

Sustainable Materials Management: Strategies for Reducing Waste and Enhancing Resource Efficiency in Construction

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Abstract

The construction industry is a critical driver of economic development, but it also plays a significant role in environmental degradation due to its high demand for natural resources and its substantial contribution to global waste production. In response to these environmental challenges, sustainable materials management (SMM) has emerged as a comprehensive framework aimed at promoting resource efficiency, reducing waste, and lowering the overall environmental impact of construction activities. This study delves into the core principles of SMM and their application within the construction sector, focusing on strategies to enhance sustainability across various phases of a building's life cycle, from design and material selection to construction, use, and eventual demolition. One of the key strategies explored is the adoption of circular economy principles, which encourage the reuse, recycling, and repurposing of materials to extend their lifecycle and reduce the need for virgin raw materials. This approach reduces waste, conserves resources, and decreases the overall carbon footprint of construction projects. The study also emphasizes the importance of selecting sustainable materials, such as those that are renewable, recycled, or have low environmental impacts, as a means of reducing the consumption of finite resources. Incorporating these materials not only helps in lowering the environmental costs associated with extraction and processing but also contributes to the development of more resilient and eco-friendly structures.

Keywords: Construction industry, eco-friendly structures, economic development, natural resources, sustainable materials

INTRODUCTION

The thorough integration of advanced technologies, particularly building information modeling (BIM), is identified as a pivotal tool for achieving sustainable material management in construction. BIM enables detailed planning, tracking, and optimization of materials throughout the project lifecycle, facilitating better decision-making and reducing material waste. Additionally, life cycle assessments

(LCA) are presented as critical tools for evaluating the long-term environmental and economic impacts of material choices, helping stakeholders make informed decisions that promote sustainability over the entire life of a building. This study concludes by emphasizing the necessity of a collaborative approach involving architects, engineers, policymakers, and other stakeholders to advance sustainable material management in construction. By adopting these strategies, the construction industry can make significant strides toward reducing its environmental footprint, conserving resources, and fostering the development of a more

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sustainable, resilient, and resource-efficient built environment. The adoption of SMM is not only essential for mitigating the environmental impacts of construction but also for promoting long-term economic viability and social well-being, ensuring that future generations can continue to thrive in a resource-constrained world [1].

According to Miyazaki (2023), 39% of global carbon emissions, with 28% from operational emissions and 11% from construction materials, were observed in the Philippines—a significant drop of 10% was recorded during the year 2020 of the COVID-19 pandemic. It was also stated that developers now use green building certification to meet standards for construction projects. This includes LEED (Leadership in Energy and Environmental Design), WELL building standard, EDGE (Excellence in Design for Greater Efficiencies), and BERDE (Building for Responsive Design Excellence) [2].

Also, as stated by Yu et al. (2021), a large quantity of solid waste is also produced during construction activities and demolition. It causes an adverse impact on biodiversity. Around 7.52 million people live in about 1107 square kilometers with a high population density of 6793 people per square kilometer in Hong Kong, the United States (US), and China. All of those are facing challenging problems caused by construction waste and landfill sites. Thus, preservation of the environment and conservation of diminishing natural resources will be essential for sustainable management; reviewing practices of waste management, as well as the current strategies for waste reduction, can create highly efficient construction projects [3].

Moreover, as claimed by Kabirifar et al. (2020), the principal waste stream of gross waste creation in contemporary civilization is construction and demolition waste (CDW). Along with the present global urbanization, CDW is increasing. The top three CDW generators are the three largest economies: China, the US, and the EU. While the US and the EU28 have relatively high rates of urban population, at 82.67% and 74.96% in 2020, respectively, China's urban population rose from 35.88% in 2000 to 61.43% in 2020 [4]. As a result of its rapid urbanization, China was predicted to have generated approximately 1704 Mt. of CDW in 2018 [5].

