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Production Layout Optimization to Reduce Transportation Waste and Improve Process Cycle Efficiency in Passenger Seat Assembly

Amrin[1]✉, Feby Gusti Dendra[2], Ahlandika Wirasatria[3]

[1, 2, 3] Automotive Industrial Engineering, Politeknik STMI Jakarta, Indonesia

✉ **Corresponding Author :** Amrin (e-mail: amrinrapi88@gmail.com)

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ABSTRACT

Passenger seat assembly is a critical process in bus manufacturing because it directly affects production completion and delivery performance. This study aimed to optimize the production layout to reduce transportation waste and improve Process Cycle Efficiency (PCE) in the passenger seat assembly process of a bus manufacturing company. A quantitative case study was conducted using data collected through direct observation, time studies, interviews, and questionnaires. The analysis integrated Value Stream Mapping (VSM), Waste Assessment Model (WAM), Value Stream Analysis Tools (VALSAT), and Process Activity Mapping (PAM) to identify dominant waste and develop layout improvement strategies. The results showed that transportation waste was the dominant waste, accounting for 18.37% of the total waste score. The proposed layout reduced the number of activities from 36 to 32, decreased transportation time from 72.1 to 14.8 minutes, and eliminated all non-value-added activities. Consequently, lead time decreased from 543.03 to 456.67 minutes, while Process Cycle Efficiency increased from 51.64% to 61.88%. These findings demonstrate that lean-based production layout optimization effectively reduces transportation waste and improves operational efficiency in make-to-order bus manufacturing.

INTRODUCTION

The increasing level of competition in the manufacturing sector has encouraged companies to continuously improve operational performance to maintain productivity, quality, and responsiveness to customer demand (Sahoo, 2021). One of the critical indicators of manufacturing performance is lead time, which reflects the total time required to complete a production process from the receipt of an order until the product is ready for delivery (Suri, 2020). Excessive lead time may lead to delayed deliveries, increased operational costs, lower resource utilization, and reduced customer satisfaction (Mohammed & Mandal, 2023). Therefore, efforts to reduce lead time have become an essential aspect of manufacturing system optimization, particularly in industries characterized by high product variability and make-to-order production systems.

Lean manufacturing has been widely recognized as an effective approach for improving manufacturing performance by systematically identifying and eliminating activities that do not add value to the final product (Kumar et al., 2022). According to Taher & Bashar, (2024), lean manufacturing focuses on maximizing customer value while minimizing waste through continuous improvement initiatives. The implementation of lean principles enables organizations to improve process flow, shorten production cycles, reduce operational costs, and enhance overall competitiveness (Nicholas, 2018). Within the lean philosophy, waste refers to any activity consuming resources without adding value from the customer's perspective (Chroneer & Wallström, 2016). Traditionally, seven categories of waste have been identified, namely overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion, and defects (Ngerndee et al., 2022).

Among various lean tools, Value Stream Mapping (VSM) has been extensively employed to visualize material and information flows across the production process and identify sources of waste (Vilventhan et al., 2019). VSM facilitates the distinction between value-added and non-value-added activities, enabling organizations to prioritize improvement opportunities effectively (Ahmad et al., 2022). However, while VSM provides a comprehensive overview of the production flow, it may not adequately determine the interrelationships among different waste categories or identify which waste should receive priority attention (Dinis-Carvalho et al., 2019). Therefore, additional analytical tools are often required to support more focused improvement efforts. Waste Assessment Model (WAM), developed by (Bergeron, 2017), has emerged as a complementary approach for identifying dominant waste and evaluating the relationships among different types of waste through the integration of Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ). The application of WAM allows organizations to prioritize improvement initiatives based on the magnitude and influence of specific waste types (Maulana et al., 2025). Furthermore, the integration of WAM with Value Stream Analysis Tools (VALSAT) enables the selection of appropriate mapping tools to support detailed analysis and improvement planning (Nurlina & Hidayat, 2021).

