

Total Quality Control Analysis on Plywood Using Six Sigma, New Seven Tools, and Kaizen Methods

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Abstrak

Kontrol merupakan bentuk perlindungan terhadap berbagai tindakan atau gangguan yang tidak diinginkan, baik internal maupun eksternal, yang dapat memengaruhi suatu sistem. Penelitian ini bertujuan untuk menganalisis cacat pada produk multipleks di Toko Mebel JatiMulyo dengan menggunakan metode Total Quality Control (TQC) guna menentukan prioritas permasalahan yang harus segera diselesaikan. Pendekatan yang digunakan adalah mixed-method dengan menggabungkan analisis kualitatif dan kuantitatif. Fishbone diagram digunakan untuk mengidentifikasi secara sistematis kemungkinan penyebab cacat produk. Hasil penelitian menunjukkan terdapat tiga jenis cacat utama, yaitu multipleks retak (103 unit atau 32%), multipleks tidak simetris (114 unit atau 36%), dan ketebalan multipleks yang tidak sesuai (103 unit atau 32%), dengan total 320 unit cacat. Pada penelitian ini tidak dilakukan koreksi data karena seluruh persentase berada dalam batas yang dapat diterima. Analisis ini memungkinkan identifikasi faktor kunci yang memengaruhi kualitas produk serta memberikan arahan untuk perbaikan berkelanjutan. Hasil penelitian diharapkan dapat menjadi pedoman dalam upaya pengendalian kualitas, dengan perbaikan lebih lanjut melalui pemantauan dan tindakan korektif secara berkesinambungan.

Kata kunci: analisis cacat, fishbone diagram, kualitas mebel, pendekatan mixed-method, perbaikan kualitas

Abstract

Control is a form of protection against various undesirable actions or disturbances, both internal and external, that can affect a system. This research aims to analyze defects in plywood products at the JatiMulyo Furniture Store using the Total Quality Control (TQC) method to determine priority problems that must be resolved first. The study adopts a mixed-method approach by combining qualitative and quantitative analyses. A fishbone diagram is utilized to systematically identify possible causes of defects. The findings reveal three main types of defects: cracked plywood (103 units, 32%), unsymmetrical plywood (114 units, 36%), and inappropriate plywood thickness (103 units, 32%), with a total of 320 defective units. No data correction was necessary as all percentages fall within acceptable limits. This thorough analysis enables the identification of key factors affecting product quality and provides direction for continuous improvement. The results are expected to guide quality control efforts. Further improvements can be made using continuous monitoring and corrective action.

Keywords: defect analysis, fishbone diagram, furniture quality, mixed-method approach, quality improvement

1. Introduction

Quality control (QC) is not merely a supporting element but a core pillar in the manufacturing sector, particularly in the furniture industry, where the interplay of product durability, visual appeal, and ergonomic functionality directly determines customer satisfaction, brand loyalty, and long-term business sustainability (Loppolo et al., 2025). In small to medium sized enterprises like JatiMulyo Furniture Store, recurring

quality issues including cracked plywood, unsymmetrical panel joints, and deviations from standard material thickness represent not only production flaws but systemic inefficiencies that jeopardize customer trust and overall business credibility (Erwansyah & Aryanny, 2025). These defects are often rooted in inconsistent standard operating procedures (SOPs), inadequate material handling practices, limited employee training, and the

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absence of an integrated quality assurance system that continuously monitors and controls production quality (Zondo et al., 2024)

In response to these challenges, Nugraha & Ramadhan (2024) stress the importance of implementing total quality strategies as a means of enhancing customer satisfaction, streamlining operations, and delivering consistent output. As customer expectations evolve and global competition intensifies, a proactive, systematic, and data driven approach toward defect identification and elimination is becoming increasingly vital for organizations that wish to remain agile and competitive (Joseph Chukwunweike & Opeyemi, 2024). More than just improving product quality, these strategies foster operational excellence and promote organizational resilience, ensuring that manufacturing entities are capable of adapting to dynamic market demands while sustaining profitability (Brauel, 2023)

To address recurring quality challenges, numerous manufacturing sectors have adopted comprehensive quality management frameworks, among which Total Quality Control (TQC), Six Sigma, Kaizen, and the New Seven Tools (7QC Tools) stand out for their proven effectiveness (Dartawan & Setiafindari, 2023). TQC emphasizes holistic quality involvement at every stage of production, empowering every individual (within the organization to contribute to continuous quality assurance (Loppolo et al., 2025). Meanwhile, Six Sigma adopts a rigorous, statistical methodology for process optimization by minimizing variability and identifying root causes of defects through techniques like DMAIC (Define, Measure, Analyze, Improve, Control) (Muhammad et al., 2024). The Kaizen philosophy promotes a culture of incremental and ongoing improvements, driven by the participation of workers at all levels, fostering a sense of ownership and accountability toward quality outcomes (Kareska, 2024) These frameworks are further strengthened by analytical tools such as Pareto analysis, cause-and-effect diagrams (Ishikawa), histograms, control charts, and scatter diagrams, which serve as key instruments for structured problem-solving and performance monitoring (McDermott et al., 2023).

