Scenario 2. This reduction signifies an improvement in workflow efficiency. Similarly, VA Time decreases from 1 hour 2 minutes to 55 minutes in both scenarios, reflecting greater operational efficiency.

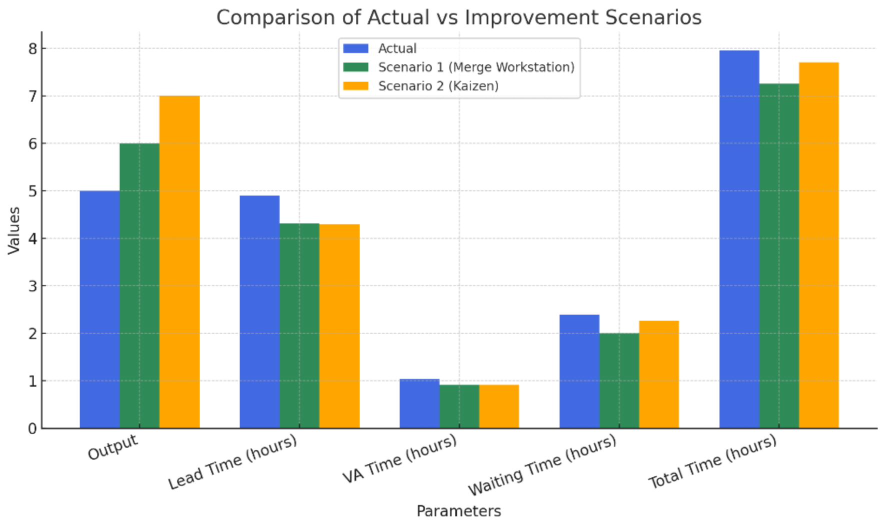

Figure 10. Comparative Analysis

Furthermore, Waiting Time is significantly reduced in Scenario 1, from 2 hours 23 minutes to 1 hour 59 minutes, while in Scenario 2, the reduction is less substantial, reaching 2 hours 15 minutes with a 6% decrease in waiting time from the actual set-up. This suggests that Merge Workstation is more effective in minimizing waiting time than the Kaizen approach. Overall, the Total Time in Scenario 1 is 7 hours 15 minutes, while in Scenario 2, it is 7 hours 42 minutes, compared to 7 hours 57 minutes in the current state. In conclusion, if the primary goal is to increase output, Kaizen at Measure & Cutting Process is more suitable, as it achieves a 40% improvement in production. However, if the main objective is to reduce overall processing time, Merge Workstation is more effective, providing more significant time savings across the entire process. Therefore, the improvement method should be based on organizational priorities, such as maximizing production volume or optimizing processing time.

CONCLUSION

In conclusion, this research has successfully met all its objectives. First, comprehensive data was collected on a furniture fabrication company's multiple supply chain processes to develop an accurate VSM state map. Second, the manufacturing process was simulated using Tecnomatix, facilitating a thorough assessment of production line performance and providing critical insights into existing inefficiencies. The simulation pinpointed bottlenecks, particularly in the measuring and cutting processes, and established a foundation for strategic improvements. Rigorous verification and validation confirmed the model's accuracy in representing real-world conditions, ensuring its reliability for future optimization. The proposed improvements significantly enhanced production efficiency. Scenario 1 effectively reduced waiting time by merging workstations, while Scenario 2, incorporating Kaizen, led to a 40% increase in output while maintaining the same workforce. Notably, Scenario 2 achieved the lowest lead time and optimized resource utilization, making it the most impactful solution. These findings underscore the effectiveness of integrating lean principles with simulation techniques to minimize NVA activities, enhance productivity, and improve product quality. By implementing VSM-driven enhancements, this research demonstrates the potential for sustainable process improvements in manufacturing. Future work should explore additional lean methodologies such as Just-in-Time (JIT) and Heijunka for further refinement. Additionally, real-time monitoring and digital simulations could provide deeper insights for ongoing operational excellence in furniture manufacturing.

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