Previous studies have demonstrated the effectiveness of integrating lean tools in reducing waste and improving production performance. Setiawan et al., (2021) reported that the implementation of WAM successfully identified dominant waste in automotive assembly processes and contributed to improvements in Process Cycle Efficiency (PCE). Similarly, Wirasatria & Dendra, (2025) found that the combination of VSM and WAM reduced lead time in automotive electrical component assembly through layout modifications and workflow improvements. Tasdemir & Gazo, (2018) also emphasized that lean-based approaches significantly contribute to waste elimination and operational efficiency enhancement in manufacturing systems. Despite these contributions, most previous studies primarily focused on identifying waste and proposing general recommendations without emphasizing the implementation of layout improvement strategies, particularly in bus manufacturing environments characterized by high customization and make-to-order production systems.

Bus manufacturing companies generally operate under a make-to-order production strategy, where each product is designed according to specific customer requirements (Chepkania, 2018). This production characteristic introduces a high degree of variability in materials, components, and assembly activities, potentially increasing the complexity of production management and the occurrence of waste (Javadi et al., 2025). In finishing operations, passenger seat assembly represents a critical process due to its direct influence on production completion and delivery schedules. Inefficient material handling, excessive transportation, and repetitive work activities may significantly increase lead time and reduce overall process efficiency. Based on observations conducted in a bus manufacturing company, the passenger seat assembly process in the finishing division experienced operational inefficiencies resulting from unnecessary transportation activities and repeated adjustments during installation. The initial assessment indicated that the total lead time reached 543.03 minutes per unit, while the Process Cycle Efficiency was only 51.64%. These conditions prevented the production system from achieving its expected performance targets and highlighted the need for systematic improvement efforts. Since transportation activities are categorized as non-value-added operations, reducing unnecessary movement through layout optimization may provide substantial opportunities for improving process performance.

Unlike previous studies that primarily emphasized waste identification, this study focuses on the implementation of lean-based layout optimization to minimize transportation waste and enhance Process Cycle Efficiency in passenger seat assembly operations. The integration of Value

Stream Mapping, Waste Assessment Model, and Process Activity Mapping selected through VALSAT provides a comprehensive analytical framework for identifying dominant waste, evaluating process activities, and designing effective improvement strategies (Nur'Anisa & Pramesti, 2025). The novelty of this study lies in the application of layout improvement as a practical intervention within a make-to-order bus manufacturing environment, thereby contributing both theoretically and practically to the field of lean manufacturing and production system optimization. Unlike previous studies that mainly focused on waste identification, this study integrates Value Stream Mapping, Waste Assessment Model, Value Stream Analysis Tools, and Process Activity Mapping to develop and evaluate a production layout optimization strategy for reducing transportation waste and improving Process Cycle Efficiency in a make-to-order bus manufacturing environment. Therefore, This study employed a quantitative case study approach to evaluate the existing production process and develop an improved production layout using lean manufacturing techniques. The findings are expected to provide practical insights for manufacturing practitioners seeking to enhance operational efficiency through lean-based improvement initiatives while enriching the existing body of knowledge related to waste reduction strategies in customized production environments.

RESEARCH METHODS

Research Design

This research employed a quantitative case study conducted in the finishing division of a bus manufacturing company. The study consisted of four main stages: preliminary observation, current state analysis, improvement design, and performance evaluation. Primary data were obtained through direct observation, time studies, interviews, and questionnaires, while secondary data included production layouts, standard operating procedures, and production records. Figure 1 illustrates the overall research procedure adopted in this study.