Recent studies have also highlighted the potential benefits of integrating Total Quality Management (TQM) with lean manufacturing principles, which collectively aim to eliminate waste, optimize workflows, and increase customer value (Jum'a et al., 2023). Similarly, Skorupińska et al. (2024) found that adopting a structured TQM model enabled small-scale furniture manufacturers to minimize product inconsistencies, streamline production processes, and build a more competitive market position.

In light of previous studies, it becomes essential to analyze how a synergistic application of these strategies can improve production performance. A comparative review of literature also highlights the opportunity for

improvement in small to médium scale manufacturing operations such as JatiMulyo Furniture Store. Table 1 below outlines the state of the art approaches drawn from relevant literature and positions the current study within these research developments.

Table 1: State of the Art Review

Author(s)	Method/ Tools Used	Research Focus	Relation to Current Study
Otoki (2021)	Kaizen	Continuous Improvement in Manufacturing	Relevant for fostering continuous quality improvement culture
(Adeodu et al., 2021)	Lean Six Sigma	Process Optimization, Defect Reduction	Aligned with the study's focus on defect reduction
(Jannaah & Winursito, 2025)	TQC & New Seven Tools	Root Cause Analysis in Production	Provides direct insights into quality control tool implementation
(Zakaria et al., 2024)	RCA & SPC	Process Monitoring in Wood Industry	Supports statistical analysis of defects
(Jaware et al., 2018)	Seven Tools	Visual Data Tools for Quality Analysis	Useful for identifying patterns and problem sources

Based on these insights, the objective of this study is to evaluate how the implementation of TQC, Six Sigma, Kaizen, and the New Seven Tools can reduce defects in plywood manufacturing at JatiMulyo Furniture Store. The study also aims to assess the effectiveness of these methods in enhancing product quality, optimizing production processes, and increasing customer satisfaction, thus providing a practical framework that can be replicated by other SMEs in the furniture industry.

Furthermore, this research intends to fill the gap in the application of integrated quality improvement tools within small and medium enterprises (SMEs), especially in the Indonesian furniture manufacturing sector. While most previous studies focus on individual methods or are conducted in large-scale industries, there is limited empirical evidence on the combined implementation of TQC, Kaizen, Six Sigma, and the New Seven Tools in smaller production units (Ghelani, 2023). This study also seeks to contribute theoretically by demonstrating how system based quality tools, when employed synergistically, can yield sustainable operational improvements.

2. Research Methods

This research was conducted at Jatimulyo Rungkut Furniture Store, located at St. Raya Pandugo No. 26, Rungkut, Surabaya. The study took place in May 2024 and utilized defect data from plywood production over the past year. The focus of this research is to analyze product defects in plywood sized 30 cm x 42 cm and propose quality improvements using a combination of Total Quality Control (TQC), Six Sigma, New Seven Tools, and Kaizen approaches.

The operational variables identified in this study consist of dependent and independent variables. The dependent variable is the number of defective plywood products with a size of 30 cm x 42 cm. The independent variables include the types of defects found in the products, such as cracks in the plywood, asymmetrical shapes, and non-standard thicknesses. These variables were selected based on their direct influence on product quality and are considered measurable and specific.

Primary data were obtained through field observations, which included documentation of the production process, production capacity, and defect handling procedures. Secondary data were gathered from existing company records, including production volumes, defect logs, machine specifications, and company profiles. The data collection techniques involved direct observation of the production line, interviews with production managers, and documentation of production activities and defect occurrences.

The data analysis employs a mixed-methods approach combining qualitative insights with quantitative evaluations. The Six Sigma method is used to identify the root causes of product defects with high precision (Byrne et al., 2021). New Seven Tools, including affinity diagrams and matrix data analysis, offer a structured framework for categorizing and interpreting data. Kaizen is applied to promote continuous improvement in the production process (Okpala et al., 2024). These methods are expected to work synergistically in providing effective solutions for quality control.

3. Results and Discussion

Jatimulyo Rungkut Furniture Store is one of the local businesses engaged in plywood production. This store is a family-owned business that has been passed down for two generations and continues to experience high market demand. The consistent flow of customer orders requires Jatimulyo Rungkut Furniture Store to manage its production processes effectively while maintaining product quality to ensure customer satisfaction. In plywood production, the main raw material used is wood, making quality control crucial to minimize defects and optimize production output. In this research, data processing was carried out using the Six Sigma method through the DMAIC (Define, Measure,

Analyze, Improve, and Control) phases, supported by the New Seven Tools and Kaizen analysis. Prior to that, Statistical Quality Control (SQC) methods were used as supporting tools to evaluate and monitor the production process (Rochmoeljati et al., 2022).

