IJMECIE International Journal of Mechanical, Electrical and Civil Engineering

E-ISSN: 3047-4531
P-ISSN: 3047-4523

Research Article

PDCA-Based Improvement of Packing Systems to Reduce Double Handling and Downtime in Material Handling Operations

Medi Humaedi[1]*, Amalina Putri Salsabila[2], Ridwan Setiawan[3], Ade Omar Hidayat[4], Yudi Prastyo[5]

[1,5]Industrial Engineering Study Program, Universitas Pelita Bangsa, Indonesia; E-mail: medihumaedi74@gmail.com
[2] Industrial Engineering Study Program, Universitas Pelita Bangsa, Indonesia; E-mail: amalinaputri28@gmail.com
[3] Industrial Engineering Study Program, Universitas Pelita Bangsa, Indonesia; E-mail: setyarid76@gmail.com
[4] Industrial Engineering Study Program, Universitas Pelita Bangsa, Indonesia; E-mail: adeomar323@gmail.com
* Corresponding Author: medihumaedi74@gmail.com

Abstract: An inefficient packing system can result in excessive material handling activities, increased downtime, and higher occupational safety risks. One of the major issues identified in manufacturing operations is double handling, which represents a non-value-added activity that negatively affects operational efficiency. This study aims to improve the packing system by reducing double handling activities, minimizing downtime, and enhancing workplace safety through the implementation of the Plan–Do–Check–Act (PDCA) methodology. Data were collected through direct observation, interviews, and documentation of material handling activities in the production area. Root cause analysis was conducted using a Fishbone Diagram integrated within the PDCA framework to identify the factors contributing to inefficiencies in the existing packing system. Improvement actions included direct pallet utilization, workplace layout optimization, and the addition of towing equipment to facilitate material movement. The results demonstrated significant improvements, with handling activities reduced by 66.7%, handling time reduced by 86.7%, and downtime reduced by 75%. Furthermore, occupational safety risks decreased substantially due to the reduction of manual handling activities. Process capacity also improved, as indicated by the increase in handling frequency from 32 to 240 times per shift. The findings confirm that integrating PDCA with material handling optimization effectively improves operational efficiency, reduces waste, and enhances workplace safety. This study provides practical insights for manufacturing companies seeking to develop more efficient and sustainable packing systems.

Keywords: Double Handling; Downtime; Material Handling; Occupational Safety; PDCA.

Received: January 10, 2026
Revised: March 26, 2026
Accepted: May 23, 2026
Published: July 01, 2026
Curr. Ver.: July 01, 2026

1. Introduction

Material handling systems play a vital role in manufacturing operations because they facilitate the movement, storage, and control of materials throughout the production process. An effective material handling system contributes significantly to operational efficiency, productivity improvement, and cost reduction. Conversely, inefficient material handling activities may generate excessive transportation, unnecessary motion, process delays, and increased operational costs. Therefore, continuous improvement of material handling systems is essential for maintaining competitive manufacturing performance.

Numerous studies have investigated methods for improving material handling performance. Lean Manufacturing has been widely adopted to identify and eliminate non-value-added activities within production systems. Ohno (1988) emphasized that waste elimination is a fundamental principle for improving manufacturing performance, while

Womack & Jones (2003) highlighted the importance of creating value through the reduction of unnecessary activities. Previous studies have also demonstrated that improvements in material handling systems can significantly reduce process inefficiencies and enhance productivity. Furthermore, Fishbone Diagram analysis has been extensively utilized to identify the root causes of operational problems, while the Plan–Do–Check–Act (PDCA) methodology has proven effective as a structured framework for continuous improvement initiatives.

Although previous approaches have successfully improved production performance, several limitations remain. Lean Manufacturing initiatives often focus on general waste reduction without specifically addressing packing system inefficiencies. Similarly, root cause analysis techniques effectively identify operational problems but do not always provide a structured mechanism for implementing and sustaining improvements. The PDCA methodology offers a systematic improvement cycle; however, studies integrating PDCA with direct pallet utilization and material handling optimization in packing operations remain limited. Consequently, there is still a need for practical research that combines root cause analysis and continuous improvement methods to address double handling activities in material handling systems.

