

Vitalii Zalitok*Educational Institution "KROK University", Kyiv, Ukraine**E-mail: vitaliizalitok@yahoo.com**ORCID: <https://orcid.org/0009-0006-8912-5230>*

Quality and Standards in Custom Furniture Production: A Practical Small-Scale Production Approach

Abstract

Purpose. The purpose of this study is to develop a practical quality management framework for custom furniture production that enables small-scale manufacturers to ensure product quality while maintaining the flexibility required for highly customized, low-volume production. *Methodology.* The research is based on an analytical review of recent developments in wood defect detection, Total Quality Management (TQM), Lean methodologies and intelligent manufacturing systems. Approaches such as Artificial Intelligence (AI)-based inspection, Multi-Criteria Decision-Making (MCDM) methods and sustainability-driven design were adapted to small-scale conditions, resulting in a hybrid quality management model that integrates simplified Lean Six Sigma tools, defect detection technologies and process optimization strategies. *Results.* Consistent quality in custom furniture production depends primarily on structured process control, effective knowledge transfer and flexible production planning rather than on extensive automation; small manufacturers can achieve high product quality with a limited number of appropriate digital technologies alongside continuous process improvement. *Practical implications.* The framework offers a scalable solution for small and medium-sized custom furniture enterprises, improving process consistency, reducing defects and aligning quality assurance with customer-specific requirements without compromising operational flexibility. *Value/originality.* Unlike quality systems developed for mass manufacturing, the model combines Lean Six Sigma principles, modern defect detection technologies and process optimization techniques in a framework adapted to artisanal and highly customized production, bridging the gap between industrial quality standards and small-scale furniture production.

DOI: <https://doi.org/10.30525/2500-946X/2026-3-12>

Keywords

custom furniture production, quality management, small-scale manufacturing, process optimization, defect detection, sustainable production

JEL: L15, L23, M11



This is an Open Access article, distributed under the terms of the Creative Commons Attribution CC BY 4.0

1 Introduction

Custom furniture production combines the craftsman's creativity with the structured elements of manufacturing. Client-specific designs make product variation far higher than in mass production, which allows differentiation but makes consistent quality across production cycles hard to maintain. Small workshops rarely have a formal quality system, so quality varies between cycles, causing rework, material waste, lower productivity and higher labor costs. Lacking resources for such a system, they rely on employees' skills, whose largely tacit knowledge is experiential, hard to document, usually passed on orally, and therefore difficult to measure, although vital to organizational success.

Approaches developed for larger manufacturers could nonetheless help. Total Quality Management (TQM), Lean Six Sigma and process optimization models have improved product quality and efficiency (Hernadewita et al., 2022; Klarić, Barčić, et al., 2024; Skorupińska et al., 2024). Technology offers a second

route: deep learning models, including YOLO-based systems and hybrid architectures, detect surface defects and contaminants in wood-based products in real time (Djedidi et al., 2025; Haonan et al., 2023; Kılıç et al., 2025), and frequency-domain analysis, image segmentation and particleboard inspection add complementary information (Li et al., 2024; Yang et al., 2024; Zhao et al., 2022). Yet both were developed for large-scale environments with abundant resources and data and cannot be applied directly to smaller workshops without adaptation.

Research gap. Although quality management systems (QMS), defect detection technologies and process optimization methods have advanced considerably, most studies focus on large-scale manufacturing and offer few practical, integrated frameworks that reflect the constraints and operational realities of small-scale custom furniture production.

Aim and novelty. The aim of this study is to create a structured yet adaptable quality management system for small-scale custom furniture production. Its novelty lies in combining simplified TQM

principles, selective AI-based defect detection, lean process optimization tools and adaptive scheduling in a unified, scalable model for resource-constrained environments. The study seeks (1) to examine current approaches to quality management, defect detection and production optimization in furniture manufacturing; (2) to evaluate their applicability to small-scale custom production; and (3) to develop an implementation-oriented hybrid framework that balances standardization and flexibility, thereby contributing theoretically to quality consistency and practically to bridging industrial quality systems and artisanal production.