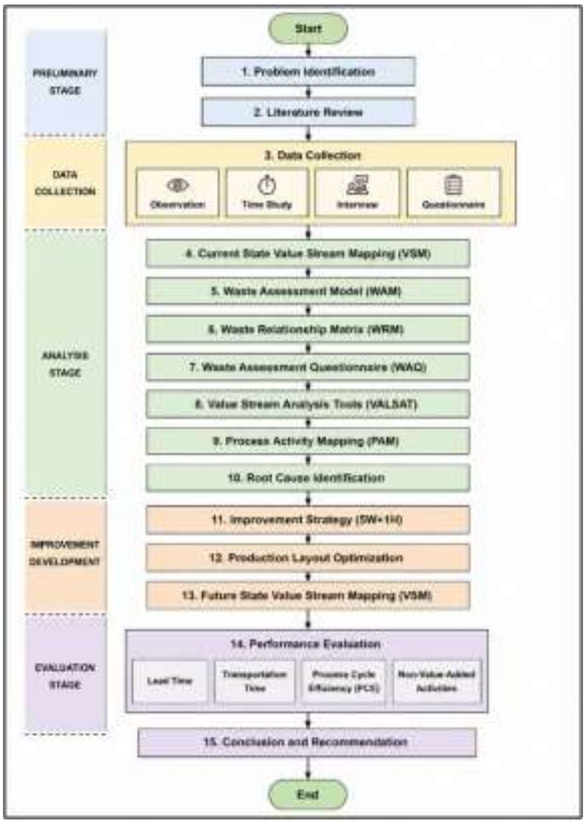

Figure 1. Research Flowchart

The study consisted of four main stages: preliminary observation, current state analysis, improvement design, and evaluation of the proposed improvements. The research framework is illustrated through a systematic sequence beginning with problem identification and ending with performance evaluation after improvement implementation. The analysis was conducted under several assumptions to ensure consistency throughout the study. Production demand was assumed to remain constant during the observation period. The number of operators, equipment, and working hours remained unchanged before and after layout improvement. Machine breakdowns, material shortages, and operator absenteeism were not considered. The study focused exclusively on the passenger seat assembly process in the finishing division and did not evaluate other production lines or supporting logistics activities.

Data Collection

Primary data were collected through direct observation of the production process, time studies using a stopwatch, interviews with operators and supervisors, and questionnaires required for Waste Assessment Model (WAM) analysis. Secondary data included production targets, process flow information, production layout drawings, standard operating procedures, and company records related to passenger seat assembly activities. Table 1 summarizes the primary and secondary data used in this study together with the corresponding data collection methods.

Table 1. Research Data Sources

Data Type	Data Collected	Collection Method
Primary	Cycle time	Stopwatch observation
Primary	Transportation time	Direct observation
Primary	Operator activities	Observation
Primary	Waste relationship	Questionnaire
Primary	Process verification	Interview
Secondary	Production layout	Company document
Secondary	SOP	Company document
Secondary	Production records	Company document
Secondary	Process flow	Company document

Data Analysis Procedure

The first stage involved mapping the existing production process using Value Stream Mapping (VSM). Current State Value Stream Mapping (CVSM) was developed to visualize the flow of materials and information during passenger seat assembly activities. Data required for the VSM included cycle time, waiting time, transportation time, inventory levels, number of operators, and information flow among production stations. The current state map enabled the identification of value-added and non-value-added activities contributing to excessive lead time. Time study analysis was conducted to determine the standard time for each assembly activity. The observed cycle time was calculated as follows:

$$CT = \frac{\sum X_i}{n} \quad (1)$$

where CT represents the average cycle time, X_i is the observed time for each observation, and n is the number of observations. Subsequently, the normal time was determined by considering the operator performance rating using Equation (2):

$$NT = CT \times PR \quad (2)$$

where NT denotes normal time and PR represents the performance rating factor. Standard time was then calculated by incorporating allowance factors using Equation (3):

$$ST = \frac{NT}{1-A} \quad (3)$$

where ST is the standard time and A is the allowance factor expressed as a decimal value. Waste identification was performed using the Waste Assessment Model (WAM), which integrates the Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ). The WRM was employed to identify the relationships among the seven types of waste, namely overproduction, inventory, defects, motion, transportation, inappropriate processing, and waiting. The relationship strength among waste categories was determined using a structured questionnaire adapted from Rawabdeh (2005). The WAQ was subsequently used to assess the occurrence level of each waste category in the passenger seat assembly process. The questionnaire consisted of questions classified into "from" and "to" categories, reflecting whether a specific waste contributed to or resulted from other wastes. The scoring results obtained from the WAQ were combined with WRM weighting factors to determine the dominant waste requiring improvement priority.

