Terbit *online* pada laman web jurnal : https://jes-tm.org/index.php/jestm/index

Journal of Engineering Science and Technology Management

| ISSN (Online) 2828 -7886 |

JES-TM
Journal of Engineering Science & Technology Management

Article

Optimization of Wood Waste Utilization for Sustainable Material Processing in the Furniture Industry

Anshah Silmi Afifah[1*], Alfani Risman Nugroho[2], Nurmadina[3], Taufik Ramadhan Fitriyanto[4], Dhian Juwitasari[5]

[1,2,3,4,5]Department of Furniture Production Engineering, Politeknik Industri Furnitur dan Pengolahan Kayu, Kendal Regency, 51371, Indonesia

DOI: 10.31004/jestm.v5i2.266

E-mail: [a]anshah.silmi@poltek-furnitur.ac.id (Corresponding author)

ARTICLE INFORMATION

Volume 5 Issue 2
Received: 5 August 2025
Accepted: 31 August 2025
Publish *Online*: 05 September 2025
Online: at https:JESTM.org/

Keywords

Machining
Material Processing
Solid wood
Wood waste

A B S T R A C T

This study aims to identify and quantify wood waste produced during the machining of solid wood components using kiln dried *Durio zibethinus* boards. A descriptive quantitative approach was employed to measure the volume and weight of waste generated at each production stage, including ripping, crosscutting, planing, and thicknessing. Sampling was conducted using a precision digital scale to collect and compare the actual and theoretical waste. The results indicate that only 43% of the raw material volume was utilized in finished components, while 57% was lost as waste, primarily in the form of sawdust, shavings, and offcuts. The thicknesser contributed the largest proportion of waste (58%), followed by the ripsaw (21%), single planer (20%), and jumpsaw (1%). These findings highlight the need for improved raw material selection, more efficient cutting list design, enhanced nesting strategies, and better machine calibration. Implementing these practices can reduce wood waste, improve material efficiency, and minimize occupational exposure to wood dust in furniture manufacturing.

1. Introduction

The solid wood furniture industry faces significant challenges in optimizing the use of raw materials. As a non-renewable natural resource, wood must be utilized efficiently to ensure both environmental sustainability and economic viability (Wati et al., 2024). One of the main issues is the high amount of wood waste generated throughout the production process, particularly during the initial machining stages (Kurniasih et al., 2022). Such waste not only affects material efficiency but also poses health risks to workers if not managed properly.

Various studies have shown that wood waste can account for more than 50% of the total raw material volume, especially in small and medium sized furniture industries. In Indonesia's wood processing sector, sawmills commonly lose ≥ 40 - 50% of processed wood as waste, while plywood production averages 50%, implying a national waste potential on the order of 5.6 million m³ when aggregated across major subsectors (Haryanto, et. al., 2021). In Jepara, furniture production specifically has been reported to generate up to 58.85% waste relative to total material used (Sudiryanto and Suharto, 2020). At the global level, manufacturing studies report substantial material losses for example, 37% wastage in massive wood production and overall wood circularity remains limited, with only 8.4% of wood entering recycling streams (Brownellet al., 2018). Recent circular economy scenarios further underscore the need to raise wood waste recycling rates by 27 percentage points to curb disposal, highlighting the urgency of efficiency and recovery measures in furniture manufacturing (Yayla, et. al., 2025).

The dispersion of fine wood particles, especially micro sized dust, can have direct impacts on workers' respiratory systems and skin. Hidayati et al. (2018) highlighted that prolonged exposure to wood dust may lead to serious health problems. Similarly, Utami et al. (2020) reported frequent health complaints among wood processing workers, such as coughing, shortness of breath, chest pain, and eye irritation. Putri et al. (2016) further noted that direct skin contact with wood dust during sanding operations can trigger allergic reactions and dermatitis.

In depth analysis of the forms, types, and proportions of waste for specific furniture products remains limited. Yet, such information is crucial for developing targeted strategies to improve raw material efficiency and to support waste management practices that ensure a safer and healthier working environment. Fine wood particles generated from cutting and planing processes can remain suspended in the air, posing risks of respiratory diseases or skin irritation. Consequently, wood waste management is not only a matter of material efficiency but also an urgent occupational health and safety (OHS) issue in the furniture industry. Quantitative assessments of waste volume and weight at each production stage provide a scientific basis for designing more precise, healthy, and sustainable production systems.