2 Results

Quality management in the furniture industry has evolved from conventional inspection toward continuous improvement and customer satisfaction. TQM, which emphasizes process standardization, employee participation and evidence-based decisions, is now the primary model and improves product quality and organizational performance when applied consistently (Klarić, Barčić, et al., 2024). Structural barriers remain, however: the available methodologies for wooden furniture are fragmented and poorly integrated across the production process (Skorupińska et al., 2024), particularly in small workshops, where formal procedures and performance metrics are simplified or absent.

Lean Six Sigma adds methods for reducing waste and variability and has been linked to significant reductions in defects and inefficiency (Hernadewita et al., 2022), but it depends on structured data collection, statistical tools and formal training, so small workshops cannot adopt it fully without simplification. Hybrid models address such limitations, as when MCDM is combined with FMEA for process optimization and risk assessment (Klarić, Perić, et al., 2024), yet they add complexity, reinforcing the need for flexible, scalable solutions for smaller systems.

Visual inspection of wood panels is increasingly augmented or replaced by AI and computer vision. Deep learning methods, especially YOLO (You Only Look Once), identify contaminants and surface defects in real time and reduce the errors of manual assessment (Djedidi et al., 2025; Haonan et al., 2023). Hybrid sensor-based models perform better under varying environmental conditions (Kılıç et al., 2025), frequency-domain transformations and adaptive down-sampling reveal subtle surface irregularities (Li et al., 2024), and image segmentation and particleboard-specific methods improve precision in identifying structural defects (Yang et al., 2024; Zhao et al., 2022). Yet many of these methods need large training datasets and substantial investment in hardware, software and expertise, and, having been

developed for standardized products, they may not reliably detect defects in unique, customized pieces; they should therefore be adopted selectively.

Consistent quality also depends on optimized processes: the Theory of Constraints (TOC) identifies and controls bottlenecks and has been shown to increase throughput and shorten lead times (Ukey et al., 2025); in furniture production they typically arise in material preparation, assembly and finishing, where variability and manual activity are highest. AI-based scheduling adjusts workflows dynamically to real-time conditions (Lu, 2025), which suits custom jobs whose requirements vary, and multi-objective optimization can balance cost, time and quality simultaneously (Marcinekova & Janáková Sujová, 2024). Both need modeling and data that small workshops often lack, so their success depends on simple methods, modular implementation and fit with existing practices.

Digital technologies add precision and integration: 3D scanning offers accurate measurement, reverse engineering and better fitting during assembly (Muminović et al., 2024), and combining digital smart manufacturing systems, with their real-time monitoring and adaptive control, with TQM can enhance the sustainability and innovation of custom furniture production (Lee & Hsu, 2025). High costs, complexity and the need for specialized personnel nevertheless put such systems out of reach for many small producers, who prefer incremental adoption, applying digital tools to the most impactful stages rather than undertaking full digital transformation.

Sustainability is increasingly treated as an inherent element of product quality, extending it beyond functionality to environmental impact, durability and life-cycle factors. Suandi et al. (2022) stress incorporating materials selection, energy efficiency and recyclability into furniture design, and Zhang et al. (2023) propose frameworks for assessing the recyclability of wooden furniture, showing how design decisions enable circular economy practices. Product lifespan is also a crucial quality metric: durability and long-term performance significantly affect consumer preference, particularly for eco-friendly purchases (Sabbir, 2025), which favors custom producers, whose items are typically built to last. Knowledge management supports sustainable production too, as the SECI model facilitates knowledge creation and transfer, continuous improvement and resource efficiency (Sepúlveda-Rojas et al., 2024). Yet sustainability is still commonly handled as a separate quality characteristic, leaving room for holistic systems that combine quality, efficiency and sustainability objectives.