Following the identification of dominant waste, Value Stream Analysis Tools (VALSAT) were utilized to select the most appropriate analytical tool for detailed process evaluation. The selection process was based on the relationship between identified waste categories and the capability of available mapping tools. The mapping tool with the highest weighted score was chosen for further analysis. Based on the VALSAT results, Process Activity Mapping (PAM) was employed to analyze the detailed activities involved in passenger seat assembly. Each activity was classified into three categories: Value Added (VA), Necessary but Non-Value Added (NNVA), and Non-Value Added (NVA). PAM facilitated the identification of activities that contributed to waste generation and provided insights into opportunities for process improvement.

Improvement alternatives were formulated using the 5W+1H approach, consisting of What, Why, Where, When, Who, and How. The primary improvement strategy focused on optimizing the production layout to minimize unnecessary transportation activities identified during the analysis phase. The proposed layout changes were designed to shorten material movement distances and eliminate repetitive handling activities during passenger seat assembly operations. The effectiveness of the improvement strategy was evaluated by comparing the performance indicators before and after implementation. The key performance indicator used in this study was Process Cycle Efficiency (PCE), which measures the proportion of value-added time relative to the total lead time. PCE was calculated using Equation (4):

$$PCE(\%) = \frac{Value\ Added\ Time}{Lead\ Time} \times 100 \quad (4)$$

An increase in PCE indicates an improvement in process efficiency resulting from the reduction of non-value-added activities. Finally, Future State Value Stream Mapping (FVSM) was developed to visualize the improved production system after implementing the proposed layout optimization. The comparison between the current state and future state conditions provided evidence regarding the effectiveness of the improvement strategy in reducing transportation waste and enhancing operational efficiency within the passenger seat assembly process.

Validation of Improvement Results

The proposed production layout was validated by comparing process performance indicators before and after improvement. Validation focused on lead time, transportation time, Process Cycle Efficiency (PCE), the number of production activities, and the elimination of non-value-added activities. The proposed layout was also reviewed with production supervisors to confirm its operational feasibility and implementation practicality under existing production conditions.

RESULTS AND DISCUSSION

Waste Identification Using Waste Assessment Model

The Waste Assessment Model (WAM) was applied to identify the dominant type of waste occurring in the passenger seat assembly process. The analysis integrated the Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ) to evaluate the interrelationship and intensity of the seven categories of waste. The findings revealed that transportation waste was the most dominant waste category, accounting for 18.37% of the total waste score. The high percentage of transportation waste indicated that excessive movement of materials and products significantly contributed to process inefficiency. Field observations revealed that passenger seats had to be transported from the storage area located near workstation SK 8 Line B to the assembly area at SK 4 Line C. In addition, repetitive seat positioning activities occurred because operators frequently had to readjust the seat positions during installation. These activities prolonged the production process without adding value to the final product. The dominance of transportation waste aligns with the characteristics of make-to-order production systems, where material flow complexity often increases due to product customization. Similar findings have been reported in previous lean manufacturing studies, emphasizing that inefficient layouts and excessive material handling substantially affect production lead time and operational performance.