Based on field observations conducted in the Material Handling Department, the existing packing system relied on a conventional shutter-based process. Materials arriving on pallets were transferred into shutters before entering the production line, creating unnecessary double handling activities. This practice increased handling time, generated production downtime, and exposed operators to higher occupational safety risks due to repetitive manual handling tasks. In addition, the absence of appropriate handling equipment and an inefficient workplace layout further contributed to operational inefficiencies. These conditions indicate that the existing packing system requires systematic improvement to support more efficient material flow.

To address these issues, this study proposes the implementation of the Plan–Do–Check–Act (PDCA) methodology integrated with Fishbone Diagram analysis. Improvement actions focus on direct pallet utilization, workplace layout optimization, and the introduction of towing equipment to eliminate unnecessary material transfers. Through this approach, the study seeks to reduce double handling activities, minimize downtime, improve operational efficiency, and enhance workplace safety.

The contributions of this study are threefold. First, it identifies the root causes of packing system inefficiencies using Fishbone Diagram analysis. Second, it demonstrates the effectiveness of PDCA-based improvement initiatives in reducing double handling activities and downtime. Third, it provides practical recommendations for manufacturing companies seeking to improve material handling performance and establish more efficient packing systems.

The remainder of this paper is organized as follows. Section 2 presents the literature review related to material handling systems, Lean Manufacturing, Fishbone Diagram analysis, PDCA methodology, and ergonomics. Section 3 describes the proposed research method and improvement framework. Section 4 discusses the results and findings obtained from the implementation process. Section 5 compares the findings with previous studies. Finally, Section 6 concludes the paper and provides recommendations for future research.

2. Literature Review

This section presents the theoretical foundations and related studies relevant to material handling systems, Lean Manufacturing principles, Fishbone Diagram analysis, the Plan–Do–Check–Act (PDCA) methodology, and ergonomic considerations. In addition, previous studies are reviewed to identify research gaps and highlight the contribution of the present study.

Material Handling Systems

Material handling refers to the movement, storage, protection, and control of materials throughout manufacturing and distribution processes. An effective material handling system plays an important role in improving production efficiency, reducing operational costs, and ensuring smooth material flow within production facilities. According to Tompkins et al. (2010), inefficient material handling systems may increase transportation distances, prolong processing time, and generate operational waste. Therefore, the design of material handling systems should support continuous and uninterrupted material flow while minimizing unnecessary movement activities.

In manufacturing environments, material handling activities account for a significant portion of production costs. Poorly designed systems often create bottlenecks that negatively affect productivity and overall system performance. Consequently, organizations continuously seek opportunities to optimize material movement through facility layout improvement, equipment utilization, and process standardization.

Double Handling and Lean Manufacturing

Double handling is a condition in which materials are moved more than once without adding value to the final product. Such activities are categorized as non-value-added activities and are considered a form of waste within Lean Manufacturing philosophy. According to Ohno (1988), waste elimination is a fundamental principle for improving manufacturing performance and increasing operational efficiency. Likewise, Womack & Jones (2003) emphasized that organizations should continuously identify and eliminate activities that do not contribute value to customers.

Previous studies have reported that excessive transportation and material movement significantly increase processing time and operational costs. Wibowo et al. (2024) found that eliminating unnecessary material handling activities improved production efficiency and reduced process delays. Similarly, Kurniawan & Putri (2023) demonstrated that reducing non-value-added activities positively affected production performance. These findings indicate that minimizing double handling activities is essential for achieving efficient manufacturing operations

Fishbone Diagram for Root Cause Analysis

The Fishbone Diagram, also known as the Cause-and-Effect Diagram, is a problem-solving tool used to identify and categorize the root causes of operational issues. The method systematically groups contributing factors into categories such as Man, Method, Material, Machine, and Environment. By organizing potential causes in a structured manner, organizations can more effectively identify underlying problems and develop targeted improvement strategies.