Taken together, the reviewed studies show substantial progress in quality control methodology, technology, optimization and sustainable design, but three gaps remain. First, most of the literature addresses large-scale mass production,

with standardized processes, abundant data and access to technology, whereas small-scale custom manufacturers face the opposite: high variability, limited resources and heavy reliance on manual skill. Second, individual approaches such as TQM and AI-based defect detection are well researched, but no integrated system combines them for small-scale manufacturing. Third, existing models prioritize technical complexity over practical feasibility, which limits their use where resources are scarce. A simple, scalable framework that integrates current methodologies and suits the operating conditions of small custom furniture manufacturers is therefore needed.

3 Methodology

This study is an analytical, qualitative and conceptual investigation aimed at developing a practical, scalable quality management framework for small-scale custom furniture production. As the research question is exploratory and no existing model applies directly, a structured synthesis of prior studies was chosen: a systematic literature review integrated with conceptual framework development across quality management, defect detection, process optimization and sustainability.

The review covered recent academic literature on furniture manufacturing, wood defects, production optimization and quality management systems. Studies were selected on three criteria: relevance (quality management methodologies such as TQM and Lean Six Sigma, defects in wood-based materials, scheduling optimization, digitalization and smart manufacturing, or sustainability and lifecycle design in furniture production); applicability to furniture manufacturing or related wood-processing industries; and recency and methodological contribution (mainly 2022 to 2025 studies on innovations such as AI-based inspection, hybrid optimization models and sustainability frameworks). This captures both current developments and practical approaches, consistent with the research objectives.

On this basis, a multi-layered framework was constructed that combines quality management, defect detection, process optimization and sustainability principles in a simple, adaptable and scalable system; Table 1 summarizes the tools considered and their applicability to small-scale production. The framework has four interconnected layers (Fig. 1). The Process Structure Layer standardizes the stages common to every product (material selection, cutting, assembly and finishing), reducing variability while preserving design flexibility, in line with TQM principles (Klarić, Barčić, et al., 2024; Skorupińska et al., 2024). The Quality Control Layer places inspection at critical points, combining manual checks with selective technology-based methods, such as YOLO models, hybrid systems and other advanced detection techniques, where defects are most likely, so that they are detected and prevented early (Djedidi et al., 2025; Haonan et al., 2023; Kılıç et al., 2025; Li et al., 2024; Yang et al., 2024; Zhao et al., 2022). The Process Optimization Layer applies simplified lean tools, bottleneck analysis (TOC) and adaptive scheduling: Lean Six Sigma contributes waste reduction (Hernadewita et al., 2022), TOC and scheduling improve workflow and responsiveness (Lu, 2025; Ukey et al., 2025), and further optimization methods can be added as needed (Marcineková & Janáková Sujová, 2024). The Support and Sustainability Layer covers sustainability and knowledge management: durable, recyclable designs raise quality (Suandi et al., 2022; Zhang et al., 2023) and shape customer perception (Sabbir, 2025), SECI-based knowledge sharing supports continuous improvement (Sepúlveda-Rojas et al., 2024), and digital tools such as 3D scanning and smart systems are applied selectively (Lee & Hsu, 2025; Muminović et al., 2024).

The layers work as an integrated system: process structure provides the foundation, quality control ensures consistency, optimization improves efficiency, and support mechanisms sustain long-term performance, enabling small producers to maintain high quality while preserving flexibility.

TABLE 1 Tools and Framework Applicability

Tool / Method	Purpose	Complexity	Suitability for Small-Scale	Notes
TQM (simplified)	Process standardization	Medium	High	Focus on core principles only
Lean tools (basic)	Waste reduction	Low	High	Easy to implement
Lean Six Sigma	Defect reduction	High	Medium	Requires simplification
AI defect detection (YOLO)	Surface defect identification	High	Low-Medium	Use selectively
Hybrid detection systems	Improved inspection accuracy	High	Low	Cost-intensive
TOC (Theory of Constraints)	Bottleneck management	Low	High	Highly practical
Scheduling systems (basic)	Workflow planning	Low	High	Manual methods effective
AI scheduling	Dynamic optimization	High	Low	Optional
3D scanning	Precision measurement	Medium	Medium	Use for complex designs

