

Green Supply Chain Management and 3R on Wood Waste Utilization: A Systematic Literature Review

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ARTICLE INFO

ABSTRACT

Green supply chain management, 3R, Wood waste, Sustainability, Environmental management

This research aims to apply green supply chain management and 3R (reduce, reuse, recycle) to the utilization of wood waste and to determine to what extent wood waste is useful for human life. A total of 30 articles related to green supply chain management, 3R, and Wood Waste Utilization have been identified following the recommended systematic literature review methodology. The methodology in this research uses a systematic literature review approach. The systematic literature review research above shows that green supply chain management is combined with GIS for geospatial decision-making and the transportation of wood waste in the furniture industry to utilize wood waste. Wood waste is mainly produced by the woodworking or furniture industry as solid waste (wood chips, small pieces of wood, sawdust, and wood ash). By implementing green supply chain management and 3R in managing wood waste, it is hoped that wood waste will have added economic value and make more helpful use of waste. The results of wood waste management, such as mini carving crafts, particle board, and wood ash as a concrete mixture and shiny ceramics, biomass, and wood waste, are used to reduce iron oxide. Managing and utilizing wood waste will help increase the income of wood artisans and reduce production costs. Apart from that, managing wood waste as environmental preservation and maintaining forest sustainability. Like other systematic literature review studies, this research has limitations, such as translation procedures, data collection over time, and the need for systematic references. Future research can include additional variables interconnected with green supply chain management and 3R.

1. Introduction

1.1 Background

Nowadays, wood waste represents a significant economic and environmental issue. Currently, the recycling potential of wood waste is still low, mainly caused by a lack of sustainable reusing or recycling applications. Some studies show favourable results and good potential for the use of wood waste in a new product (Berger et al., 2020; Mancini et al., 2024; Tamanna et al., 2020). Therefore, developing new applications for wood waste is possible, but to expand the range of applications for these products, many issues persist, especially concerning health and safety (Tseng et al., 2019).

Wood waste is broadly classified into avoidable and unavoidable waste. Waste considered unavoidable cannot be prevented even if the number of saw strokes is minimal and the factory workers are experienced and efficient. These include sawdust, slabs, and strips that cannot be

changed. In contrast, avoidable waste is caused by a lack of initial inspection of trees and logs, inadequate saw maintenance, and poor harvesting techniques that leave residue in the forest through twigs, tree crowns, cuts, twigs, stumps, and small diameters. Wood waste's avoidable and unavoidable impacts are critical to deforestation (Ogunjobi et al., 2018). Wood waste can be utilized to manufacture various products, such as engineered wood products, energy generation, and additive manufacturing (Abu et al., 2023).

'Green' concept is 'doing actions while integrating environmental or ecological concern.' The supply chain is an essential branch of operations management, and it significantly impacts the environment, including emissions, pollution, the health hazards of the community, etc. Organizations are now trying to minimize environmental impact by integrating environmental concerns into their supply chain operations. Integrating environmental concerns into the supply chain management practices is called 'green supply chain management' (GSCM). GSCM has been established as an essential discipline in the academic world and a separate sustainability branch. The research on GSCM has been proliferating for the last two decades and still needs further insights for future studies (Tseng et al., 2019).

GSCM practices help to build a win-win situation, considering both economic and environmental positive impact. Furthermore. Explained that the GSCM's goal is to incorporate environmentally conscious principles into all phases of supply chain management. (Song & Gao, 2018) point out the differences between green supply chains and supply chains in general. Green supply chain coordination objects include manufacturers, retailers, and consumers in traditional supply chains. (Dai et al., 2017) stated that more and more manufacturers joining the ecological supply chains will contribute to the rapid growth of the green market due to the increase of green consumers caused by the growing environmental awareness. (Basiri & Heydari, 2017; Yang & Xiao, 2017) The top priority of GSCM is innovation to a higher green level. Innovation in green products can improve the environment and also increase the manufacturer's competitive advantage. Green innovation depends on the effective integration of resources and capabilities of supply chain partners and manufacturers.

Renewable energies should have a share of 40–45 per cent of the total power consumption by 2025. There will be steady growth in the installed capacity, whereas dismantling old renewable energy plants will offset the installation of new ones afterwards. With this new energy act, the cascade use of waste wood will likely be employed since the regulation of the installed capacity will reduce the amount of waste wood destined for energy production, and it will be available for other processes (Garcia & Hora, 2017). The Waste Wood Supply Chain (WWSC) includes three processes: Waste wood collection (centralized or decentralized), transportation (road, rail, or water), and sorting and processing (centralized or decentralized).