Several studies have applied Fishbone Diagram analysis in manufacturing environments to investigate production inefficiencies and quality-related problems. Pradana & Darmawan (2023) reported that Fishbone Diagram analysis facilitated more accurate identification of production process failures, enabling organizations to implement corrective actions more effectively. Therefore, Fishbone Diagram analysis serves as an important tool for identifying the factors contributing to double handling activities within material handling systems.

Plan–Do–Check–Act (PDCA) Methodology

The Plan–Do–Check–Act (PDCA) methodology is a continuous improvement framework widely used in quality management and operational improvement initiatives. The PDCA cycle consists of four stages: planning improvement activities (Plan), implementing solutions (Do), evaluating results (Check), and standardizing successful practices (Act). This structured approach enables organizations to continuously improve operational performance through systematic problem-solving processes.

Previous research has demonstrated the effectiveness of PDCA in improving production efficiency and quality performance. Nugroho et al. (2022) found that PDCA implementation significantly improved production quality through structured corrective actions. Similarly, Rahman et al. (2024) reported that PDCA-based improvements successfully reduced operational inefficiencies and enhanced production performance. These findings support the use of PDCA as a suitable methodology for addressing material handling inefficiencies and eliminating double handling activities.

Ergonomics in Material Handling Operations

Ergonomics focuses on designing work systems that optimize human performance while ensuring safety, comfort, and well-being. In material handling operations, repetitive lifting, carrying, and moving activities can expose workers to physical fatigue and musculoskeletal disorders. According to Niebel & Freivalds (2009), ergonomic work design contributes significantly to productivity improvement and workplace safety by reducing physical strain and minimizing injury risks.

Several studies have highlighted the relationship between ergonomic improvements and operational performance. Siregar & Hidayat (2022) found that non-ergonomic work systems increased operator fatigue and reduced work effectiveness. Therefore, ergonomic considerations should be incorporated into material handling system design to support both operational efficiency and occupational safety.

Numerous studies have investigated material handling improvements using Lean Manufacturing principles, Fishbone Diagram analysis, and PDCA methodology. Most previous studies focused on reducing waste, improving production quality, or enhancing process efficiency. However, limited studies have specifically examined the integration of Fishbone Diagram analysis and PDCA methodology with direct pallet utilization as a solution for eliminating double handling activities in packing systems.

Furthermore, previous research has generally evaluated operational performance using productivity and quality indicators, while relatively few studies have simultaneously examined handling time, downtime, occupational safety risks, and process capacity. Therefore, this study contributes to the existing literature by integrating root cause analysis, continuous improvement methodology, and material handling optimization to develop a more efficient and safer packing system.

3. Research Method

This study employed the Plan–Do–Check–Act (PDCA) methodology as a continuous improvement approach to improve the packing system in the Material Handling Department. The method was selected because it provides a systematic framework for identifying operational problems, implementing corrective actions, evaluating improvement outcomes, and standardizing successful practices. The primary objective of this study was to reduce double handling activities, minimize production downtime, and improve occupational safety through material handling optimization.

Research Design

This research adopted a quantitative descriptive approach. The object of the study was the packing system used in the Material Handling Department of a manufacturing company. Initial observations revealed that materials arriving on pallets were transferred into shutters before entering the production process, resulting in double handling activities, excessive handling time, downtime, and increased occupational safety risks.

Data collection was conducted during one work shift of eight hours (480 minutes). The performance of the packing system was evaluated by comparing operational conditions before and after the implementation of improvement initiatives.

Research Flow Diagram

The overall research procedure adopted in this study is illustrated in Figure 1. The research began with problem identification, followed by data collection, root cause analysis using a Fishbone Diagram, planning and implementation of improvement actions through the PDCA methodology, evaluation of the improvement results, and standardization of the improved work system.

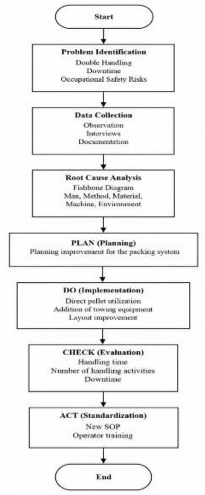

Figure 1. Research Flow Diagram.