Given these considerations, this study aims to analyze raw material utilization and wood waste generation in the production of furnittures made from durian wood (Durio zibethinus). The research focuses on classifying waste by machining stages, calculating the volume and weight of waste generated at each machine, and determining the percentage of waste relative to the total raw material used.

The findings are expected to offer a comprehensive overview of material loss points and potential health hazards from fine wood particles. These insights can serve as a basis for developing more efficient and safer waste management strategies for workers in the furniture industry. Moreover, understanding the critical points of waste generation such as excessive material loss during the initial cutting stage due to suboptimal cutting patterns can help improve cutting list design and promote more efficient nesting techniques. Classifying waste by type, such as sawdust or offcuts, also supports the selection of appropriate recycling or reuse methods, for instance, for particle boards, wood pellets, or additional furniture components. This information is valuable for choosing more precise machinery, training operators in raw material processing, and planning raw material usage more accurately.

2. Literature Review

2.1 Solid Wood Furniture Production

The production of solid wood furniture involves several machining processes, including initial cutting, surface preparation, and component assembly (Ratnasingam, 2022). Each stage uses different types of machines that generate various forms and volumes of wood waste. The quality of raw materials, cutting accuracy, and machine precision significantly influence the amount of waste produced (Nasir and Cool, 2020). According to Sriyanalugsana, & Suwantararangsri (2025), production efficiency in the furniture industry is affected by the integration of cutting list planning, proper selection of raw materials, and the operator's skill in machine handling.

2.2 Types and Classification of Wood Waste

Wood waste in furniture manufacturing can be classified based on physical form and process origin. In general, wood waste consists of (Nnaji and Udokpoh, 2022):

a. Fine dust: commonly generated by thicknessers or planers.
b. Shavings and splinters: produced during surfacing operations.
c. Offcuts: excess material trimmed during cutting, especially by ripsaws and jumpsaws.

This classification is important for identifying both the reuse potential of the waste and the risks it poses whether environmental or occupational. Fine dust, for instance, is more hazardous as it becomes airborne easily and is difficult to collect manually (Pole and Basu, 2017).

2.3 Raw Material Utilization Efficiency

Efficiency of raw material utilization is defined as the ratio between the net volume of product components and the total volume of raw material used. According to Pawanr & Gupta (2024), low efficiency indicates a high degree of material waste, which may result from suboptimal dimension planning or excessive material removal during machining. Optimization of cutting lists and nesting patterns is a critical strategy to improve this efficiency.

2.4 Cutting List

A cutting list is a planning document detailing the dimensions and cutting sequences for each furniture component (Oliveira, et. al., 2016). An effective cutting list considers available stock dimensions and optimizes nesting to minimize excess and offcuts (Ghodsi & Sassani, 2005).

2.5 Impact of Machining Processes on Wood Waste Generation

Each machining process has its own characteristics and produces different types of waste. For example, ripsaws and jumpsaws mainly produce offcuts, while planers and thicknessers produce finer shavings and dust. The more material that needs to be removed to achieve the final dimensions, the higher the volume of waste generated. Therefore, selecting raw materials with dimensions close to the final product and using precision calibrated machines are key to minimizing waste (Qin, et. al., 2021).

3. Research Methodology

This research employed a descriptive quantitative approach to identify and analyze wood waste generation during the machining of solid wood components made from Durio zibethinus (durian wood), commonly used in furniture manufacturing. The primary focus was to assess the volume and weight of waste generated at each machining stage and for each type of component, in order to evaluate raw material utilization efficiency and identify critical stages contributing most to waste.

The raw material used in this study was kiln-dried durian wood boards with initial (gross) dimensions of 2100 mm × 400 mm × 60 mm. The boards were randomly selected from available stock in the production workshop. A set of representative furniture components was produced for sampling and data collection.