The 3R's principle of waste minimization strategy, including 3R, is considered as the main element of construction and demolition waste management strategies from the academic perspective, although the waste management hierarchy includes five steps (Huang et al., 2018). Reduction and reuse are the most effective strategies for saving natural resources, environmental protection, and money. Other benefits of reusing building wastes are to mitigate greenhouse gas emissions, which contribute to global climate change, help maintain the environment for future generations, and allow products to be used to their fullest extent (Park & Tucker, 2017). Virgin wood can be used for energy applications and recycled for producing panel boards, biomass, and so on (Mancini et al., 2024). Certain materials can be recycled from building sites, including concrete, metal, asphalt, wood, roofing, plasterboard, and corrugated cardboard. By recycling building materials, a considerable amount of CO₂ is finally saved (Oyenuga, 2016). The 3R strategy can be used to improve the sustainability of industrial solid

waste management systems by the following methods: Reducing waste at the source by using a sorting process, increasing the rate of reuse as a result of waste sorting, increasing the rate of recycling, which results in reduced natural resource.

Wood has many advantages over the concepts of the bio-economy and circular economy. It is a material of natural and renewable origin, biodegradable, with remarkable mechanical and thermal characteristics (Besserer et al., 2021). An increase in waste wood production from end-of-life wood-based products accompanies the increase in wood consumption. Recycling this large deposit could thus constitute a source of abundant and inexpensive raw materials for producing new materials (Besserer et al., 2021). Wood wastes are divided into two main categories: industrial wastes generated within the industry and final wastes after the use of the products (Besserer et al., 2021). A better knowledge of wood waste composition and quality is critical. The impurities and contaminants considerably vary depending on the origin of wood waste. Wood waste should not be considered a homogeneous material but rather be managed as a complex and variable material flow (Faraca et al., 2019). Narasimhan and Carter (1998) in (Balon, 2020) environmental supply chain management supply chain management consists of purchasing involvement of the purchasing function in activities that include reduction, recycling, reuse (3R) and substitution of materials. Wood recycling generally requires reducing size to small particles (chips, fibres, etc.) that can be reused to produce composite materials (Ihnat et al., 2020). Wood waste can be recycled and used to produce new products that are useful for humans through the stages of GSCM by applying the concepts of reuse, reduce, and recycle (3R). Therefore, this research aims to apply green supply chain management and 3R in the use of wood waste and to see how much wood waste is helpful for human life

1.2 Problem Statement

Therefore, this research aims to apply green supply chain management and 3R in the use of wood waste and to see how much wood waste is helpful for human life.

RQ1: How is GSCM applied in the processing of wood waste utilization?

RQ2: How to apply 3R in utilizing wood waste?

1.3 Objectives and Scope

The main objective of this research is to explore the implementation of Green Supply Chain Management (GSCM) and the 3R principles (Reduce, Reuse, Recycle) in the utilization of wood waste. The study seeks to examine how GSCM practices can be integrated into the wood waste supply chain to promote environmental sustainability, resource efficiency, and economic value creation. Specifically, the research aims to identify the potential applications of wood waste in the development of new, eco-friendly products; evaluate the current challenges in wood waste recycling and reuse, particularly regarding health and safety; and analyze the contribution of GSCM and 3R principles in minimizing environmental degradation and supporting the circular economy.

The scope of this research focuses on wood waste generated from both industrial activities and post-consumer wood-based products. It covers key processes in the Waste Wood Supply Chain (WWSC), including collection, transportation, sorting, and processing. The research emphasizes conceptual strategies for sustainable waste management, drawing insights from existing literature and case studies across various industries. It also examines the role of innovation, collaboration, and environmental awareness among supply chain actors in promoting green practices.

However, the study has several limitations. It does not include primary data collection or experimental testing, relying instead on secondary sources from previous academic and industry

research. The analysis is broad and not limited to a specific geographical region or wood-processing industry. Health and safety concerns are addressed in general terms, without a detailed exploration of the chemical properties or potential contaminants in wood waste. Furthermore, while the study discusses the technological and environmental aspects of wood waste management, it does not provide technical specifications for product development. Despite these limitations, this research aims to contribute valuable insights into sustainable wood waste utilization within the framework of green supply chain management and the 3R concept.

2. Literature Review

2.1 Green Supply Chain Management

Academicians and practitioners propose the concept of GSCM as a potential solution for improving environmental performance. The trend in the growth of academic publications shows that it gained popularity after 2000, Although the concept of GSCM can be found in the early 1990s (Fahimnia et al., 2015). The concept of GSCM can be traced back to the 1960s as an environmental management movement. GSCM is an evolution of supply chain management to increase resource efficiency through all supply chain phases, from product acquisition until its final disposal after use, to minimize environmental impacts (Song & Gao, 2018). GSCM practices help to build a win-win situation, considering both economic and environmental positive impact.