Data Collection

Data were collected using the following techniques:

Observation

Direct observations were conducted to identify material handling activities, measure handling time, and determine the amount of downtime occurring within the packing system.

Interviews

Interviews were conducted with operators and supervisors to obtain information regarding operational problems and existing work practices.

Documentation

Documentation was used to support and validate data obtained from observations and interviews.

PDCA Framework

The improvement process was carried out using the Plan–Do–Check–Act (PDCA) methodology. The PDCA cycle consists of four stages: planning (Plan), implementation (Do), evaluation (Check), and standardization (Act), as illustrated in Figure 2.

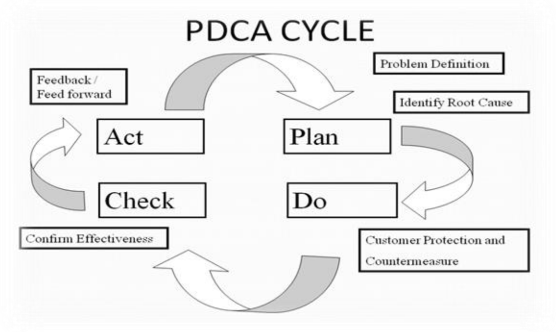

Figure 2. Plan–Do–Check–Act (PDCA) Cycle.

Plan

The Plan stage focused on identifying operational problems and determining their root causes using a Fishbone Diagram. The primary problems identified were double handling activities, excessive downtime, and occupational safety risks.

Do

Improvement actions were implemented through direct pallet utilization, workplace layout optimization, and the addition of towing equipment to facilitate material movement.

Check

The effectiveness of the implemented improvements was evaluated based on handling activities, handling time, downtime, and occupational safety conditions.

Act

Successful improvements were standardized through the establishment of Standard Operating Procedures (SOPs), operator training programs, and continuous monitoring activities.

Root Cause Analysis Using Fishbone Diagram

To systematically identify the causes of inefficiencies within the packing system, a Fishbone Diagram was employed. The analysis categorized potential causes into five major factors, namely Man, Method, Material, Machine, and Environment. This approach facilitated the identification of root causes contributing to double handling activities and operational inefficiencies, thereby supporting the development of targeted improvement actions.

Performance Evaluation

The effectiveness of the proposed improvements was evaluated by comparing operational performance before and after implementation. The percentage reduction was calculated using Eq. (1):

Reduction (%) = ((Initial Condition − Final Condition) / Initial Condition) × 100 (1) …… I

where:

a. Initial Condition = Performance value before improvement.
b. Final Condition = Performance value after improvement.

The evaluation indicators included handling activities, handling time, downtime, occupational safety risks, and process capacity per shift.

4. Results and Discussion

This section presents the results obtained from the implementation of the proposed packing system improvement and discusses its impact on operational performance. The analysis begins with the evaluation of the initial condition of the packing system, followed by root cause identification using the Fishbone Diagram, implementation of improvement actions based on the Plan–Do–Check–Act (PDCA) methodology, and assessment of the improvement outcomes. The effectiveness of the proposed improvements is evaluated through several performance indicators, including handling activities, handling time, downtime, occupational safety conditions, and process capacity. The findings are further discussed to demonstrate how the elimination of double handling activities contributes to improving material handling efficiency and overall operational performance.

Initial Condition of the Packing System

Based on field observations, the packing system still utilized a conventional shutter-based material transfer method. Materials arriving on pallets were transferred into shutters before entering the production process. This condition resulted in double handling activities, increased handling time, production downtime, and occupational safety risks due to repetitive manual handling operations. Furthermore, material transfer activities were performed manually by operators, resulting in excessive physical workload and reduced operational efficiency. These conditions indicate that the existing packing system was inefficient and required improvement. The initial conditions observed during the study are presented in Table 1.

Table 1. Initial Condition of the Packing System

Parameter	Initial Condition
Handling Activities	3 Transfers
Handling Time	15 Minutes
Downtime	20 Minutes
Occupational Risk	High (Manual Handling)

The data presented in Table 1 show that the existing packing system contained several non-value-added activities that negatively affected operational efficiency. The requirement to transfer materials from pallets into shutters created unnecessary handling operations that increased processing time and operator workload.