3.1. Six Sigma Analysis Using DMAIC (Define, Measure, Analyze, Improve, and Control)

Quality evaluation and improvement efforts were carried out using the Six Sigma method with the Define Measure Analyze Improve Control (DMAIC) approach (Helmi et al., 2024). Six Sigma is a structured methodology focused on improving product and process quality by minimizing variation and reducing defects (Nugraha et al., 2025). This study applies the DMAIC approach. Define, Measure, Analyze, Improve, and Control to systematically identify problems in plywood production and implement sustainable improvements:

a. Define

The Define phase is the initial step in the Six Sigma DMAIC methodology, aimed at identifying key quality issues and outlining the critical aspects that directly impact customer satisfaction. This study focuses on analyzing product defects in the plywood production process at Jatimulyo Rungkut Furniture Store. Plywood is a widely used material in construction due to its lightweight, ease of installation, and affordability. With increasing market demand, maintaining consistent product quality is essential to meet customer expectations and uphold the company's reputation.

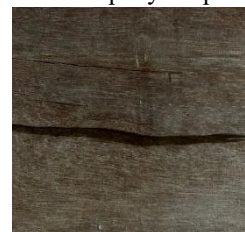


Figure 1. Crack Plywood Defects



Figure 2. Unsymmetrical Plywood Defects



Figure 3. Defects of Plywood Thickness

Three primary types of defects were identified during production: figure 1 cracked plywood, figure 2 unsymmetrical plywood, and figure 3 inappropriate thickness. Cracked plywood is typically caused by substandard raw materials, often due to insufficient inspection or the use of leftover wood, resulting in compromised strength and durability. Unsymmetrical plywood is usually the result of inaccurate cutting or operator errors, making it inefficient and undesirable for precise applications in construction. Inappropriate thickness defects occur due to measurement and cutting mistakes or lack of operator concentration, leading to deviation from the expected specifications.

The objective of this Six Sigma project is to analyze the types of defects and identify the root causes of variations in the plywood production process. The project aims to implement the necessary improvements to enhance product quality and reduce the number of defects. By doing so, the company can improve customer satisfaction, strengthen its market reputation, and increase production efficiency. The project is scheduled for implementation between January and March 2024. The SIPOC (Supplier, Input, Process, Output, Customer) diagram is a high-level visual tool used to map and understand the core components of a process from beginning to end. It provides a structured overview of the suppliers involved, the materials and resources they provide, the steps of the process itself, the outputs produced, and the customers who receive them.

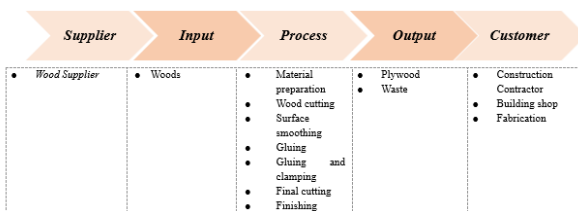


Figure 4. Crack Plywood Defects

In this research, Figure 4 SIPOC diagram helps visualize the plywood production flow and identify potential sources of defects. By presenting this workflow in a structured manner, the SIPOC diagram ensures clarity in defining the process boundaries and aligns team efforts in targeting improvement initiatives effectively.

b. Measure

The *Measure* phase is a critical step in the Six Sigma methodology, aiming to collect and analyze quantitative data to understand the initial condition of the production process. This phase begins with the identification of *Critical to Quality* (CTQ) elements, which in the case of plywood manufacturing include three main types of defects: cracked plywood,

asymmetrical plywood, and incorrect plywood thickness. These defects significantly affect product quality and customer satisfaction, often caused by factors such as substandard raw materials, unskilled operators, and measurement inaccuracies. Following this, a normality test using the Kolmogorov-Smirnov method was conducted, yielding a significance value of 0.367, indicating that the residuals are normally distributed. Process control was then assessed using P, U, X, and R control charts.