The measurement procedure consisted of two steps. First, the volume of waste generated from each machining stage was determined by measuring the dimensions (length, width, and thickness) of the remaining offcuts and calculating their cubic volume. Second, the weight of waste was obtained using a digital weighing scale with 0.01 g precision. All measurements were recorded separately for each component and each machining process.

The data collected were tabulated and analyzed descriptively to calculate the proportion of waste relative to the gross input material and to identify which machining stages and components contributed most to overall wood waste generation.

The components analyzed included

a. Structural support elements (4 pieces)
b. Long frame rails (2 pieces)
c. Side rails (4 pieces)

d. Lower internal connector (1 piece)
e. Vertical partition (1 piece)

Each component was designed with gross and finished dimensions to meet the product's structural and aesthetic requirements. The difference between gross and finished sizes represented potential material loss, which was measured directly using a precision digital scale.

The production process followed typical industrial machining stages:

a. Single Rip Saw: to rip boards into specified widths
b. Jump Saw: to crosscut boards to required lengths
c. Single Planer: to square and smooth two sides of the boards
d. Thicknesser: to achieve the desired thickness and finish the opposite sides

Sampling was conducted throughout the machining process. For each machine and component, the resulting wood waste was collected and weighed using a precision digital scale (0.01 g accuracy). This procedure was repeated twice per machine per component, and the average values were calculated.

All data were grouped and analyzed to determine:

a. The average waste weight per component and per machine
b. The percentage of each machine's contribution to total waste
c. The machining stage responsible for the highest waste generation

The total volume of raw material used was 50,400,000 mm³ with an initial weight of 32,256 grams. The resulting furniture components had the following net dimensions:

a. Structural supports: 420 mm × 50 mm × 55 mm
b. Long rails: 940 mm × 25 mm × 55 mm
c. Side rails: 340 mm × 25 mm × 55 mm
d. Lower connector: 980 mm × 25 mm × 55 mm
e. Partition: 380 mm × 25 mm × 55 mm.

Each component was weighed and measured to determine volume and leftover offcuts. The weight of both finished parts and resulting waste was recorded to assess material utilization.

4. Results and Discussion

4.1 Wood Waste from the Ripsaw and Jumpsaw Processes

The initial raw wood boards, measuring 2100 mm × 400 mm × 60 mm, were ripped into eight parts using the ripsaw (see Fig. 1) and then crosscut with the jumpsaw (Fig. 2) to produce components with gross dimensions (see Table 2).

Fig. 1 Cutting Using Ripsaw

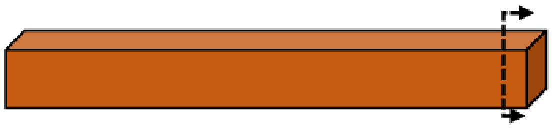

Fig2. Cutting Using Jumpsaw

Table 2. Gross Dimensions of Components

Component	Quantity	Length (mm)	Width (mm)	Thickness (mm)
Structural supports	4	440	55	60
Long frame rails	2	1000	30	60
Side rails	4	400	30	60
Lower connector	1	1000	30	60
Vertical partition	1	400	30	60

Sampling showed that the ripsaw process produced 1,647.5 grams of waste from eight cuts.

However, based on calculated removed volume and wood density (0.64), the expected weight was 1,935.36 grams. This suggests that approximately 287.86 grams of fine waste were not captured, likely dispersed or retained within the machine. The uncollected waste rate was 0.00009 grams per mm³.

In the jumpsaw process, similar discrepancies occurred. For example, structural supports generated 25.3 grams of calculated waste, but only 20.5 grams were collected, resulting in an estimated 0.00014 grams per mm³ of uncollected dust.

4.2 Wood Waste from the Single Planer Process

The gross components were then planed on one face to reduce both width and thickness by 2 mm (Fig. 3). For instance, planing the structural supports produced 323.8 grams of calculated waste, but only 282 grams were collected. Across all components, the uncollected portion averaged 0.00009 grams per mm³.