Root Cause Analysis Using Fishbone Diagram

To identify the root causes of inefficiencies within the packing system, a Fishbone Diagram was utilized. The analysis categorized the causes into five major factors: Man, Method, Material, Machine, and Environment.

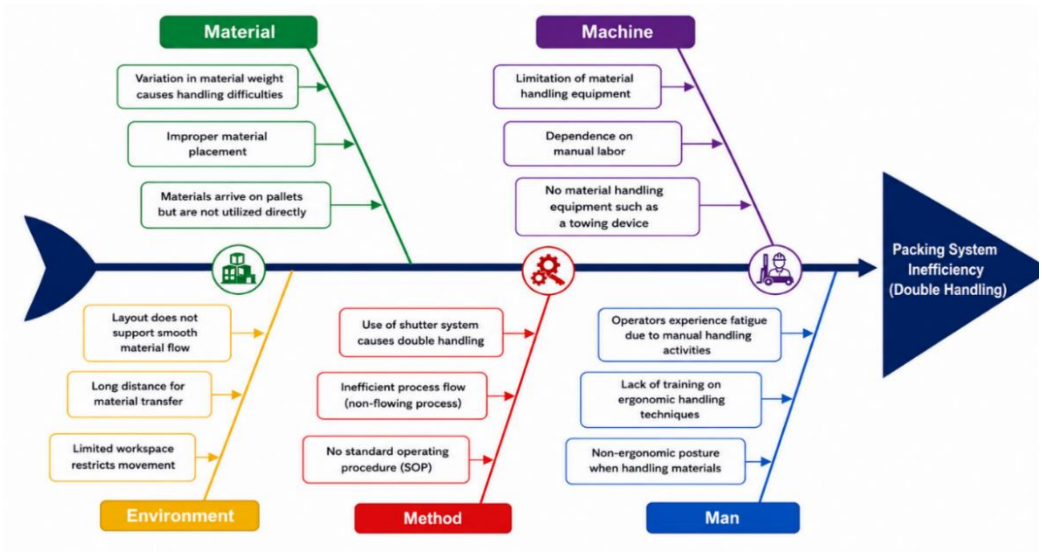

Figure 3. Analysis of the Root Causes of Double Handling in the Packing System (Fishbone Diagram).

The Fishbone Diagram analysis revealed that the inefficiency of the packing system was caused by several interconnected factors.

Man Factor

a. Operators experience fatigue due to repetitive manual handling activities.
b. Lack of ergonomic handling training.
c. Non-ergonomic working postures during material movement.

Method Factor

a. The shutter-based system causes unnecessary material transfers.
b. Inefficient process flow.
c. Absence of standardized operating procedures.

Material Factor

a. Materials arrive on pallets but are not utilized directly.
b. Improper material placement.
c. Variations in material size and weight.

Machine Factor

a. Lack of towing equipment.
b. Dependence on manual labor.
c. Limited material transportation equipment.

Environment Factor

a. Layout does not support smooth material flow.
b. Long material transfer distances.
c. Limited workspace.

Based on the analysis, the major root causes were identified as double handling activities, the absence of towing equipment, and an inefficient facility layout. These findings formed the basis for the development of improvement initiatives implemented during the Do stage of the PDCA methodology.

Improvement Implementation

Based on the findings obtained during the Plan stage, improvement actions were implemented to eliminate double handling activities and improve material flow efficiency.

The primary improvement involved changing the material transfer system from a shutter-based process to direct pallet utilization. Under the previous system, materials arriving on pallets were transferred into shutters before entering the production line, resulting in additional handling activities that did not add value to the process. Through the proposed improvement, pallets were utilized directly, eliminating unnecessary transfer operations.

In addition, towing equipment was introduced to facilitate material movement and reduce manual handling activities. The workplace layout was also optimized to enable pallets to be delivered directly to the production line without requiring additional transfer processes.

Figure 4. Existing Packing System Before Improvement

Figure 5. Improved Packing System After Implementation

The implementation of these improvements was expected to reduce operational waste, improve material flow continuity, minimize downtime, and enhance workplace safety.