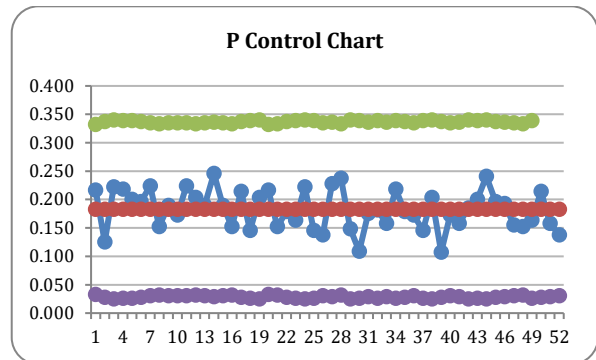


Figure 5. P Control Chart

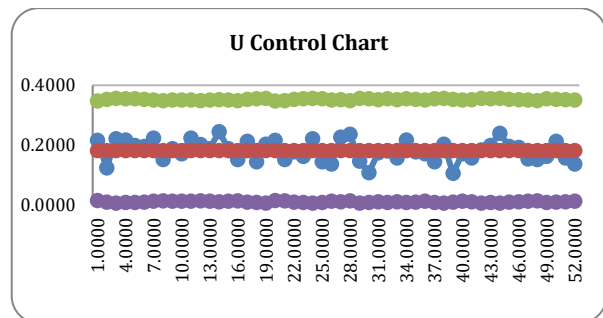


Figure 6. U Control Chart

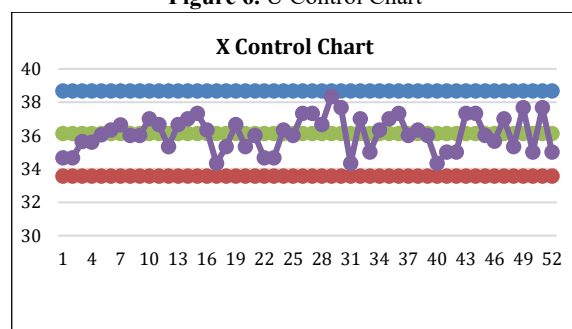


Figure 7. X Control Chart

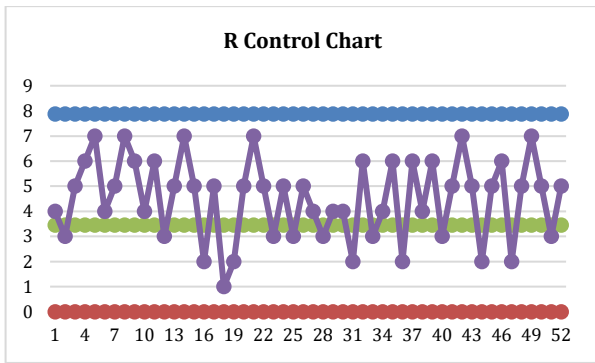


Figure 8. R Control Chart

As shown in the accompanying control charts (see Figure: P, U, X, and R Charts), all data points fall within the upper and lower control limits, suggesting that the process is statistically in control. A process capability analysis was also performed based on the plywood length specification, with a lower specification limit (LSL) of 30 cm, an upper specification limit (USL) of 42 cm, and a target of 35 cm.

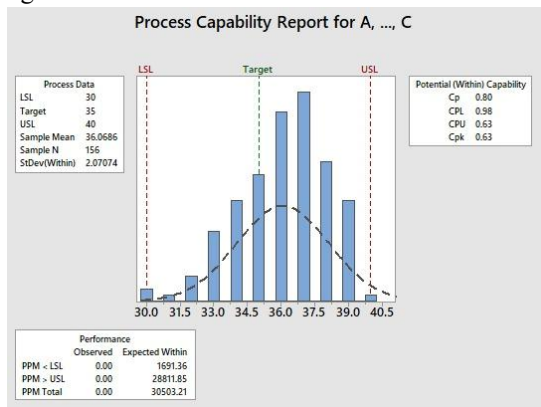


Figure 9. Process Capability Report

As illustrated in the Process Capability Report (see Figure: Capability Analysis), the results show a Cp value of 0.80 and a Cpk value of 0.63. These values indicate that the process is not capable of consistently producing within specifications and is not centered within the limits. Additionally, the value of $1/Cp$ equals 1.25, meaning that only 12.5% of the specification range is effectively used by the current process. Finally, defect metrics were calculated, showing a Defect per Unit (DPU) of 0.182, Total Opportunities (TOP) of 8,826, Defect per Opportunity (DPO) of 0.0609, and Defects per Million Opportunities (DPMO) of 3,164,345.60, which corresponds to a sigma level of 3.0548. These findings demonstrate that while the process is under control, the level of defects remains high, indicating the need for continuous improvement efforts to enhance process capability and overall product quality.

c. Analyze

The *Analyze* phase is the third step of the Six Sigma methodology, focused on gaining a deeper understanding of the root causes behind the problems identified during the Define phase. This phase employs analytical tools to

diagnose issues within the process, helping to direct improvement efforts effectively. Two key tools commonly used in this stage are the Pareto Diagram and the Cause-and-Effect (Fishbone) Diagram. The Pareto Diagram (see accompanying figure) graphically illustrates the relative distribution of various types of non-conformities in descending order of significance. In the plywood production process, a total of 537 defects were recorded, consisting of 176 cracked plywood units (33%), 187 asymmetrical plywood units (35%), and 174 units with incorrect thickness (32%). The most frequent defect—*asymmetrical plywood*—should be prioritized for improvement, as addressing it could significantly reduce the occurrence of other defects in subsequent production cycles.

The Cause-and-Effect Diagram (Fishbone Diagram) helps identify potential root causes of defects by organizing them into major categories such as Man, Machine, Method, Material, and Environment.

1. For cracked plywood, key causes include inattentive operators, decreased machine performance, vague SOPs, poor raw material quality, and an uncondusive working environment.
2. For asymmetrical plywood, contributing factors include untrained operators, worn-out machines, reliance on manual cutting methods, use of non-standard materials, and lack of environmental control.
3. For uneven plywood thickness, causes are linked to unskilled operators, unmaintained machines, hasty production methods, improper material inspection, and suboptimal working conditions.

d. Improve

The *Improve* phase is the fourth step in the DMAIC methodology and centers on developing and implementing effective solutions to address the root causes identified earlier. The primary goal is to improve the process performance so that it aligns with quality standards and customer expectations.