Background of Study

According to Kedir (2021), specifically, resource efficiency has been studied in construction resources; it points out the accommodation and changing of layout demands, which indicates that increased demand has led to the global crisis, including too little supply and too high demand [6]. It also mentioned that balanced sustainability requirements for growing demand, non-renewable materials, and creation of high-quality products with minimal waste have been a potential source for construction methods and numerous opportunities for industry; global sustainability that balances the economic development, environmental services can be improved by building life cycle phases beyond the system approach of resource efficiency and construction in reducing waste [3].

In terms of sustainable materials management (SMM) of construction, it involves construction, renovation, roads, bridges, and the demolition of buildings. It is also stated that the sustainable materials management (SMM) approach can identify construction materials as commodities that can be used in new building projects, resulting in the processing of virgin materials and avoiding the need to mine. Regarding the benefits of the SMM approach, it can reduce overall building project expenses, conserve landfill space, require fewer disposal facilities, and offset the environmental impact associated with the consumption of virgin resources and the production of new materials [7].

In addition by Keenan (2023), there are five tips to reduce waste in construction; these are the following: (1) planning ahead: building a plan before diving into the job can help the project to organized in a properly manner (e.g., measuring materials exactly, conduction of regular inventory, preparation for construction site waste, and to know what materials can be reused and recycle); (2) operation for deconstruction before demolition: a soft tear down before demolition is an opportunity to

salvage materials for reuse [8]. It is also better for the environment; (3) reuse or donate materials in good condition: before tossing all debris in a construction dumpster, identify materials that can be reused or donated; (4) recycle what cannot be reused: having a recycle bin for discarded materials will help reduce the number of items to be tossed in the dumpster; (5) rent a dumpster for the rest: for all things that cannot be reused, donated or recycled, a dumpster is the most efficient disposal.

In regard to the Philippine construction industry, a House Bill no. 7044 – (An Act of Promoting the Recycling of Construction and Demolition Wastes as Components in Building Materials), was proposed since the industry expanded around 9.4%, which computed that construction waste amounts to 30% of solid waste produced by the country; 10% of the weight of materials purchased for construction projects end up as waste. The said bill also mentioned that the bill aims to reduce waste from construction and demolition by granting the following economic incentives: Firstly, exempting from import taxes equipment used for recycling construction and demolition waste. Secondly, allowing tax credits on the purchase of said equipment in the Philippines. Thirdly, exempting from taxes all donations to people and entities recycling construction and demolition waste. Fourthly, directing government-owned banks to help finance businesses recycling said waste, and lastly, giving financial grants to local government with DENR—approved programs for recycling said waste [9]. Furthermore, in line with this bill, the purpose of this is to protect every Filipino, to a balanced and healthy ecology [10–12].

Statement of the Problem

This study aims to determine sustainable material management and strategies for reducing waste to enhance resource efficiency in the construction industry.

Specifically, this study will seek answers to the following questions:

1. What are the sustainable material management and strategies for reducing waste in terms of enhancing resource efficiency in the construction industry?
2. What is the relationship between SMM and waste reduction for enhancing resource efficiency in the construction industry?
3. How does enhancing resource efficiency in construction affect SMM and strategies for reducing waste?
4. Is there a significant relationship between SMM and strategies for reducing waste to enhance resource efficiency in the construction industry?

Objectives

The primary objective of this current study is to investigate and propose SMM strategies aimed at reducing construction waste and enhancing resource efficiency, with a focus on mid-rise commercial buildings within the Philippine construction sector [13, 14].

Specifically, the study aims to:

1. Identify Construction Waste Reduction Practices
 - To assess current construction practices contributing to waste generation.
 - To recommend improved practices, such as accurate material estimation, proper sizing, minimization of rework, and effective vendor coordination.
 - To evaluate on-site waste segregation, handling, and disposal methods to reduce environmental impact and promote occupational safety.
2. Enhance Resource Efficiency in Mid-Rise Commercial Building Projects
 - To examine strategies for the optimal use of construction resources, including energy, raw materials, and labor.
 - To analyze how innovative technologies (e.g., BIM) and management systems improve efficiency during various construction stages.
 - To conduct a systematic review of the relevant literature on resource efficiency and apply best practices to local case scenarios.