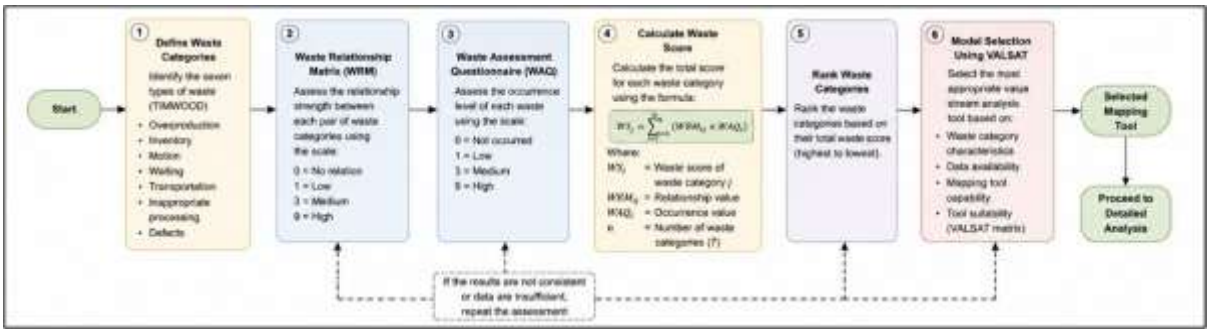

Figure 2. Flowchart of Waste Identification and Model Selection

Selection of Improvement Tools Using VALSAT

After identifying transportation as the critical waste category, Value Stream Analysis Tools (VALSAT) were employed to determine the most appropriate analytical tool for improvement planning. The selection process was based on the multiplication of waste percentages obtained from WAM with the weighting factors defined in the VALSAT matrix. The VALSAT analysis identified Process Activity Mapping (PAM) as the most suitable tool for further investigation. PAM was selected because it enables detailed classification of activities into Value Added (VA), Necessary but Non-Value Added (NNVA), and Non-Value Added (NVA), thereby facilitating the identification of activities contributing to waste generation.

Evaluation Criteria	Mapping Tools				Weight (Wi)	Weighted Score (Wi × Ri)
	Process Activity Mapping (PAM)	Supply Chain Response Matrix (SCRM)	Quality Filter Mapping (QFM)	Demand Amplification Mapping (DAM)		
1. Information Flow Ability to capture and analyze information flow.	Medium (3)	High (4)	Low (2)	High (4)	0.15	0.45 0.60
2. Material Flow Ability to capture and analyze material flow.	High (4)	High (4)	Medium (3)	Medium (3)	0.20	0.80 0.60 0.60
3. Lead Time Focus Ability to support lead time reduction analysis.	High (4)	Medium (3)	High (4)	Low (2)	0.20	0.80 0.60 0.40
4. Waste Identification Ability to identify waste in detail.	High (4)	Medium (3)	High (4)	Low (2)	0.20	0.80 0.60 0.40
5. Data Requirement Amount and complexity of data required.	Medium (3)	High (4)	Medium (3)	High (4)	0.15	0.45 0.60 0.45
6. Ease of Application Ease of use and implementation in the company.	High (4)	Medium (3)	Medium (3)	Medium (3)	0.10	0.40 0.30 0.30
Total Score (∑ Wi × Ri)	3.70	3.50	3.25	2.90	1.00	-
Rank	1	2	3	4		-

Figure 3. VALSAT Selection Chart for Mapping Tool

Figure 3 presents the VALSAT selection chart used to determine the most appropriate detailed mapping tool for analyzing the production process. The selection was performed by evaluating several mapping tools based on six criteria, namely information flow, material flow, lead time focus, waste identification capability, data requirements, and ease of application. Each mapping tool was assessed according to its capability in addressing these criteria, and the overall suitability was determined using a weighted scoring approach. The evaluation results indicate that Process Activity Mapping (PAM) achieved the highest total weighted score among the alternative mapping tools. This result suggests that PAM is the most suitable analytical tool for this study because it provides a detailed representation of every production activity and classifies them into Value-Added (VA), Necessary Non-Value-Added (NNVA), and Non-Value-Added (NVA) categories. Such detailed activity classification is essential for identifying transportation waste and evaluating the impact of production layout optimization. Consequently, Process Activity Mapping was selected for the subsequent detailed analysis of the passenger seat assembly process. The selected mapping tool was then used to quantify process activities, identify non-value-added operations, and support the development of improvement strategies aimed at reducing transportation waste and increasing Process Cycle Efficiency (PCE).

Process Activity Mapping Before Improvement

The Process Activity Mapping analysis revealed that the passenger seat assembly process consisted of 36 activities, covering operation, transportation, inspection, storage, and delay activities. The total processing time required was 463.03 minutes, and operators traveled a total distance of 840 meters throughout the assembly process. Table 2 summarizes the distribution of activities before improvement.