In this phase, the 5W+1H method is employed to systematically plan improvement actions. This method ensures that all aspects of the proposed solution are thoroughly considered:

Table 2. 5W + 1H Methods

5W + 1H Element	Description
What	Implement training programs for operators and revise the SOP for cutting and thickness measurement
Why	To reduce defects related to human error and ensure consistency in production quality
Where	In the cutting, assembly, and thickness-checking sections of the production line

5W + 1H Element	Description
When	To be implemented starting the first week of the next production cycle
Who	The Quality Control team and Production Supervisors, in collaboration with Line Operators
How	Through training sessions, visual SOPs at workstations, and regular audits of operator performance and machine conditions

e. Control

The *Control* phase represents the final step in the Six Sigma quality improvement methodology. This stage is crucial in ensuring that the improvements achieved in the previous phases are sustained over time and that the production process consistently meets the company’s Sigma level and DPMO (Defects Per Million Opportunities) targets. The primary objective is to maintain the stability of the process so that products continuously meet quality expectations.

To support this, several key control actions are implemented. Regular inspections are conducted every two weeks to monitor machine maintenance and evaluate the performance of production components. Additionally, routine checks are carried out across all aspects of the process—including materials, methods, workforce, and equipment—to identify and address potential issues before they escalate. Periodic calculations of DPMO and Sigma values are also essential, as they help track the level of defects and determine how effectively the process is producing defect-free products.

Moreover, adherence to established Standard Operating Procedures (SOPs) is enforced to minimize the risk of human error that could disrupt production flow. These procedures serve as a consistent guide for operators and are instrumental in maintaining process discipline. The success of the Control phase relies heavily on the involvement of all personnel, from top management to production and quality control teams, ensuring a unified commitment to quality and operational excellence.

3.2. New Seven Tools

The New Seven Tools are modern quality management instruments used for problem solving, decision making, and continuous improvement in production. This multi method integration ensures that improvements are not only data driven but also process oriented and human centered, allowing the researcher to address both technical and organizational factors contributing to product defects. While Six Sigma identifies what is wrong and quantifies how much, the New Seven Tools reveal why and where issues occur, and Kaizen addresses how to sustainably prevent them through everyday practices. In the context of plywood product defects at Toko Mebel Jatimulyo, the following tools were applied:

a. Affinity Diagram

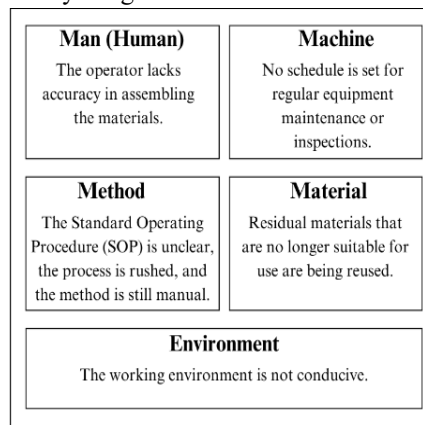


Figure 10. Affinity Diagram

The Affinity Diagram (see Figure 10) is used to group facts, ideas, and customer feedback based on natural relationships. Analysis shows that defects originate from five factors: human, machine, material, method, and environment. For example, human-related defects result from inattentive operators, while machine defects arise from poor maintenance and wear.

b. Relationship Diagram

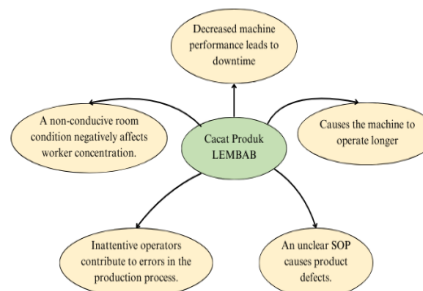


Figure 11. Relationship Diagram

The Relationship Diagram (refer to the Figure 11) illustrates cause-effect connections between various defect sources. An unconducive environment reduces worker focus, leading to lower quality, while unclear SOPs and machine issues like performance decline also contribute significantly.

c. Matrix Diagram

Low operator concentration level	□	●	●
Less conducive work environment	●	□	●
The quality and size of plywood products that do not meet the standard	●	●	□
Factor-Factor			
Repair Activities	Improve operator performance	Improving the conditions of the production environment	Improvements to plywood standards sent by suppliers
SpecificActivities			
Supervise workers regularly	□	●	●
Creating an ergonomic workstation	□	□	●
Rearrange the layout of the production room	△	□	●
Improving the facilities in the production room	△	□	●
Communication with suppliers regarding the quality of plywood raw materials	●	●	□
Re-checking the plywood when entering the production section	●	●	□
Creating an efficient measuring tool	△	●	△
Perform standard supervision	△	●	△

Noted :

□ Highly Related △ Related ● Unrelated

Figure 12: Matrix Diagram

As shown in the Matrix Diagram (see Figure 12), connections between causes, improvement activities, and specific actions are categorized using symbols. Strong links (squares) include adjusting production layout to improve environment. Medium links (triangles) relate to operator supervision. Weak links (circles) highlight non-related factors like operator focus and material quality.

d. Affinity Diagram

Matrix data in Table 3 reveals key improvement priorities. Enhancing operator performance through regular supervision and environmental upgrades such as optimizing layout and facilities are critical. Ensuring material quality through supplier communication and material checks is also essential.