3. Promote SMM
 - To assess the life cycle of materials used in mid-rise commercial buildings from extraction and manufacturing to disposal, and identify ways to reduce their environmental footprint.
 - To encourage the selection and use of renewable, recycled, or low-impact materials that contribute to long-term sustainability.
 - To promote stakeholder engagement in material sourcing, handling, and disposal through ethically based sustainability efforts [10].
4. Apply Statistical Analysis to Evaluate Sustainability Practices
 - Descriptive statistics (mean, standard deviation) were used to measure the extent of implementation of sustainable practices among construction firms.
 - To apply independent samples *t*-tests to determine whether there are significant differences in SMM practices between companies implementing green initiatives and those that do not.
 - To utilize correlation analysis to examine the relationship between waste reduction strategies and perceived improvements in resource efficiency.

Significance of the Study

This study is significant in addressing the increasing need for sustainable construction practices, particularly for mid-rise commercial building projects in the Philippines. The results of this study are expected to provide insights and actionable recommendations that will benefit the following stakeholders:

- *Government agencies (e.g., DPWH)*: The findings may support the development and enhancement of national policies and regulations related to construction waste reduction, resource efficiency, and SMM. This aligns with environmental goals and compliance with green building codes such as BERDE, LEED, and EDGE.
- *Construction professionals and workers*: This study will help engineers, project managers, and site workers adopt more efficient construction methods, minimize rework, and handle materials responsibly, resulting in increased productivity and improved on-site safety.
- *Construction firms and developers*: This study may help companies reduce operational costs, improve environmental performance, and enhance project sustainability by providing practical and measurable strategies to reduce material waste and energy usage.
- *Future researchers*: This study will contribute to the growing body of knowledge on sustainable construction in the local context and serve as a foundation for further academic inquiry, comparative studies, or experimental research on green practices in the built environment.

Scope and Limitation

This study will strictly focus on SMM and the reduction of waste for resource efficiency in construction. In terms of distribution of questionnaires, the researcher will use a researcher-made or adapted questionnaire, which can be facilitated using an online platform. In addition, when it comes to the scope and limitation of this research, the researcher will revise if there are changes in terms of the respondents, questionnaire, and variables.

Definition of Terms

The following key terms are defined conceptually and operationally to understand the study.

Sustainable Materials Management

SMM is a methodical strategy for making better use of materials across their full life cycles. The way our culture views the utilization of natural resources and environmental preservation has changed as a result. Sustainable materials may be derived from low-impact or renewable resources, have a longer lifespan, require less energy to produce or use, or be simpler to decompose at the end of their useful lives. Some can even be constructed by humans and intended to assist in protecting natural resources.

Strategies for Reducing Waste

The utilization of less material and energy to reduce trash creation and protect natural resources is known as waste reduction or source reduction. Recycling is just one aspect of trash reduction, and it also includes measures to prevent items from becoming rubbish before they are recycled. Reusing goods, such as plastic and glass containers, buying more durable goods, and using reusable goods like dishrags instead of paper towels are all part of waste reduction. Donating goods, such as clothing, furniture, and office supplies, lowers the overall amount of material produced. Buying goods that use biodegradable elements in place of toxic ones minimizes waste and pollution [12–14].

Resource Efficiency in Construction

Reduced use of raw materials and non-renewable resources, production of high-quality goods with little waste, and preservation of product value over the long term are all examples of resource efficiency. The growing use of industrialized house building, which uses new construction items and procedures, is one possible source of resource efficiency. Recent research has identified several opportunities for resource efficiency in industrialized house building.

REVIEW OF RELATED LITERATURE

In this section, the author has gathered existing related literature and studies, both foreign and local, which were reviewed to substantiate the present study. The primary method used to gather related literature is electronic databases. These include articles, journals, and Google Scholar. Manual searches of relevant literature in articles and journals were also conducted. Articles and journals in the English language were considered and published from January 2019 to March 2023. As part of the search and screening process, the author independently reviewed and paraphrased all English language citations from the search to identify relevant titles and abstracts. The search technique aims to discover all studies with concepts related to the study's goal, which is to determine SMM and strategies for reducing waste to enhance resource efficiency in construction.