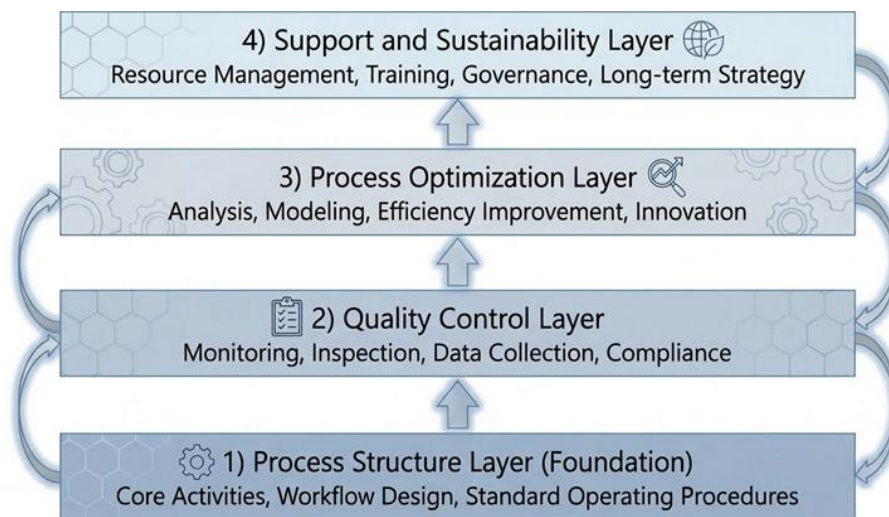


FIGURE 1 Conceptual Framework Development

4 Findings

The analysis identified seven patterns relevant to small-scale custom furniture makers (Table 2). First, structuring production into standard stages (material preparation, machining, assembly and finishing) reduces variability between customized products. Second, early-stage quality control outperforms final inspection, because defects found early do not propagate and rework falls. Third, applying defect detection technology at critical control points is far more practical than widespread adoption, as its effect on quality can be measured with few resources. Fourth, inefficiencies concentrated in assembly and finishing, and addressing them stabilized workflow and shortened production time. Fifth, simple tools such as basic lean practices and scheduling methods sufficed for operational improvement. Sixth, durability and material efficiency were significantly related to higher customer ratings of product quality. Seventh, knowledge transfer, training and skill development were among the most important factors of consistency where expertise is primarily manual.

In the workflow shown in Fig. 2, raw materials are selected and then pass the first quality control checkpoint (QC-C1), which verifies that they meet the

specifications set before production. After cutting, components proceed to assembly, where the second checkpoint (QC-C2) is placed because inefficiencies and defects are most prevalent when components are joined into the product's structure. Finishing, whose surface treatments and final adjustments determine durability and perceived quality, is followed by the third checkpoint (QC-C3), which confirms that the finished product meets all predefined requirements.

5 Discussion

The study shows that the configuration of the production system, not its size, constrains quality in custom furniture production: quality is achievable at workshop or factory scale because it depends on how well all elements of the process work together, so the traditional relationship between quality and size does not hold.

In customized production, process standardization replaces product standardization as the main route to consistency, in line with the process focus of TQM (Klarić, Barčić, et al., 2024). Where large systems standardize extensively on measurable data, small workshops rely on simplified, often informal structures, supporting the observation of Skorupińska

TABLE 2 Findings: Practical Use of Methods

Quality Approach	Impact on Defects	Impact on Time	Impact on Cost	Impact on Consistency
Process standardization	High	Medium	Medium	High
Early defect detection	High	High	High	High
AI-based inspection	High	Medium	Low	High
Bottleneck management	Medium	High	Medium	Medium
Lean tools	Medium	High	High	Medium
Scheduling optimization	Low	High	Medium	Medium
Sustainability practices	Low	Low	Medium	High
Knowledge management	Medium	Medium	Low	High