Table 3. Affinity Diagram

Primary	Secondary	Impotancy	Toko Mebel Jatimulyo
Improving Operator Performance	Supervising workers on a regular basis	3	1
	Perform standard supervision	3	3
	Creating an ergonomic workstation	3	2
Improving Production Environment Conditions	Rearrange the layout of the production room	3	2
	Improving the facilities in the production room	3	1
Raw Materials from Suppliers Do Not Meet Standards	Communication with suppliers regarding the quality of plywood raw materials	3	2
	Re-checking the plywood when	3	1

Primary	Secondary	Impotancy	Toko Mebel Jatimulyo
	entering the production section		

e. Tree Diagram

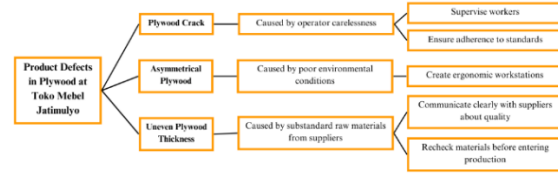


Figure 13. Tree Diagram

The Tree Diagram (see Figure 13) systematically breaks down defect causes. Cracks are due to inattentiveness, asymmetry stems from poor ergonomics, and incorrect thickness results from substandard materials. Solutions include strict supervision, workspace improvement, and quality control on incoming raw materials.

f. Arrow Diagram

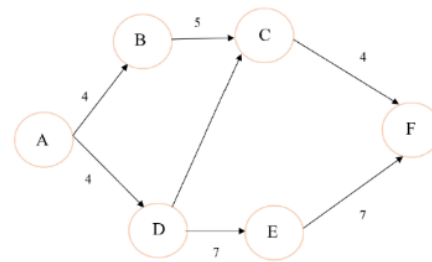


Figure 14. Arrow Diagram

The Arrow Diagram (see Figure 14) maps out the sequence of activities and process flow, supported by the detailed table of activities and processing time. The table lists key actions such as equipment and material inspection, workspace reorganization, operator supervision, and SOP development, along with their respective durations.

Table 4. Details of Activities and Process Time of the Network Diagram

Activity Code	Activities Carried Out	Duration of Activity (days)
A	Appliance and Material Inspection	4
B	Analyzing the Cause of the Defect	5
C	Employee Performance Evaluation	4
D	Workstation Checking	6
E	Repairing Tools and Materials	7
F	Providing Clear and Structured SOPs	2

Based on Table 3, the entire quality improvement process spans 28 days. This timeline helps visualize dependencies between tasks and identify where delays or defects may occur. It also supports scheduling and resource allocation for smoother workflow and better production outcomes.

g. Process Decision Program Chart (PDPC)

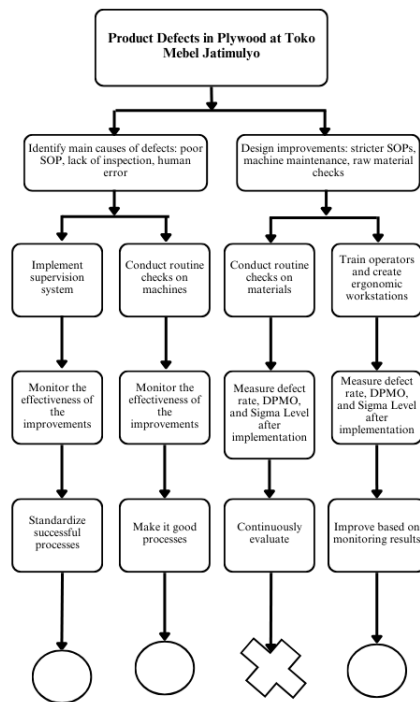


Figure 15. Process Decision Program Chart (PDPC)

The PDPC (see Figure 15) helps anticipate potential issues and formulate countermeasures. Key focus areas include enhancing operator performance, improving workplace conditions, and ensuring supplier compliance. Solutions involve stricter SOPs, facility upgrades, and clearer communication channels to minimize the risk of recurring product defects.

3.3. Kaizen Methods

Kaizen 5S is a continuous improvement method that focuses on workplace organization and operational efficiency. It originates from five Japanese principles: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain). These principles are applied systematically to minimize waste, prevent errors, and improve productivity.

At Toko Mebel JatiMulyo, the implementation of the Kaizen 5S approach in the context of product quality improvement specifically for plywood can be described as follows:

Table 5. Kaizen 5S Methods

Concept	Repair
Seiri (Simple)	At the JatiMulyo Furniture Store, the application of the seiri (conceive) concept requires a focus on grouping and separating unnecessary items from the workplace. JatiMulyo Furniture Shop implements this step by conducting periodic audits to ensure that only the equipment and materials that are really needed are in the production area. Items that are no longer used or that could cause immediate clutter are moved or discarded. The goal is to create a more efficient workplace and increase the effectiveness of the production process with a neat arrangement of materials and tools.
Seiton (Neat)	The application of the Seiton concept in the JatiMulyo Furniture Store involves arranging the necessary items in the most logical and accessible place. JatiMulyo Furniture Shop ensures that each tool and material has a special place that is clearly labeled, so that it is easy to find and return after use. This helps in reducing the