(Song & Gao, 2018) point out the differences between green supply chains and supply chains in general. Green supply chain coordination objects include manufacturers, retailers, and consumers in traditional supply chains. (Dai et al., 2017) stated that more and more manufacturers joining the ecological supply chains will contribute to the rapid growth of the green market due to the increase of green consumers caused by the growing environmental awareness.

(Basiri & Heydari, 2017; Yang & Xiao, 2017) the top priority of GSCM is innovation to a higher green level. Innovation in green products can improve the environment and also increase the manufacturer's competitive advantage. Green innovation depends on the effective integration of resources and capabilities of supply chain partners and manufacturers.

Renewable energies should have a share of 40–45 per cent of the total power consumption by 2025. There will be steady growth in the installed capacity, whereas dismantling old renewable energy plants will offset the installation of new ones afterwards (Appun, 2016). With this new energy act, the cascade use of waste wood will likely be employed since the regulation of the installed capacity will reduce the amount of waste wood destined for energy production, and it will be available for other processes (Garcia & Hora, 2017). The Waste Wood Supply Chain (WWSC) includes three processes: Waste wood collection (centralized or decentralized), transportation (road, rail, or water), and sorting and processing (centralized or decentralized).

2.2 3R (Reduce, Reuse, and Recycle)

The 3R's principle of waste minimization strategy, including 3R, is considered as the main element of construction and demolition waste management strategies from the academic perspective, although the waste management hierarchy includes five steps (Huang et al., 2018).

Among the 3 R strategies, reduction is the optimal management measure because it has the least detrimental effects on our environment. Therefore, a reduction strategy is rated the highest priority in management plans (Huang et al., 2018). It is substantial to reduce the amount of created waste. It is imperative to identify ways to reuse the materials. Finally, if

materials cannot be reused, it is crucial to collect them to recycle and dispose of them, which is the last step in managing waste. (Department of the Environment and Energy, 2018) explained some benefits of reducing waste, such as generating income from collecting some materials, reducing costs from purchasing less material, reducing CO₂ emissions, reducing the cost of transportation of wastes to landfills, etc.

Reduction and reuse are the most effective strategies for saving natural resources, protecting the environment, and saving money. Other benefits of reusing building wastes include mitigating greenhouse gas emissions, which contribute to global climate change, helping maintain the environment for future generations, and allowing products to be used to their fullest extent (Park & Tucker, 2017).

Certain materials can be recycled from building sites, including concrete, metal, asphalt, wood, roofing, plasterboard, and corrugated cardboard. By recycling building materials, a considerable amount of CO₂ is finally saved (Oyenuga, 2016). The 3R strategy can be used to improve the sustainability of industrial solid waste management systems by the following methods: Reducing waste at the source by using a sorting process, increasing the rate of reuse as a result of waste sorting, increasing the rate of recycling, which results in reduced natural resource depletion (Usapein & Chavalparit, 2014). Landfill wastes were reduced by employing the 3R options at the plant; furthermore, disposal costs and using raw natural resources were reduced. Sustainable procurement and extended producer responsibility should be introduced to factories to increase the effectiveness of the 3R methodology and reduce waste generation at the source.

2.3 Wood Waste

Wood has many advantages over the concepts of the bio-economy and circular economy. It is a material of natural and renewable origin, biodegradable, with remarkable mechanical and thermal characteristics (Besserer et al., 2021). Since the beginning of the 21st century, in addition to traditional uses, there has been an increase in wood consumption for new applications (energy production, building materials, chemicals, etc.) (Bernstein et al., 2016). An increase in waste wood production from end-of-life wood-based products accompanies the increase in wood consumption. Recycling this large deposit could thus constitute a source of abundant and inexpensive raw materials for producing new materials (Besserer et al., 2021).

Wood wastes are divided into two main categories: industrial wastes generated within the industry and final wastes after the use of the products (Besserer et al., 2021). A better knowledge of wood waste composition and quality is critical. The impurities and contaminants considerably vary depending on the origin of wood waste. Wood waste should not be considered a homogeneous material but rather be managed as a complex and variable material flow (Faraca et al., 2019). Wood recycling generally requires reducing size to small particles (chips, fibres, etc.) that can be reused to produce composite materials (Ihnat et al., 2020).