Evaluation of Improvement Results

The effectiveness of the implemented improvements was evaluated by comparing operational performance before and after implementation.

Table 2. Evaluation of Improvement Results.

Parameter	Before	After	Reduction
Handling Activities	3 Times	1 Time	66.7%
Handling Time	15 Minutes	2 Minutes	86.7%
Downtime	20 Minutes	5 Minutes	75.0%
Occupational Risk	High	Low	Significant

The results demonstrate substantial improvements in operational performance following the implementation of the proposed improvements. Handling activities were reduced from three transfers to one transfer, representing a reduction of 66.7%. This reduction confirms that double handling activities were successfully eliminated.

Handling time decreased from 15 minutes to 2 minutes, resulting in an 86.7% improvement. Similarly, downtime decreased from 20 minutes to 5 minutes, representing a reduction of 75%. These improvements indicate that the optimized material handling system successfully enhanced operational efficiency and reduced production interruptions.

In addition to operational improvements, occupational safety conditions also improved considerably. The reduction in manual handling activities lowered operator workload and minimized the risk of fatigue and work-related injuries.

Analysis of Handling Activities per Work Shift

The reduction in handling time significantly increased process capacity. Table 3 presents the comparison of handling performance before and after improvement.

Table 3. Analysis of Handling Activities per 8-Hour Work Shift.

Parameter	Before	After	Change
Handling Time per Activity	15 Minutes	2 Minutes	↓ 86.7%
Handling Activities per Shift	32 Times	240 Times	↑ 650%

The increase in handling activities per shift should not be interpreted as a form of waste. Instead, it reflects a substantial improvement in process capacity resulting from shorter handling cycles. The elimination of double handling enabled materials to be moved more efficiently while maintaining operational effectiveness.

The shorter cycle time allowed operators to perform material handling activities more frequently without increasing non-value-added work. Consequently, the system became more responsive to production requirements and capable of supporting higher operational performance.

Discussion

The results demonstrate that the implementation of the PDCA methodology significantly improved the efficiency of the packing system. The reduction in handling activities confirms that double handling was successfully eliminated through direct pallet utilization and improved material flow.

The reduction in handling time by 86.7% and downtime by 75% indicates that the proposed improvements effectively minimized operational waste and reduced process bottlenecks. These findings are consistent with Lean Manufacturing principles, which emphasize the elimination of non-value-added activities to improve production performance.

Furthermore, the implementation of towing equipment reduced dependency on manual material handling activities. This improvement not only increased operational efficiency but also enhanced workplace safety by reducing operator fatigue and minimizing the risk of musculoskeletal injuries.

The increase in handling capacity from 32 to 240 activities per shift demonstrates the significant impact of reducing cycle time on overall system performance. This result confirms that improvements in material handling processes can directly influence productivity and operational responsiveness.

Overall, the integration of Fishbone Diagram analysis and the PDCA methodology proved effective in developing systematic solutions for reducing operational waste and improving material handling performance. The findings highlight the importance of continuous improvement practices in achieving sustainable operational excellence and safer working conditions.

5. Comparison

Comparison with previous studies is important to evaluate the contribution of the proposed improvement and to determine its effectiveness relative to existing approaches. Table 4 presents a comparison between the findings of this study and several related studies that applied PDCA, Fishbone Diagram analysis, and Lean Manufacturing principles to improve operational performance.

Table 4. Comparison with Previous Studies.

Study	Method	Main Findings
Nugroho et al. (2022)	PDCA	Improved production quality through continuous improvement activities
Santoso et al. (2023)	Fishbone Diagram + PDCA	Improved production performance and reduced operational problems
Rahman et al. (2024)	PDCA	Increased operational efficiency and reduced process inefficiencies
Wibowo et al. (2024)	Lean Manufacturing	Reduced waste and improved production efficiency
This Study	PDCA + Fishbone Diagram + Material Handling Optimization	Reduced handling activities by 66.7%, handling time by 86.7%, and downtime by 75.0%

Table 4 shows that previous studies mainly focused on quality improvement, waste reduction, and overall production efficiency through the implementation of PDCA and Lean Manufacturing approaches. While these studies demonstrated positive impacts on operational performance, limited attention was given to the elimination of double handling activities in material handling operations.