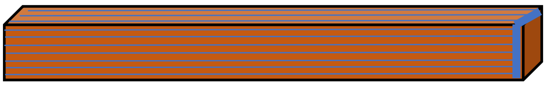

Fig. 3 Cutting Using Planer

4.3 Wood Waste from the Thicknesser Process

The final machining was done using a thicknesser, which removed material from the opposite faces to reach final thickness. This stage generated the highest volume of fine airborne dust. In one example, structural supports generated 795.5 grams of calculated waste, while only 692.5 grams were collected. On average, 0.00018 grams per mm³ of waste went uncollected.

4.4 Distribution of Wood Waste by Component and Production Implications

A breakdown of total waste showed that the thicknesser process generated the largest portion of waste (58%), followed by the ripsaw (21%), single planer (20%), and jumpsaw (1%). The thicknessing stage produces large amounts of fine sawdust that is often difficult to capture due to its lightweight, airborne nature.

A breakdown of total waste showed that the thicknesser process generated the largest portion of waste (58%), followed by the ripsaw (21%), single planer (20%), and jumpsaw (1%). The thicknessing stage produces large amounts of fine sawdust that is often difficult to capture due to its lightweight, airborne nature. Similar findings were reported in the Sri Lankan furniture industry, where secondary processing stages contributed more than 50% of fine particulate waste due to over-sizing and machine calibration issues (Abeysooriya, 2017).

A significant factor influencing waste generation was the gap between gross and net dimensions, especially during the initial processing stage. Larger discrepancies result in higher waste volumes and more airborne dust, which may pose health risks for workers. Prior studies (Hidayati et al., 2018; Putri et al., 2016) have shown that prolonged exposure to wood dust can lead to respiratory and dermatological problems.

A significant factor influencing waste generation was the gap between gross and net dimensions, especially during the initial processing stage. Larger discrepancies result in higher waste volumes and more airborne dust, which may pose health risks for workers. Prior studies (Hidayati et al., 2018; Putri et al., 2016) confirm that prolonged exposure to wood dust is associated with respiratory and dermatological problems. Comparable studies in Europe and Africa further emphasized that inadequate dust management increases the incidence of occupational asthma and dermatitis among furniture workers (Donkoh, 2021; Schlünssen et al., 2018).

These findings highlight the urgent need to improve raw material management in solid wood furniture production. Key strategies include selecting initial raw materials that closely match the dimensions required in the cutting list, thereby minimizing dimensional excess from the outset (Hosseini & Peer, 2022). In addition, refining cutting list design, optimizing nesting techniques to reduce offcuts, and enhancing machine calibration can all contribute to reducing material waste (Abeysooriya, 2017). Furthermore, providing targeted training for machine operators helps ensure more consistent machining quality and minimizes the generation of fine dust, ultimately lowering the risk of respiratory exposure in the workplace (Donkoh, 2021).

Classifying wood waste based on its

physical characteristics such as fine sawdust, shavings, and solid offcuts also supports more effective reuse strategies (Korba, et. al., 2025). Fine sawdust may be utilized for applications such as biomass fuel (e.g., wood pellets or briquettes), while larger offcuts and shavings can be repurposed into secondary furniture components, simple joinery elements, or used in prototyping and sample production (Udokpoh & Nnaji, 2023). These approaches not only reduce waste sent to landfills but also promote circularity and material efficiency in the furniture manufacturing process.

From an industrial engineering perspective, these findings highlight systemic inefficiencies in raw material management. Lean manufacturing frameworks classify excessive material loss as a form of muda (waste), suggesting that reducing dimensional excess and optimizing cutting layouts are central strategies for waste minimization (Radin, et.al., 2024). Sustainable manufacturing principles also emphasize integrating 6R strategies (Reduce, Reuse, Recycle, Recover, Redesign, Remanufacture) into production planning to improve material efficiency (Maqbool et al., 2019). Key approaches include selecting raw materials closer to final dimensions, refining cutting list design, applying nesting optimization, and enhancing machine calibration (Swift & Booker, 2013; Abeysooriya, 2017).