2.4 Research Gap

Wood waste can be recycled and used to produce new products useful for humans. Despite the growing body of literature on Green Supply Chain Management (GSCM), 3R (Reduce, Reuse, Recycle) strategies, and wood waste utilization, several research gaps remain unaddressed. While many studies emphasize the environmental and economic benefits of GSCM and the 3R approach, there is a lack of integrated research that specifically explores the synergy between GSCM and the 3R principles in managing wood waste across the entire supply chain. Most existing studies tend to focus on either the theoretical framework of green practices or the technical aspects of wood waste processing in isolation. Moreover, limited

attention has been paid to the operational challenges and practical applications of these approaches within the context of the Waste Wood Supply Chain (WWSC), particularly regarding sorting complexity, contamination issues, and product innovation. The variability and heterogeneous nature of wood waste are often underexplored in terms of how they affect recycling efficiency and downstream supply chain performance. Therefore, this study aims to fill the gap by investigating how the integration of GSCM and 3R principles can optimize wood waste management while addressing critical issues of sustainability, resource efficiency, and practical implementation in real-world industrial settings

3. Methodology

This research is a systematic literature review. The primary purpose of a literature review is to identify, classify, and summarize existing research on the object of interest and to identify areas and opportunities for future research. Below is an illustration of the article search flow.

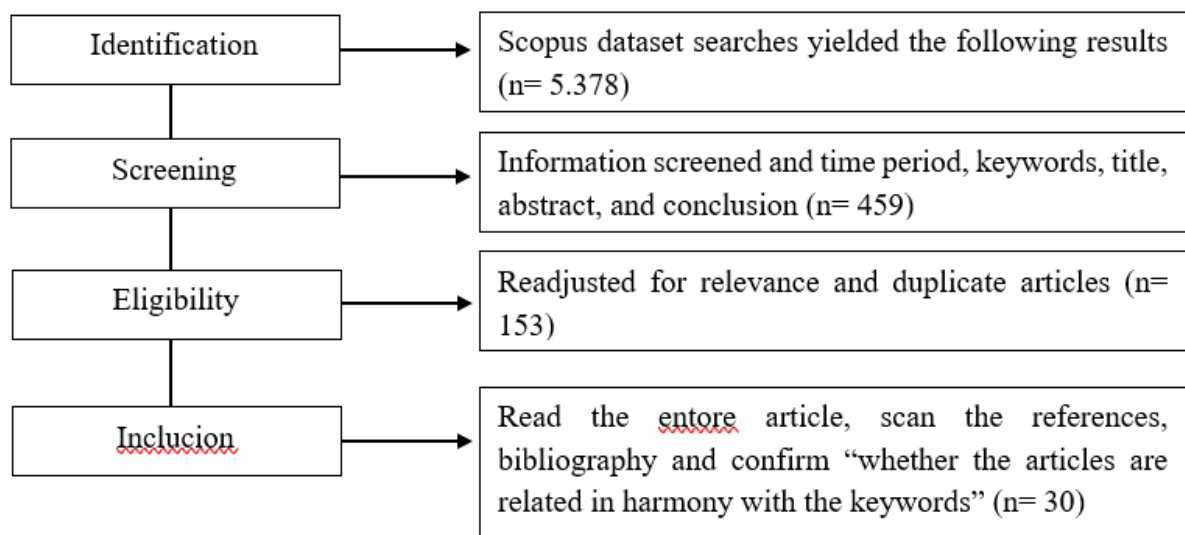


Figure. 1 Source Moher, Liberati, Tetzlaff, and Altman (2009)

The search was based on keywords, titles, and abstracts, with articles containing green supply chain management, 3R practice, and wood waste utilization. The samples in this article matched the keywords of a systematic literature review. In addition, we limited the sample to articles written in English and published from 2020 to 2024. The initial finding of articles according to keywords in Scopus was 5.378; readjusted to abstracts and conclusions was 459; readjusted to relevance, quality, and duplicate articles was 153, and the last stage of article selection was reading the entire article, scanning references, bibliographies, and making sure again "whether the articles are related in line with the keywords" so that 30 top articles were found.

3.1 Article Filtering Process

The first step in the article screening process involved 153 articles. These articles were screened for relevance, quality, and duplicate articles. This screening process reduced the sample to 30 articles. This step was done to ensure the completeness and accuracy of the data in the articles. Here is the list of the top 30 articles:

Table 1. Top 30 Cited and Influential Papers in This Research

Authors	Title of Articles	Publisher	Publication Year	Cited By
Tamanna et al	Utilization of wood waste ash in construction technology: A review	ELSEVIER	2020	104
Berger et al	The recycling potential of wood waste into wood-wool/cement composite	ELSEVIER	2020	93
Tej Singh et al	Physical, Mechanical, and Thermal Properties of Dalbergia Sissoo Wood Waste-Filled Poly (Lactid Acid) Composites	Wiley Online Library	2021	20
Han Ku Nam et al	Laser-induced Graphene Formation on Recycled Woods for Green Smart Furniture	Wiley Online Library	2024	-
Foti et al	Physical and Mechanical Properties of Eco-Friendly Composites Made from Wood Dust and Recycled Polystyrene	Tech Science Press	2021	7
de Meira et al	Insights into the reuse of urban forestry wood waste for charcoal production	Springer Verlag	2021	29
de Souza Pinho et al	Wood waste management from the furniture industry: the environmental performances of recycling, energy recovery, and landfill treatments	Multidisciplinary Digital Publishing Institute (MDPI)	2023	5
Van limbergen et al	Characterisation of Two Wood-Waste and Coffee Bean Husk Biochars for the Removal of Micropollutants from Water	Frontiers in Environmental Science	2022	9
Calovi Massimo and Stefano Rossi	From wood waste to wood protection: New application of black bio renewable water-based dispersions as pigment for bio-based wood paint	ELSEVIER	2023	23
Elginoz Nilay et al	Wood Waste Recycling in Sweden Industrial,	Multidisciplinary Digital Publishing	2024	2