The findings of the present study indicate that the integration of Fishbone Diagram analysis, PDCA methodology, and material handling optimization provides significant operational benefits. The implementation of direct pallet utilization and towing equipment successfully reduced handling activities from three transfers to one transfer, representing a 66.7% reduction. Furthermore, handling time decreased from 15 minutes to 2 minutes, while downtime was reduced from 20 minutes to 5 minutes.

In addition, process capacity increased substantially from 32 handling activities per shift to 240 handling activities per shift, representing an improvement of approximately 650%. This result demonstrates that the elimination of double handling activities not only reduced operational waste but also significantly improved system responsiveness and productivity.

Compared with previous studies, this research offers a more specific and practical contribution by addressing material handling inefficiencies at the packing stage. In addition to improving operational efficiency, the proposed improvements also reduced occupational safety risks associated with repetitive manual handling activities. Therefore, the proposed approach not only supports productivity improvement but also contributes to the development of a safer and more ergonomic working environment.

Overall, the results demonstrate that the integration of PDCA methodology with material handling optimization is an effective strategy for eliminating non-value-added activities, reducing operational waste, and improving the overall performance of manufacturing operations.

6. Conclusions

This study aimed to improve the efficiency of the packing system in the Material Handling Department by reducing double handling activities through the implementation of the Plan–Do–Check–Act (PDCA) methodology. Based on the results of the analysis and improvement implementation, the primary problems identified in the existing system were excessive double handling activities, production downtime, and occupational safety risks caused by inefficient work methods, the absence of appropriate material handling equipment, and an ineffective workplace layout.

The improvement initiatives, which included direct pallet utilization, workplace layout optimization, and the introduction of towing equipment, successfully enhanced the performance of the packing system. The results showed that handling activities were reduced from three transfers to one transfer, representing a reduction of 66.7%. In addition, handling time decreased from 15 minutes to 2 minutes (86.7%), while downtime was reduced from 20 minutes to 5 minutes (75.0%). These improvements indicate that the elimination of non-value-added activities significantly enhanced material flow efficiency and operational performance.

Furthermore, the implemented improvements contributed positively to occupational safety by reducing manual handling activities and lowering operator workload. The reduction in repetitive material handling operations minimized the risk of fatigue and work-related injuries, resulting in a safer and more ergonomic working environment.

Overall, the findings demonstrate that the integration of Fishbone Diagram analysis and the PDCA methodology is effective in identifying operational problems, eliminating double handling activities, reducing operational waste, and improving material handling performance. The proposed improvement strategy can therefore serve as a practical reference for manufacturing companies seeking to enhance operational efficiency, workplace safety, and sustainable continuous improvement initiatives.

For future research, it is recommended to integrate additional improvement approaches such as Lean Manufacturing, Value Stream Mapping (VSM), or automation technologies to further optimize material handling systems and achieve higher levels of operational performance.

Acknowledgments

The authors would like to express their sincere gratitude to Universitas Pelita Bangsa for academic support throughout this research. The authors also thank the management and employees of the company involved in this study for providing access, operational data, and valuable assistance during the research process. Their cooperation and support contributed significantly to the successful completion of this study.

References

Antony, J., Sony, M., & Gutierrez, L. (2022). An empirical study into the limitations and emerging trends of Lean Six Sigma in manufacturing industries. *The TQM Journal, 34*(2), 257–276. https://doi.org/10.1108/TQM-10-2020-0244

Bhamu, J., & Sangwan, K. S. (2014). Lean manufacturing: Literature review and research issues. *International Journal of Operations & Production Management, 34*(7), 876–940. https://doi.org/10.1108/IJOPM-08-2012-0315

Bortolotti, T., Boscari, S., & Danese, P. (2021). Successful lean implementation: Organizational culture and soft lean practices. *International Journal of Production Economics, 236*, 108114. https://doi.org/10.1016/j.ijpe.2021.108114

Chiarini, A., & Kumar, M. (2021). Lean management and operational performance improvement: A systematic literature review. *Business Process Management Journal, 27*(6), 1731–1754. https://doi.org/10.1108/BPMJ-02-2021-0094

Deming, W. E. (1986). *Out of the crisis*. MIT Press.