Beyond process improvements, workforce capability plays a critical role. Providing targeted training for machine operators helps ensure machining consistency and minimizes fine dust generation, ultimately reducing occupational exposure risks (Donkoh, 2021). However, barriers such as cost of new optimization software, investment in high-precision equipment, and limited policy enforcement in waste reduction remain significant challenges for implementation in small- and medium-scale enterprises (Udokpoh & Nnaji, 2023).

Finally, waste classification based on physical characteristics—such as fine sawdust, shavings, and solid offcuts—supports tailored reuse strategies (Korba et al., 2025). Fine sawdust can be valorized as biomass fuel (wood pellets or briquettes), while larger offcuts may be integrated into secondary furniture components, simple joinery elements, or prototyping. Such practices align with circular economy models that encourage closing material loops and reducing landfill dependency (Ezekwu et al., 2025). By embedding these strategies, the furniture industry can simultaneously address environmental sustainability, occupational health, and production efficiency.

5. Conclusion

This study concludes that significant wood waste is generated during the machining of solid wood components, with only 43% of the raw material volume effectively utilized. The remaining 57% was lost in the form of sawdust, shavings, and offcuts. The thicknesser machine accounted for the highest portion of total waste (58%), followed by the ripsaw (21%), single planer (20%), and jumpsaw (1%).

The findings emphasize the importance of optimizing raw material usage through better cutting list planning, more accurate nesting strategies, and enhanced machine calibration. Additionally, selecting raw materials that closely match the net component sizes and training machine operators can substantially reduce wood waste and dust emissions. Implementing these improvements can contribute to material efficiency, environmental sustainability, and safer working conditions in the furniture manufacturing industry.

Beyond technical interventions, actionable strategies are needed to embed waste reduction within a broader sustainability framework. First, wood dust and fine residues can be integrated into waste to energy initiatives, such as briquette or pellet production, thereby converting by products into renewable biofuel. Second, policy support and industry incentives for example, government subsidies or green certification schemes can encourage small and medium sized enterprises (SMEs) to adopt sustainable waste management practices. Third, integrating furniture production into a circular supply chain offers opportunities for collaboration, where offcuts and by products from one manufacturer can serve as inputs for another (e.g., panel producers or biomass energy plants). Finally, adopting lean manufacturing and 6R principles (Reduce, Reuse, Recycle, Recover, Redesign, Remanufacture) provides a structured framework to systematically minimize waste while improving operational efficiency. These combined efforts can help shift the furniture industry toward a more sustainable, circular, and competitive model.

Acknowledgement (if applicable)

The authors would like to express their sincere gratitude to the Politeknik Industri Furnitur dan Pengolahan Kayu for providing research funding support through the institutional grant scheme. The support facilitated all stages of this study, including material preparation, data collection, and analysis. The authors also thank the workshop staff and technicians for their valuable assistance during the production and sampling process.

References

Abeysooriya, R. P. (2017). Cutting patterns for efficient production of irregular-shaped pieces (Doctoral dissertation, University of Southampton).

Brownell, H., Iliev, B. E., & Bentsen, N. S. (2023). How much wood do we use and how do we use it? Estimating Danish wood flows, circularity, and cascading using national material flow accounts. Journal of Cleaner Production, 423, 138720.

Donkoh, M. B. (2021). Assessment of occupational health and safety of wood machining operation at a wood processing and marketing centre in Ghana (Doctoral dissertation, University of Education Winneba).

Ezekwu, E. (2025). Sustainable supply chain practices: Driving efficiency, reducing waste, and promoting circular economy models. International Journal of Science and Research Archive, 14(1), 1167-1181.

Ghodsi, R., & Sassani, F. (2005). Online cutting stock optimization with prioritized orders. Assembly Automation, 25(1), 66-72.

Haryanto, A., Hidayat, W., Hasanudin, U., Iryani, D. A., Kim, S., Lee, S., & Yoo, J. (2021). Valorization of Indonesian Wood Wastes through Pyrolysis: A Review. Energies 2021, 14, 1407.

Hosseini, S. M., & Peer, A. (2022). Wood products manufacturing optimization: A survey. IEEE Access, 10, 121653-121683.