	Environmental, Social, and Economic Challenges and Benefits	Institute (MDPI)		
Hua Seng Lee et al	Particleboard from agricultural biomass and recycled wood waste: a review	ELSEVIER	2022	150
Ali Mohammad et al	Dynamic Analysis of Lean and Green Supply Chain Policies in Sustainability of CHOUKA Iran Wood & Paper Industries Inc.	Advances in Industrial Engineering	2021	1
Paul Sumit et al	Critical Success Factors for Supply Chain Sustainability in the Wood Industry: An Integrated PCA-ISM Model	Multidisciplinary Digital Publishing Institute (MDPI)	2022	44
Nguyen Lin et al	Production of wood-based panel from recycled wood resource:a literature review	Springer Verlag	2023	37
Cesprini Emanuele et al	Quality assessment of pellets and briquettes made from glued wood waste	Springer Verlag	2021	19
Ince C et al	Recycling waste wood in cement mortars towards the regeneration of sustainable environment	ELSEVIER	2021	59
Besserer et al	Cascading recycling of wood waste: a review	Multidisciplinary Digital Publishing Institute (MDPI)	2021	107
Elif et al	A study on wood waste potential in Turkey	ELSEVIER	2024	1
Bajno et al	Old and Modern Wooden Buildings in the Context of Sustainable Development	Multidisciplinary Digital Publishing Institute (MDPI)	2021	19
Maier Dorin	Building materials made of wood waste solution to achieve the sustainable development goals	Multidisciplinary Digital Publishing Institute (MDPI)	2021	31
Zerabruk et al	Recycling timber waste into geopolymers cement bonded wood composites	ELSEVIER	2023	7
Vergara Luis A et al	3D printing of ordinary Portland cement with waste wood derived	ELSEVIER	2023	20

	biochar obtained from gasification			
Hilary Naher et al	Recycling of waste poly (vinyl chloride) fill materials to produce new polymer composites with propylene glycol plasticizer and waste sawdust of Albizia lebbeck wood	ELSAVIER	2021	11
Ren et al	Treatment of Dyes Contaminated Water Using Biochar Derived from Eucalyptus Wood Waste	<u>Engineered Science Publisher</u>	2024	8
Ahmadi et al	Commercial waste wood in the removal of methylene blue from aqueous media	ELSEVIER	2020	1
Teaca et al	The Re-/Up-Cycling of Wood Waste in Wood–Polymer Composites (WPCs) for Common Applications	Multidisciplinary Digital Publishing Institute (MDPI)	2023	5
Nukala et al	Development of Wood Polymer Composites from Recycled Wood and Plastic Waste: Thermal and Mechanical Properties	Multidisciplinary Digital Publishing Institute (MDPI)	2022	1
Mia Rony et al	Eco-friendly coloration from mahogany wood waste for sustainable dyeing of organic nonwoven cotton fabric	ELSEVIER	2023	5
Pandey et al	Wood waste utilization and associated product development from under-utilized low-quality wood and its prospects in Nepal	<u>Springer Nature</u>	2022	45

The below is a collection of the leading journals in the current review:

Table 2. Top 30 Leading Journals in the Current Review

Name of the Journal	Publisher	Quartile Rank
Journal of Renewable Materials	Tech Science Press	Q2
Polymer Composites	Wiley Online Library	Q1
Sustainability	Multidisciplinary Digital Publishing Institute (MDPI)	Q2
EcoMat	Wiley Online Library	Q1
Clean Technologies and Environmental Policy	Springer Verlag	Q1
Original Research	Frontiers in Environmental Science	Q2
Progress in Organic Coatings	ELSEVIER	Q1
Journal of Materials Research and Technology	ELSEVIER	Q1
Construction and Building Materials	ELSEVIER	Q1
European Journal of Wood and Wood Products	Springer Verlag	Q2
Polymers	Multidisciplinary Digital Publishing Institute (MDPI)	Q1
Materials	Multidisciplinary Digital Publishing Institute (MDPI)	Q2
Case Studies in Construction Materials	ELSEVIER	Q1
Cleaner Waste Systems	ELSEVIER	Q2
Current Research in Green and Sustainable Chemistry	ELSEVIER	Q1
ES Materials and Manufacturing	Engineered Science Publisher	Q2
Desalination and Water Treatment	ELSEVIER	Q3
Journal of Composites Science	Multidisciplinary Digital Publishing Institute (MDPI)	Q2
Results in Engineering	ELSEVIER	Q1
SN Applied Sciences	<u>Springer Nature</u>	Q2