Concept	Repair
Seiso (Clean)	time wasted on searching for tools and improving efficiency. With Seiton, JatiMulyo Furniture Shop becomes more organized, speeds up service, and improves the shopping experience. The application of the Seiso concept at the JatiMulyo Furniture Shop emphasizes that the work area is kept clean and in good condition. JatiMulyo Furniture Shop emphasizes the importance of cleanliness by carrying out regular cleaning and maintenance of equipment. They also conduct periodic inspections to detect problems or potential damage to the appliance before it becomes a bigger problem. By maintaining cleanliness, stores give a professional impression and improve shopping convenience, which can increase customer satisfaction and loyalty. Seiso creates a healthy and productive working environment, supporting efficient and high-quality store operations.
Seiketsu (Take care)	The application of the Seiketsu concept at JatiMulyo Furniture Shop establishes clear standard procedures for each task, including how to store tools and clean the work area. This helps ensure that best practices are followed consistently across the company and reduces variability in the process.
Shitsuke (Diligent)	The application of the Shitsuke concept at JatiMulyo Furniture Shop ensures that the practices that have been implemented continue to be followed and improved on an ongoing basis. JatiMulyo Furniture Shop holds regular training and meetings to remind employees of the importance of 5S and to assess and improve existing practices. In this way, they ensure that positive changes persist and become part of the daily work culture.

This structured application of Kaizen 5S not only addresses existing plywood product defects such as cracks, uneven thickness, and asymmetry but also enhances the overall production process. With routine evaluations and employee involvement, the goal is to build a sustainable quality culture and eliminate root causes of inefficiencies in the long term.

4. Conclusion

In conclusion, this study successfully addressed the research objectives by identifying and analyzing the root causes of plywood product defects at Toko Mebel JatiMulyo using an integrated quality management approach involving Six Sigma, New Seven Tools, and the Kaizen 5S method. Through the application of the DMAIC phases in the Six Sigma framework, the process capability was measured and evaluated, revealing that defects such as cracks, asymmetry, and inconsistent thickness were significantly influenced by human error, machine performance, material quality, and an unstructured working environment. The New Seven Tools provided a detailed and systematic visualization of the relationships and critical points causing defects, including tools such as affinity diagrams, relationship diagrams, and matrix analyses. These tools clarified how interrelated factors such as unclear SOPs, low operator concentration, and poor environmental conditions contributed to quality issues. The implementation of Kaizen 5S further supported sustainable improvements by fostering a clean, organized, and standardized workplace, which is essential to maintaining high-quality outputs over

time. The integration of these multimethod approaches quantitative precision from Six Sigma, diagnostic clarity from New Seven Tools, and cultural transformation through Kaizen 5S proved to be highly effective in generating a comprehensive, data driven, and behaviorally sustainable quality improvement strategy. This synergy not only improved the short term defect metrics but also established a foundation for long-term operational excellence and continuous improvement in plywood manufacturing.

Despite the effectiveness of this multi-method approach, several limitations were encountered. The analysis relied heavily on qualitative observations and inputs from operators and supervisors, which may introduce subjective bias. Additionally, the timeframe of data collection and implementation was relatively short, limiting the study's ability to measure long-term impacts of corrective actions. Future research is encouraged to apply quantitative validation through control charts or simulation modeling, as well as to expand the scope by involving more departments or production units for a broader analysis. Moreover, integrating digital monitoring tools and IoT-based quality tracking could further enhance the precision and real-time responsiveness of defect prevention strategies. Overall, this research underscores the importance of a comprehensive and continuous quality management approach to improve manufacturing performance and product reliability in the plywood industry.

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References

Adeodu, A., Kanakana-Katumba, M. G., & Rendani, M. (2021). Implementation of Lean Six Sigma for Production Process Optimization In A Paper Production Company. *Journal of Industrial Engineering and Management*, 14(3), 661–680. <https://doi.org/10.3926/jiem.3479>

Brauel, K. (2023). Operational Excellence Paradigms and organizational resilience The effect of operational excellence paradigms on organizational resilience building.

Byrne, B., McDermott, O., & Noonan, J. (2021). Applying Lean Six Sigma Methodology to A Pharmaceutical Manufacturing Facility: A Case Study. *Processes*, 9(3). <https://doi.org/10.3390/pr9030550>

Chukwunweike, J., & Opeyemi, E. A. (2024). Implementing Agile Management Practices in The Era of Digital Transformation. *World Journal of Advanced Research and Reviews*, 24(1), 2223–2242. <https://doi.org/10.30574/wjarr.2024.24.1.3253>

Dartawan, K. I., & Setiafindari, W. (2023). Analisis Pengendalian Kualitas Produk Dengan Metode Seven Tools Dan Kaizen Pada PT Sinar Semesta I. *Jurnal ARTI: Aplikasi Rancangan Teknik Industri*, 18(1), <https://doi.org/10.52072/arti.v18i1.517>

Erwansyah, M. S., & Aryanny, E. (2025). Quality Control of Furniture Products With SQC and FMEA Methods at UD. XYZ. *Jurnal Al Azhar Indonesia Seri Sains dan Teknologi*, 10(1), <https://doi.org/10.36722/sst.v10i1.2915>