Table 2. Process Activity Distribution Before Improvement

Activity	Number of Activities	Percentage	Time (minutes)	Percentage
Operation	14	39%	310.4	67%
Transportation	11	31%	72.1	16%
Inspection	7	19%	54.2	12%
Storage	4	11%	26.4	6%
Delay	0	0%	0.0	0%
Total	**36**	**100%**	**463.03**	**100%**

The classification of activities based on value contribution showed that only a quarter of the activities directly added value to the product. Figure 4 demonstrates that although Value-Added (VA) activities accounted for only 25% of the total number of process activities, they consumed 59.56% of the total processing time. This finding indicates that the production process was primarily devoted to activities that directly contributed to product transformation, while a considerable proportion of supporting activities still existed within the production flow. Conversely, Necessary but Non-Value-Added (NNVA) activities represented 47% of the total activities but contributed only 28.94% of the total processing time. These activities mainly consisted of material transportation, inspection, and positioning operations that were required under the existing production conditions but did not directly increase product value. Furthermore, Non-Value-Added (NVA) activities accounted for 28% of all activities, consuming 53.2 minutes or 11.50% of the total lead time. This proportion indicates that a significant amount of production time was spent on activities that could potentially be eliminated without affecting product quality or customer requirements.

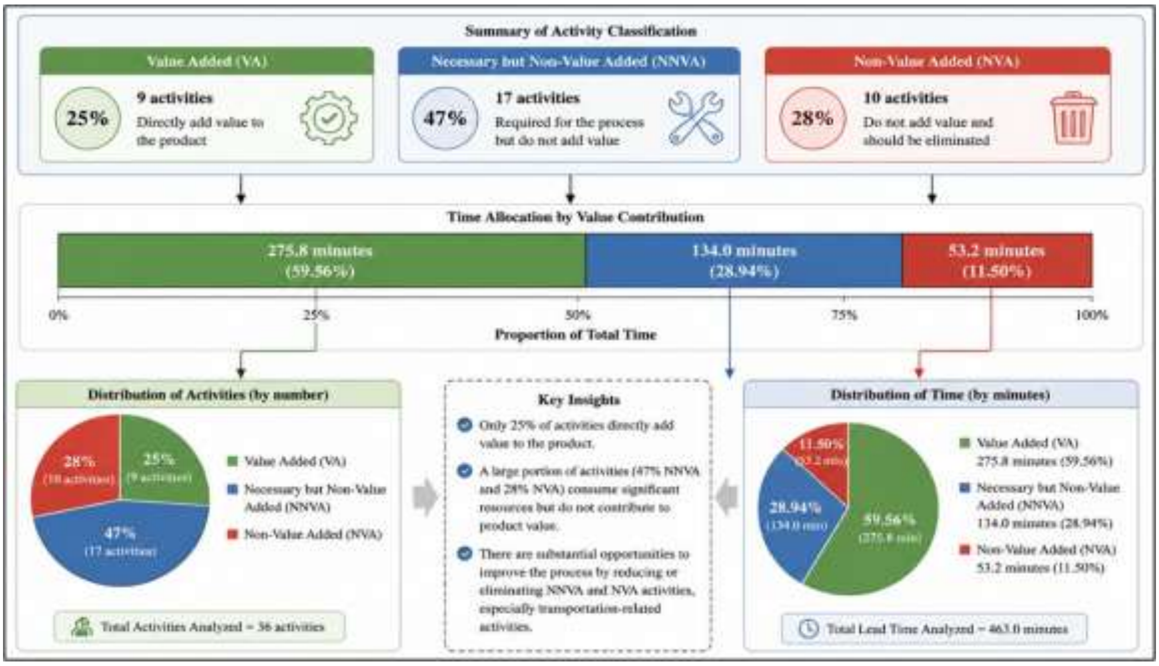

Figure 4. Classification of Activites Based on Value Contribution

The dominance of NNVA and NVA activities suggests that production inefficiency was primarily associated with material flow rather than the assembly operations themselves. Similar findings were reported by Batwara et al. (2023), who demonstrated that excessive transportation and unnecessary handling activities significantly increase manufacturing lead time despite representing a relatively small portion of the total processing time. Likewise, Saraswati (2015) found that inefficient workstation arrangements frequently generate additional transportation and waiting activities, thereby reducing overall production efficiency. These studies indicate that facility layout plays a critical role in determining the proportion of non-value-added activities within manufacturing systems.