3.2 Data Extraction

The dataset linked to Scopus was used to collect all-encompassing data such as Multidisciplinary Digital Publishing Institute (MDPI), Springer, ELSEVIER, Wiley Online Library, Frontiers in Environmental Science, and Tech Science Press. Scientific publications from 2020 to 2024 were included in the search. The search started with keywords such as "green supply chain management, 3R practice, and wood waste utilization". These keywords were chosen to strengthen the connection with all the articles and to find the desired article easily. Because this paper discusses green supply chain management, 3R practice, and wood waste utilization, these keywords are appropriate for the target of the main article to be included in this research. The initial Google Scholar search engine results are below.

Table 3. Initial Search Results with Keywords and The Number of Papers That Appeared

Keyword	Findings (Article numbers)	Limitation up to
“Green supply chain management” 3R practice”“wood waste utilization”	5.378	Title, abstract, keywords
“Green supply chain management” 3R practice”“wood waste utilization” and “Review”	459	Title, abstract, keywords

3.3 Preliminary Data Retrieval

Initial data retrieval in web searches includes conference proceedings, textbooks, articles, and chapters from books other than articles. However, the study considered only journal articles after the first search. Books, conference papers, and magazines were eliminated to limit exploration to keywords and article titles. The result was 459 articles for this systematic literature review study.

3.4 The Inclusion of the Data

In this analysis, we used 30 articles from the Scopus dataset. The articles collected also come from reputable sources such as Multidisciplinary Digital Publishing Institute (MDPI), Springer, ELSEVIER, Willey Online Library, Frontiers in Environmental Science, and Tech Science Press. Only quartile 1 to 2 journals are used. The data collected and included should come from reputable sources to share insights and for future research.

4. Results and Discussion

4.1 Results of Metadata Analysis

The descriptive analysis in the systematic literature review was built on metadata covering 30 articles, including document type, publication, year, contribution by discipline, and country. In some scenarios, this research presents a summarized format for easier reading. An initial search was conducted using the Google Scholar database with abstract titles and keywords. When only searching for green supply chain management, 3R practice, and wood waste, 5.378 were returned. Then, the search was readjusted by discarding the same articles and searching for high-quality articles, resulting in 459, which were summarized again into 30 top articles.

4.2 Publication by Most Influential Authors and Citation

In this study, we collected ideas and data about famous authors who have worked in green supply chain management, 3R practice, and wood waste. Ten famous authors and the most citations referenced in the Google Scholar data system are listed in Table 4 and Figure 1 below. Huang Seng Lee et al (2012), who received 150 citations, Besserer et al (2021) received 107 citations, and Tammana et al (2020) received 104. As a result, it is reasonable to claim that all authors included in Table 4 and Figure 1 are the most well-known in supply chain management, 3R practice, and wood waste.

Table 4. Most Influential Authors and Citation

Authors	Title of the Articles	Journal Title	Publication Year
Hua Seng Lee et al	Particleboard from agricultural biomass and recycled wood waste: a review	Journal of Materials Research and Technology	2022
Besserer et al	Cascading recycling of wood waste: a review	Polymers	2021
Tammana et al	Utilization of wood waste ash in construction technology: A review	Construction and Building Materials	2020
F. Berger, F. Gauvin, H.J.H. Brouwers	The recycling potential of wood waste into wood-wool/cement composite	Construction and Building Materials	2020
Ince C et al	Recycling waste wood in cement mortars towards the regeneration of sustainable environment	Construction and Building Materials	2021

4.3 Keyword Analysis with Vosviewer

This research includes 30 articles based on document type, year of publication, keywords, and relevance to research. The initial search turned 5.378 articles through the Scopus database, refined to 459, and finally to 153 articles.

Table 5. Keyword Based on Their Occurrence

No	Keyword	Occurrence
1.	Wood Waste	27
2.	Adsorption	17
3.	Biochar	16
4.	Circular Economy	9
5.	Recycling	8

Based on the table above, it can be interpreted that wood waste is most frequently used with 27 occurrences. The wood waste has become a significant issue for many researchers. The three prominent keywords related to wood waste are adsorption, biochar, circular economy and recycling. Therefore, this emerged as a research theme on green supply chain management and 3R practices in wood waste utilization.