Hidayati, Nurul Huda, and Suherman. 2018. “Hubungan Karakteristik Pekerja Dengan Gejala Respiratorik Gangguan Saluran Pernapasan Karena Debu Kayu Pada Pekerja Mebel Sektor Informal Di Kecamatan ‘X’ - Bogor Tahun 2018.” Environmental Occupational Health and Safety Journal 1(1): 39–50.

Korba, A., Lekawska-Andrinopoulou, L., Chatziioannou, K., Tsimiklis, G., & Amditis, A. (2025). Wood waste valorization and classification approaches: a systematic review. Open Research Europe, 5, 5.

Kurniasih, D., Sari, K.E. and Wijayanti, W.P., 2022. Kajian Peluang Alternatif Pengolahan Limbah Serbuk Gergaji di Sentra Industri Mebel Kelurahan Bukir. Planning for Urban Region and Environment Journal (PURE), 11(1), pp.9-18.

Maqbool, Y., Rafique, M. Z., Hussain, A., Ali, H., Javed, S., Amjad, M. S., ... & Atif, M. (2019). An implementation framework to attain 6R-based sustainable lean implementation—a case study. Ieee Access, 7, 117561-117579.

Nasir, V., & Cool, J. (2020). A review on wood machining: characterization, optimization, and monitoring of the sawing process. Wood Material Science & Engineering, 15(1), 1-16.

Nnaji, C. C., & Udokpoh, U. U. (2022, April). Sawdust waste management in Enugu timber market. In Proceedings of the 4 th African International Conference on Industrial Engineering and Operations Management (pp. 5-7).

Oliveira, O., Gamboa, D., & Fernandes, P. (2016). An information system for the furniture industry to optimize the cutting process and the waste generated. Procedia Computer Science, 100, 711-716.

Putri, Farah Yudhisfiari, Ari Suwondo, and Baju Widjasena. 2016. “Hubungan Paparan Debu Kayu Dengan Kejadian Dermatitis Kontak Iritan Pada Pekerja Mebel PT X Jepara.” Jurnal Kesehatan Masyarakat (e-Journal) 4(4): 652–58.

Qin, L. W., Ahmad, M., Ali, I., Mumtaz, R., Zaidi, S. M. H., Alshamrani, S. S., ... & Tahir, M. (2021). Precision measurement for industry 4.0 standards towards solid waste classification through enhanced imaging sensors and deep learning model. Wireless Communications and Mobile

Computing, 2021(1), 9963999.
Radin Umar, R. Z., Tiong, J. Y., Ahmad, N., & Dahalan, J. (2024). Development of framework integrating ergonomics in Lean’s Muda, Muri, and Mura concepts. Production Planning & Control, 35(12), 1466-1474.
Udokpoh, U., & Nnaji, C. (2023). Reuse of sawdust in developing countries in the light of sustainable development goals. Recent Progress in Materials, 5(1), 1-33.
Utami, Fitra Isna, and Sugiharto. 2020. “Identifikasi Bahaya Fisik, Mekanik, Kimia Dan Risiko.” Higea Journal of Public Health Research and Development 4(Special 1): 67–76.
Wati, E., Aspiah, H., Sari, N. and Pramasha, R.R., 2024. Strategi Penggunaan Sumber Daya Alam yang Efisien dan Berkelanjutan. Indonesian Journal of Economy and Education Economy, 2(1), pp.301-312.
Pawanr, S., & Gupta, K. (2024). A review on recent advances in the energy efficiency of machining processes for sustainability. Energies, 17(15), 3659.
Ratnasingam, J. (2022). Furniture manufacturing. Singapore: Springer Singapore.
Sriyanalugsana, S., & Suwantararangsri, K. (2025). Enhancing Planning and Control for Sustainable Custom and Project-Based Furniture Manufacturing. Engineering and Technology Horizons, 42(2), 420201-420201.
Sudiryanto, G. and Suharto, S., 2020. Analisa jenis limbah kayu di Jepara. Jurnal Disprotek, 11(1), pp.47-53
Yayla, A., Mason, A. R., Wang, J., van Ewijk, S., & Myers, R. J. (2025). Global wood harvest is sufficient for climate-friendly transitions to timber cities. Nature Sustainability, 1-13.