The results obtained in this study further support the findings of Setiawan et al. (2021), who emphasized that Process Activity Mapping (PAM) provides a detailed understanding of production activities by distinguishing Value-Added, Necessary but Non-Value-Added, and Non-Value-Added activities. However, unlike previous studies that primarily focused on identifying process waste, the present study extended the analysis by translating the PAM results into a production layout optimization strategy. This improvement successfully eliminated all Non-Value-Added activities while reducing transportation time and increasing Process Cycle Efficiency. Therefore, the findings demonstrate that integrating Process Activity Mapping with production layout optimization provides a more comprehensive approach for improving operational performance in make-to-order bus manufacturing environments.

Improvement Strategy Through Production Layout Optimization

Based on the results of PAM and the 5W+1H analysis, a production layout optimization strategy was proposed to eliminate unnecessary transportation activities. The primary improvement involved relocating the passenger seat assembly process from SK 4 Line C to the storage area near SK 8 Line B. This modification aimed to reduce the distance traveled by operators and minimize material handling activities.

Additionally, activities involving repeated seat adjustments during installation were redesigned to enable simultaneous operations and improve operator ergonomics. The proposed layout changes focused on streamlining the production flow without requiring substantial capital investment. The proposed layout changes focused on streamlining the production flow without requiring substantial capital investment

The proposed production layout optimization was developed by addressing the root cause of transportation waste identified during the Waste Assessment Model (WAM) analysis. Rather than introducing new equipment or increasing workforce capacity, the improvement strategy focused on rearranging workstation locations to shorten material travel distances and simplify the production flow. This approach is consistent with lean manufacturing principles, which emphasize eliminating waste through process redesign rather than increasing operational resources.

The relocation of the passenger seat assembly process closer to the storage area significantly reduced unnecessary material handling activities and operator movement. According to Suri (2020), reducing travel distance between consecutive operations is one of the most effective approaches for shortening manufacturing lead time because it directly decreases waiting and transportation activities that do not add customer value. Similarly, Kumar et al., (2022) reported that production layout optimization contributes substantially to manufacturing performance by improving workflow continuity and reducing excessive handling operations commonly found in assembly systems.

The improvement strategy proposed in this study also supports the findings of Setiawan et al. (2021), who demonstrated that integrating waste assessment with layout improvement provides greater operational benefits than implementing waste identification alone. Unlike previous studies that primarily emphasized waste mapping and prioritization, the present study translated the analytical findings into an implementable production layout modification specifically designed for a make-to-order bus manufacturing environment. As a result, the proposed improvement not only reduced transportation activities but also created a smoother material flow that subsequently contributed to lower lead time and higher Process Cycle Efficiency.

Process Activity Mapping After Improvement

Following the implementation of layout optimization, the total number of activities decreased from 36 to 32 activities, while the total process time was reduced to 385.7 minutes. The distribution of activities after improvement is presented in Table 3.

Table 3. Process Activity Distribution After Improvement

Activity	Number of Activities	Percentage	Time (minutes)	Percentage
Operation	18	56%	344.0	89%
Transportation	10	31%	14.8	4%
Inspection	4	13%	26.8	7%
Storage	0	0%	0.0	0%
Delay	0	0%	0.0	0%
Total	**32**	**100%**	**385.7**	**100%**

The time spent on transportation activities decreased substantially from 72.1 minutes to 14.8 minutes, representing a reduction of approximately 79.5%. Furthermore, storage activities were entirely eliminated following the implementation of the new layout configuration. The classification of activities after improvement also demonstrated significant changes. The number of VA activities increased to 11 activities (34%), while NNVA activities accounted for 21 activities (66%). Importantly, all NVA activities were successfully eliminated. The corresponding time allocation became 282.6 minutes (73%) for VA activities and 103.1 minutes (27%) for NNVA activities. These findings suggest that layout optimization effectively transformed several non-value-added activities into more productive operations, thereby enhancing the efficiency of the assembly process.