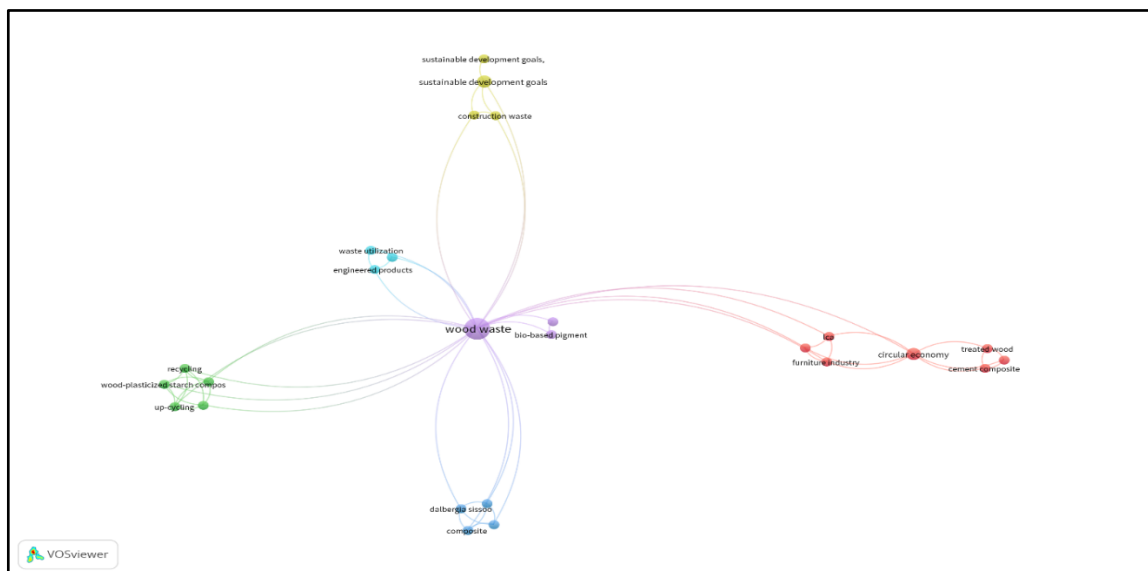


Figure. 2 Vosviewer Circles Version

Vosviewer is a software tool for building and visualizing bibliometric networks to map authors' keywords. Word combinations such as wood waste have colour (pruple), meaning show a stronger association with a higher frequency of occurrence from 2020 to 2024. Meanwhile, adsorption, biochar, circular economy and recycling are some of the keywords with the highest occurrence. Table 5 shows the top 5 keywords used in this study.

5. Discussion

Interpret and analyze the implications of your findings in a broader context. Compare with previous studies and consider any limitations.

5.1 Comparison with Prior Research

Green supply chain management has its roots in environmental management and supply chain management literature by adding "green" to supply chain management (Srivastava, 2007). Recycling wood from the furniture industry can be considered part of implementing green supply chain management (Susanty et al., 2016). Below are the results of previous research on GSCM practices in utilizing wood waste:

Table 6. The Results of Previous Research on GSCM Practices in Utilizing Wood Waste

Author	Result
Susanty et al	Geographic information systems are being applied in green supply chain management as a decision-support system in geospatial data analysis and transportation of wood waste in the furniture industry. The system will determine the ranking of small and medium businesses that are recommended as producers of wood waste and transport wood waste from each small and medium business.
Wan Hasrulnizzam Wan Mahmood et al	The research results show that improved manufacturing performance leads to an integrated green supply chain, which ultimately leads to increased environmental compliance, optimization of operational resources, and product recycling activities.
Jagdeep Singh and Mamta Kumari	This research proposes a biomass briquette factory, which processes biomass into cylindrical briquettes, which can be a substitute for coal. These briquettes are useful in various industries, brick factories, and hotels/restaurants.

The implementation of reduce, reuse, and recycle (3R) is being promoted to build a healthy material cycle of society by effectively using resources for 3R activities, thereby ensuring environmental conservation and economic growth (Sakai et al., 2017). Prioritizing the 3Rs may not promise drastic changes in the short term, but it will provide significant benefits in the long term (Visvanathan & Norbu, 2006). Reducing is reducing or reducing the waste that will be formed and using goods efficiently, thereby reducing the amount of waste thrown away. The reduction activity is carried out with reducing the use of resources in the pre-manufacturing stage, by implementing a selective cutting system. Only cut down the right trees, the right amount, and reforest. Make saving using energy, materials and other resources during manufacturing, for example using glue and paint as needed, turning off the engine when not in use, turning off the water tap when not in use, reducing the use of fuel for kilns, reducing errors in cutting wood and others. Reducing emissions and waste by consumers by recovering products and not burning post-use products (Hartini et al, 2021).