Ghelani, H. (2023). Six Sigma and Continuous Improvement Strategies: A Comparative Analysis in Global Manufacturing Industries. *International Journal of Scientific Research and Management (IJSRM)*, 11(08), 954–972. <https://doi.org/10.18535/ijssrm/v11i08.ec05>

Helmi, A. S., Ramadhani, I. K., & Januarista, N. (2024). Pengendalian Cacat Produk Pisang Nugget di IKM Almauzu dengan Pendekatan Metode Six Sigma. *Performa: Media Ilmiah Teknik Industri*, 23(2), 119. <https://doi.org/10.20961/performa.23.2.84675>

Loppolo, G., Ciliberto, C., & Katarzyna. (2025). *Total Quality Management and Lean Thinking 5.0: Theories and Methods* (Routledge, Ed.). Taylor & Francis Group.

Jannaah, P. D. R., & Winursito, Y. C. (2025). Analisis Total Quality Control Hasil Pengelasan Bengkel Welding MO & EO PT XYZ Menggunakan Metode Basic Seven Tools Dan New Seven Tools. *Jurnal Teknik Industri Terintegrasi*, 8(1), 573–584. <https://doi.org/10.31004/jutin.v8i1.39919>

Jaware, A., Bhandare, K., Sonawane, G., & Bhagat, S. (2018). Seven Quality Tools A Review. *International Research Journal of Engineering and Technology*. www.irjet.net

Jum'a, L., Alkalha, Z., Al Mandil, K., & Alaraj, M. (2023). Exploring The Influence of Lean Manufacturing and Total Quality Management Practices on Environmental Sustainability: The Moderating Role of Quality Culture. *International Journal of Lean Six Sigma*, 14(7), 1626–1654. <https://doi.org/10.1108/IJLSS-11-2021-0203>

- McDermott, O., Antony, J., Sony, M., Rosa, A., Hickey, M., & Grant, T. A. (2023). A Study on Ishikawa's Original Basic Tools of Quality Control in Healthcare. *The TQM Journal*, 35(7), 1686–1705. <https://doi.org/10.1108/TQM-06-2022-0187>
- Muhammad, S., Bukhari, S., & Akhtar, R. (2024). Leveraging Artificial Intelligence To Revolutionize Six Sigma: Enhancing Process Optimization And Predictive Quality Control. *Contemporary Journal Of Social Science Review*, 2(4).
- Nugraha, I., & Ramadhan, G. (2024). The Effect of Total Quality Management on Service Quality, Price, and Customer Satisfaction at Kita-Kita Tour and Travel. *International Journal of Eco-Innovation in Science and Engineering (IJEISE)*, 5(2). <https://doi.org/10.33005/ijeise.v5i2.130>
- Nugraha, I., Syaifullah, H., & Ramadhan, G. (2025). Application of The Six Sigma Method, Failure Mode And Effect Analysis (FMEA) and SQCDMPE Analysis in The Repair and Improvement of Screen Printing Quality at UMKM XYZ. *IOP Conference Series: Earth and Environmental Science*, 1454(1), IOP Publishing. <https://dx.doi.org/10.1088/1755-1315/1454/1/012066>
- Okpala, C., Nwamekwe, C. O., Ezeanyim, O. C., Chikwendu, O. C., Chiedu, O., & Onyeka, N. C. (2024). The Implementation of Kaizen Principles in Manufacturing Processes: A Pathway to Continuous Improvement. *International Journal of Engineering Inventions*, 24(7) <https://hal.science/hal-04669397/document>
- Otoki, N. S. (2021). A Continuous Improvement (Kaizen) Driven Approach for Realistic Digital Transformation in Smart Manufacturing. <https://www.mitsubishielectric.com/fa/sols/digital-manufacturing/en/index.html>
- Rochmoeljati, R., Nugraha, I., & Mulia, N. A. C. (2022). Welding Quality Control Using Statistical Quality Control (SQC) methods and Failure Mode Effect Analysis (FMEA) at PT. XYZ. *Nusantara Science and Technology Proceedings*, 39-45.
- Skorupińska, E., Hitka, M., & Sydor, M. (2024). Surveying Quality Management Methodologies in Wooden Furniture Production. *Systems*, 12(2). <https://doi.org/10.3390/systems12020051>
- Kareska, K. (2024). Implementing KAIZEN for Continuous Improvement in Manufacturing Processes: A Quantitative Analysis of Efficiency and Productivity Gains. <https://dx.doi.org/10.2139/ssrn.4844986>
- Zakaria, T., Dyah Juniarti, A., Ramdani, D. M., & Sulisty, A. B. (2024). Optimalisasi Pengendalian Kualitas Produk Palet Kayu Melalui Pendekatan RCA & SPC (Studi Kasus PT. Azdhi Kayu Kreasi). *Jurnal InTent*, 7(2). <https://doi.org/10.47080/intent.v7i2.3880>
- Zondo, M., Charles Mukwakungu, S., Sukdeo, N., & Mbohwa, C. (2024). Optimizing Quality Management Systems in Manufacturing: Internal and External Defects Minimization Strategies Case. <https://doi.org/10.46254/an14.20240615>