Groover, M. P. (2016). *Fundamentals of modern manufacturing* (6th ed.). Wiley.

Kurniawan, F., & Putri, D. (2023). Analisis efisiensi sistem produksi dalam mengurangi pemborosan proses. *Jurnal Teknik Industri, 5*(2), 112–120.

Liker, J. K. (2004). *The Toyota way: 14 management principles from the world's greatest manufacturer*. McGraw-Hill.

Neumann, W. P., Winkel, J., Medbo, L., Magneberg, R., & Mathiassen, S. E. (2021). Production system design elements influencing productivity and ergonomics. *International Journal of Production Research, 59*(5), 1451–1468. https://doi.org/10.1080/00207543.2020.1712491

Niebel, B. W., & Freivalds, A. (2009). *Methods, standards, and work design* (12th ed.). McGraw-Hill.

Nugroho, T., Santoso, B., & Hidayat, R. (2022). Implementasi metode Plan Do Check Act dalam peningkatan kualitas produksi. *Jurnal Teknik Industri, 6*(1), 25–32.

Ohno, T. (1988). *Toyota production system: Beyond large-scale production*. Productivity Press.

Pradana, R., & Darmawan, A. (2023). Analisis akar penyebab cacat produk menggunakan fishbone diagram pada proses produksi. *Jurnal Rekayasa Industri, 8*(2), 78–85.

Prasetyo, B., Hidayat, R., & Saputra, A. (2023). Evaluasi sistem material handling untuk meningkatkan efisiensi produksi. *Jurnal Teknik Industri, 9*(1), 34–42.

Rahman, M., Siregar, D., & Putra, A. (2024). Analisis peningkatan efisiensi produksi melalui pendekatan Plan Do Check Act. *Jurnal Sistem Industri, 10*(2), 55–63.

Santoso, E., Wibowo, A., & Pratama, D. (2023). Penerapan metode fishbone dan Plan Do Check Act dalam peningkatan kualitas produksi. *Jurnal Rekayasa Industri, 8*(1), 15–22.

Saputra, H., Nugraha, A., & Firmansyah, D. (2022). Pengendalian kualitas menggunakan fishbone diagram pada industri manufaktur. *Jurnal Teknik Industri, 7*(2), 66–73.

Siregar, D., & Hidayat, R. (2022). Analisis efisiensi proses produksi melalui perbaikan sistem kerja. *Jurnal Teknik Industri, 6*(2), 88–95.

Slack, N., Brandon-Jones, A., & Johnston, R. (2022). *Operations management* (10th ed.). Pearson.

Sundar, R., Balaji, A. N., & Kumar, R. M. S. (2014). A review on lean manufacturing implementation techniques. *Procedia Engineering, 97*, 1875–1885. https://doi.org/10.1016/j.proeng.2014.12.341

Tompkins, J. A., White, J. A., Bozer, Y. A., & Tanchoco, J. M. A. (2010). *Facilities planning* (4th ed.). John Wiley & Sons.

Tortorella, G. L., Fogliatto, F. S., Esposto, K. F., Vergara, A. M. C., Vassolo, R., & Sawhney, R. (2023). Effects of lean manufacturing implementation on operational performance: A longitudinal study. *International Journal of Production Economics, 258*, 108786. https://doi.org/10.1016/j.ijpe.2023.108786

Wibowo, A., Santoso, E., & Pratama, D. (2024). Eliminasi waste dalam sistem produksi menggunakan pendekatan lean manufacturing. *Jurnal Teknik Industri, 10*(1), 21–30.

Womack, J. P., & Jones, D. T. (2003). *Lean thinking: Banish waste and create wealth in your corporation* (2nd ed.). Free Press.

Yamashina, H. (2000). Challenge to world-class manufacturing. *International Journal of Quality & Reliability Management, 17*(2), 132–143.