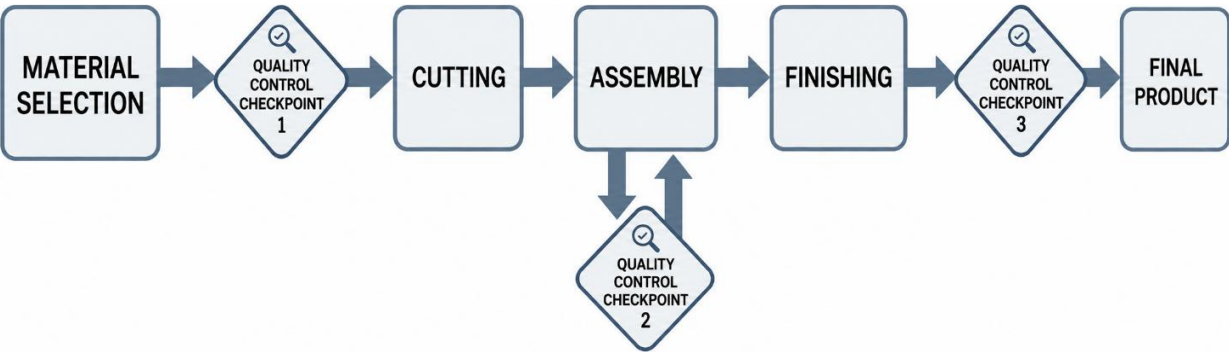


FIGURE 2 The Ultimate Production Process

et al. (2024) that quality management in furniture manufacturing is fragmented; the present study adds that even partial structuring of workflows significantly improves consistency.

The results also indicate a shift from end-of-line inspection to preventive quality control through early defect detection, consistent with AI-based inspection studies that stress early identification of material defects (Djedidi et al., 2025; Haonan et al., 2023). Full automation is not required; a hybrid model combining manual expertise with selective technological support is more realistic, extending Kılıç et al. (2025) and Li et al. (2024) by showing that the value of detection technologies lies not only in accuracy but also in their position in the workflow. Deep learning and advanced detection techniques are effective (Yang et al., 2024;

Zhao et al., 2022), but their cost, data requirements and complexity limit direct use in small workshops, favoring selective, step-by-step adoption over large-scale digitalization.

Process optimization remains a driver of performance, as studies of Lean Six Sigma and the Theory of Constraints suggest (Hernadewita et al., 2022; Ukey et al., 2025), but simplified tools proved sufficient for considerable gains. Likewise, simpler scheduling methods can match intelligent scheduling systems when the scale and variability of operations are taken into account (Fig. 3). Success in small-scale production thus depends more on usability than on sophistication.

The outcomes also support the view of sustainability as a fundamental element of product