Process Cycle Efficiency Improvement

Process Cycle Efficiency (PCE) was used to evaluate the effectiveness of the proposed improvement. Before implementation, the value-added time of 275.8 minutes and the total lead time of 534.03 minutes resulted in a PCE value of 51.64%. After layout optimization, the value-added time increased to 282.6 minutes, while the total lead time decreased to 456.67 minutes, yielding a PCE value of 61.88%. The comparison of key performance indicators before and after improvement is presented in Table 4.

Table 4. Comparison of Process Performance Before and After Improvement

Indicator	Before Improvement	After Improvement	Improvement
Lead Time (minutes)	543.03	456.67	86.36 minutes
Value-Added Time (minutes)	275.8	282.6	6.8 minutes
Process Cycle Efficiency (%)	51.64	61.88	10.24%
Number of Activities	36	32	4 activities
NVA Activities	10	0	Eliminated

The reduction in lead time and increase in PCE indicate that production layout optimization effectively enhanced process performance. The elimination of unnecessary transportation activities allowed operators to allocate more time to productive tasks, thereby increasing the proportion of value-added work. These findings support previous studies emphasizing the importance of lean-based layout improvement in manufacturing environments. However, unlike earlier research that primarily focused on waste identification, this study demonstrates the practical impact of implementing layout modifications within a make-to-order bus manufacturing setting. Therefore, production layout optimization can be considered an effective strategy for reducing transportation waste and improving operational efficiency in customized manufacturing systems.

Research Contribution and Novelty

The present study provides both methodological and practical contributions to lean manufacturing implementation in make-to-order production environments. While previous studies have primarily focused on identifying production waste using Value Stream Mapping (VSM), Waste Assessment Model (WAM), or other lean tools, the proposed approach extends beyond waste identification by integrating VSM, WAM, Value Stream Analysis Tools (VALSAT), and Process Activity Mapping (PAM) into a structured decision-making framework for production layout optimization.

Unlike earlier research, which generally emphasizes waste prioritization or process evaluation, this study demonstrates how the integrated analysis can be translated into an implementable layout improvement capable of reducing unnecessary transportation activities without requiring additional production equipment or significant capital investment. The proposed improvement was evaluated quantitatively using lead time, transportation time, and Process Cycle Efficiency (PCE), providing measurable evidence of operational performance improvement.

Furthermore, this research contributes to the limited body of literature addressing lean implementation in make-to-order bus manufacturing, where high product customization frequently creates complex material flows and excessive transportation activities. The findings indicate that optimizing production layout based on systematic waste analysis can substantially improve production efficiency while maintaining existing production resources. Therefore, the proposed framework may serve as a practical reference for manufacturing companies facing similar transportation-related inefficiencies.

CONCLUSION

This study successfully achieved its objective of optimizing the production layout to reduce transportation waste and improve Process Cycle Efficiency (PCE) in the passenger seat assembly process of a bus manufacturing company. The integrated application of Value Stream Mapping (VSM), Waste Assessment Model (WAM), Value Stream Analysis Tools (VALSAT), and Process Activity Mapping (PAM) effectively identified transportation waste as the primary source of production inefficiency and provided a systematic basis for developing an appropriate improvement strategy. The proposed production layout optimization, which involved relocating the passenger seat assembly area closer to the storage location and simplifying seat installation activities, significantly improved material flow throughout the assembly process.

The implementation of the proposed layout reduced transportation time from 72.1 minutes to 14.8 minutes, eliminated all non-value-added activities, decreased lead time from 543.03 minutes to 456.67 minutes, and increased Process Cycle Efficiency from 51.64% to 61.88%. These results demonstrate that production layout optimization based on lean manufacturing principles can effectively improve operational performance without requiring additional equipment or major capital investment. This study contributes to the practical implementation of lean manufacturing by demonstrating that the integration of VSM, WAM, VALSAT, and PAM can support data-driven production layout improvement in make-to-order manufacturing environments. The proposed framework may serve as a practical reference for manufacturing companies seeking to reduce transportation waste and improve production efficiency through systematic layout optimization. Future research is recommended to evaluate alternative layout scenarios using discrete-event simulation and to validate the proposed approach across different production lines and manufacturing industries.

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