Reuse is the act of reusing waste that can still be utilized without needing special treatment. Reuse is done by reusing waste to reduce the use of raw materials, for example using sawdust that is not utilized into board particles that can be processed into other products. Recycle converts waste into raw material for other products. Some furniture company waste recycling processes include utilizing the remnants of wood pieces into other products such as children's toys, assembly tables, and others. Utilizing sawdust for briquettes, bricks, organic fertilizer, growing media, paving blocks. At the same time, recycling is the reuse of waste that can still be used but must be processed permanently to become a different item. Recycling also involves reprocessing a product that has been used for recovery to the original state or form as new through reusing as many parts as possible without losing functionality. For example, companies do repair furniture products that are damaged by consumers rather than thrown away. are the results of research conducted by many researchers regarding the use of wood waste:

Table 7. The Results of Research Conducted by Many Researchers Regarding the Use of Wood Waste

Author	Result
Vergara Luis A et al	The results of the research conducted by Vergara et al show that gasification of woody biomass combined with ordinary portland cement and additive manufacturing (3D printing), specifically using the direct ink writing technique is important because it can help in the recycling of wood waste and other strategies such as the circular economy. Its use can be further enhanced through additives, processing and optimization, as it is an environmentally friendly and economically viable alternative.
Nukala et al	The objective of this study was to develop wood polymer composites (WPC) using recycled plastic waste (RPW) generated from university laboratories and recycled wood waste (RWW) from construction and demolition (C&D) activities by melt blending technique. The results showed that the composites with higher RWW (20%) had higher water uptake. These results suggest that the resulting WPC can be a promising eco-friendly material, while maintaining good mechanical, thermal, and wettability properties.
Berger et al	Wood waste is recycled to become cement composite materials, such as wood wool cement board (WWCB), which has emerged as a promising solution.
Tamanna et al	The results show that the use of WWA (wood waste ash) in cement and concrete is beneficial to sustainable development and zero-waste technology. Environmental issues in the use of WWA (wood waste ash) and ways to reduce harmful impacts on the environment are also presented.
Hua Seng Lee et al	This research highlights the potential of using agricultural biomass and recycled wood waste in particleboard production as a sustainable alternative to conventional wood-based materials. Particle boards made from these alternative materials often have equivalent or even better mechanical properties compared to wood-based boards. The use of these alternative raw materials can contribute to sustainable development with three main aspects: economic growth, social inclusion and environmental protection. In addition, pressure on forest resources can be significantly reduced, and new employment opportunities can be created.
Ren et al	This study evaluates the effectiveness of biochar derived from eucalyptus wood waste (EWB) in adsorbing dissolved dyes such as methylene blue (MB) and crystal violet (CV) from wastewater. The results showed that EWB carbonized at 450°C and activated with ZnCl ₂ had a maximum adsorption capacity of 14.42 mg/g for MB and 12.95 mg/g for CV.

5.2 Limitations and Future Research

Although this research, like other systematic literature review studies, strives to achieve

rigour and perfection in theoretical deduction, research design, and analysis, there are still limitations, such as translation procedures, data collection over time, and the need for systematic references—literature review research in environmental management and thoroughness in searching for collections of articles. Therefore, future research in systematic literature reviews should investigate systematic literature reviews related to green supply chain management, 3R, and wood waste further. Future research can include additional variables interconnected with green supply chain management.

6. Conclusion

This systematic literature review examines several articles on green supply chain management, ER, and Wood Waste. The utilization of wood waste is a severe problem of preserving the environment. Wood waste is mainly produced by the woodworking or furniture industry as solid waste (wood chips, small pieces of wood, sawdust, and wood ash). By implementing green supply chain management and 3R in managing wood waste, it is hoped that wood waste will have added economic value and make more helpful use of waste. The results of wood waste management, such as mini carving crafts, particle board, and wood ash as a concrete mixture and shiny ceramics, biomass, and wood waste, are used to reduce iron oxide.

7. Recommendation

This study addresses the growing problem of wood waste by exploring its potential utilization through the integration of Green Supply Chain Management (GSCM) and the 3R principles (Reduce, Reuse, Recycle). Using a systematic literature review methodology, the researchers analyzed 30 selected articles published between 2020 and 2024, drawn from reputable journals indexed in Scopus. The findings highlight that wood waste, predominantly generated by the furniture and woodworking industries, can be transformed into valuable products such as particle boards, briquettes, concrete mixtures, and biochar. The application of GSCM in conjunction with the 3R approach not only contributes to environmental sustainability but also adds economic value, supports resource efficiency, and promotes innovation in waste processing. Despite limitations such as the exclusion of primary data and technical details, this research contributes significantly by offering an integrated perspective on sustainable wood waste management and identifying research gaps for future exploration. It underscores the strategic role of GSCM and 3R as key enablers in transitioning toward a circular economy within the wood industry.

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