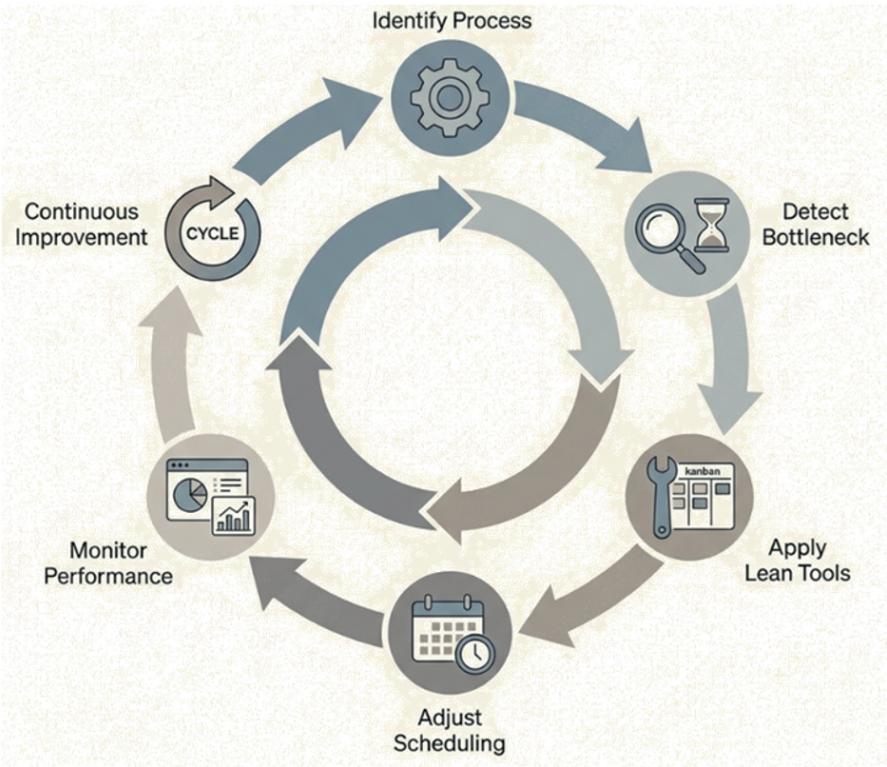


FIGURE 3 Process Optimization Flow

quality: durability and material efficiency rank among the most important quality characteristics (Suandi et al., 2022; Zhang et al., 2023), and the importance of product lifespan corresponds to the findings of Sabbir (2025) on longevity, consumer perception and buying behavior, a link especially strong in custom furniture, which is generally made to last a lifetime. In small-scale production, sustainability is therefore an essential element of quality, not an additional feature.

Knowledge management emerged as one of the most important yet least visible contributors to consistency. Formal systems such as the SECI model have been studied in manufacturing (Sepúlveda-Rojas et al., 2024), but small workshops transfer knowledge informally, and even simple structured methods such as mentorship or documentation significantly improved process reliability, suggesting that human capital matters more to quality here than in highly automated environments. More broadly, the findings support an integrated quality management system combining process structuring, targeted control and continuous improvement, which underlies the proposed framework. Unlike models that address TQM, defect detection or optimization separately, it accounts for their interdependence, which matters

most where resources are limited and solutions must be both efficient and adaptable.

6 Conclusion

The present study shows that high quality standards in custom furniture production can be achieved in small-scale environments through structured yet flexible approaches. By combining simplified TQM principles, selective technological adoption and lean-based process optimization, small producers can overcome the constraints traditionally associated with scale. The framework stresses process standardization, strategic use of defect detection technologies and adaptable scheduling, and treats sustainability and knowledge management as components of quality, helping to close the gap between industrial quality systems and artisanal production. Future studies should focus on empirical validation of the framework and on the development of low-cost digital tools suitable for small-scale manufacturers. Ultimately, quality is a function not of scale but of the design and implementation of the system.

References:

- [1] Djedidi, M., Hassen, M. B., Mrad, H., & Koubaa, A. (2025). Real time contaminants detection in wood panel manufacturing process using YOLO algorithms. *Procedia Computer Science*, 253: 1226–1235. <https://doi.org/10.1016/j.procs.2025.01.184>
- [2] Haonan, J., Huadong, X., Lihai, W., Jinsheng, Z., Xiaohui, C., & Xu, T. (2023). Quantitative identification of surface defects in wood paneling based on improved YOLOv5. *Journal of Beijing Forestry University*, 45(4): 147–155. <https://dx.doi.org/10.12171/j.1000-1522.20220419>
- [3] Hernadewita, H., Setiawan, I., & Hendra, H. (2022). Enhance quality improvement through lean six sigma in division Side Board Clavinova piano's. *International Journal of Production Management and Engineering*, 10(2): 173–181. <https://doi.org/10.4995/ijpme.2022.16140>
- [4] Kılıç, K., Kılıç, K., Doğru, İ. A., & Özcan, U. (2025). WD detector: Deep learning-based hybrid sensor design for wood defect detection. *European Journal of Wood and Wood Products*, 83: 50. <https://doi.org/10.1007/s00107-025-02211-5>
- [5] Klarić, K., Barčić, A. P., Greger, K., Vukman, K., Perić, I., & Klarić, M. (2024). Striving for excellence: deconstruction of Total Quality Management measuring model for Croatian furniture industry. *Sustainability*, 16(24): 11236. <https://doi.org/10.3390/su162411236>
- [6] Klarić, K., Perić, I., Vukman, K., Papić, F., Klarić, M., & Grošelj, P. (2024). Hybrid MCDM-FMEA model for process optimization: a case study in furniture manufacturing. *Systems*, 13(1): 14. <https://doi.org/10.3390/systems13010014>
- [7] Lee, H.-H., & Hsu, C.-M. (2025). Enhancing sustainable innovations in intelligent wood pellets through smart customized furniture and total quality management. *Sustainability*, 17(14): 6604. <https://doi.org/10.3390/su17146604>
- [8] Li, H., Yi, Z., Wang, Z., Wang, Y., Ge, L., Cao, W., & Sun, Q. (2024). FDADNet: detection of surface defects in wood-based panels based on frequency domain transformation and adaptive dynamic downsampling, 12(10): 2134. <https://doi.org/10.3390/pr12102134>
- [9] Lu, W. (2025). Enhancing efficiency in custom furniture production with intelligent scheduling systems. *Processes*, 13(9), 2721. <https://doi.org/10.3390/pr13092721>
- [10] Marcinekova, K., & Janáková Sujová, A. (2024). Multi-objective optimization of manufacturing process using artificial neural networks. *Systems*, 12(12): 569. <https://doi.org/10.3390/systems12120569>
- [11] Muminović, A. J., Gierz, Ł., Rebihić, H., Smajić, J., Pervan, N., Hadžiabdić, V., & Sydor, M. (2024). Enhancing furniture manufacturing with 3d scanning. *Applied Sciences*, 14(10): 4112. <https://doi.org/10.3390/app14104112>

- [12] Sabbir, M. M. (2025). Product feature and lifespan as a quality indicator for inducing eco-friendly furniture purchase. *Heliyon*, 11(3). <https://doi.org/10.1016/j.heliyon.2025.e42422>
- [13] Sepúlveda-Rojas, J. P., Aravena, S., & Carrasco, R. (2024). Increasing efficiency in furniture remanufacturing with AHP and the SECI model. *Sustainability*, 16(23): 10339. <https://doi.org/10.3390/su162310339>
- [14] Skorupińska, E., Hitka, M., & Sydor, M. (2024). Surveying quality management methodologies in wooden furniture production. *Systems*, 12(2): 51. <https://doi.org/10.3390/systems12020051>
- [15] Suandi, M.M.E., Amlus, M. H., Hemdi, A. R., Abd Rahim, S. Z., Ghazali, M. F., & Rahim, N. L. (2022). A review on sustainability characteristics development for wooden furniture design. *Sustainability*, 14(14): 8748. <https://doi.org/10.3390/su14148748>
- [16] Ukey, K., Chinta, L., Majumder, H., Patil, D. S., Mitkari, S., Sahu, A. R., & Dhutekar, P. K. (2025). Implementation of the Theory of Constraints (TOC) for a Furniture Manufacturing-Based Organization. *Engineering Proceedings*, 114(1): 17. <https://doi.org/10.3390/engproc2025114017>
- [17] Yang Fan, Yang Bokai, & Li Rongrong. (2024). Surface defect detection of engineered wood panels based on image segmentation and deep learning. *Journal of Zhejiang A&F University*, 41 (1): 176–182. <https://doi.org/10.11833/j.issn.2095-0756.20230280>
- [18] Zhang, Z., Zhu, J., & Qi, Q. (2023). Research on the recyclable design of wooden furniture based on recyclability evaluation. *Sustainability*, 15(24): 16758. <https://doi.org/10.3390/su152416758>
- [19] Zhao, Z., Ge, Z., Jia, M., Yang, X., Ding, R., & Zhou, Y. (2022). A particleboard surface defect detection method research based on the deep learning algorithm. *Sensors*, 22(20): 7733. <https://doi.org/10.3390/s22207733>

Received on: 20th of August, 2026

Accepted on: 05th of October, 2026

Published on: 16th of October, 2026