Review of Related Literature

Sustainable Materials in Construction

According to Construction Placement (2023), the construction industry is gradually shifting to eco-friendly building materials and construction techniques that are sustainable, given the high levels of pollution and waste in the environment. Additionally, there are three examples of sustainable technologies that can provide optimal temperature control, insulation for green roofs, management for stormwater, and renewable resources, such as cross-laminated timber and bamboo, for structural components.

In addition, sourcing and manufacturing building materials contribute to climate change, as stated by the report of the United Nations Environment Program. The total raw materials in the global economy add significant amounts of energy and greenhouse gas emissions to the life cycle of buildings. Therefore, the construction industry promotes sustainable materials that serve the people today and future generations. Also, these are the notable examples of sustainable construction materials which can be used in the construction industry, including bendable concrete, mass timber, salvage materials, bamboo mycelium, precast concrete, and 3D Printed Concrete.

In addition, as stated by Adier et al. (2023), bamboo is a sustainable material that can be used in the past and future because of its impressive strength-to-weight ratio, which can bear substantial loads and stresses. It also benefits from a reduction in carbon dioxide generation compared to conventional materials. Although it has beneficial factors, the mechanical properties of bamboo vary by species, age, location, method, and treatment [1].

However, as stated by ArchDesk (2021), there is no perfect solution, and there are no sustainable materials that can help in the construction industry. Nevertheless, the idea of green buildings cannot

help because the best solution for this is to act right away and to change with current resources that are affecting the environment negatively. In addition, sustainable materials should be materials that try to minimize the impact on the environment by reducing adverse effects.

Strategies for Reducing Waste in Constructions

The construction industry generates a large amount of waste. In the United States, an estimated 251 million tons of solid waste is generated. Thus, less than a third of the solid waste is recycled and composted. One of the strategies that can benefit in reducing waste in construction is to plan, choose vendors wisely, deconstruction instead of demolition, recycle what is not reusable, donate materials that are in good condition, reduce packaging, know local recycling, reuse scrap instead of cutting new materials, obtain a contract with C&D recycling and waste, and lastly, to organize construction site.

In addition to TTFS (2023), creating a waste management strategy is one that management can use to significantly reduce waste and costs in construction projects. The implementation of new procedures, such as waste segregation and storage, can sort, recycle waste, and select rubbish, as it is a great option to easily dismantle and flat pack for storage and future use [4]. Likewise, reuse, planning orders, and managing package waste can minimize excess waste as well as significant cost savings.

Managing construction waste is important because it may help establish a sustainable construction industry. Also, working with the construction industry, you need to have expertise when it comes to this, since if the company has the capacity to control waste, the reduction of cost can significantly reduce the impact of construction and demolition projects. There are also tips for becoming an effective individual when it comes to construction waste management: (1) set up a designated on-site area for waste sorting and separation; (2) identify and label different waste streams, such as wood, concrete, metal, and plastic; and (3) develop partnerships with local recycling and reuse organizations to ensure that materials are being recycled efficiently [13].

In addition, the construction industry generates a massive volume of construction waste. The Philippines is a country that can adapt to create more sustainable construction by presenting a multitude of potential strategies and solutions. The Philippines also integrates and propagates the life cycle, which directs and processes concepts, coordination, logistics, and decision-making for systemic-level management of waste. It also includes six major groups that can be used to attain sustainable construction in waste: information technology, policy, design, operations, knowledge, and procurement based [14].

Furthermore, in terms of strategies for reducing waste, the waste management plan covers various aspects, such as specifying responsibility for on-site waste management, establishing goals and objectives, estimating waste types and amounts, setting targets for reducing waste sent to landfills, describing recycling/reuse methods for each material, identifying waste destinations and transport modes, including segregation of materials for reuse or recycling on site, tracking progress, describing special measures for material use and handling, describing communication and training to support and encourage participation from everyone on site, and methods for deconstruction projects and project reviews.

Resource Efficiency in Construction

According to Grantham Research Institute (2015), the Philippine Green Building Code seeks to improve efficiency by using measures that promote the management of resources when it comes to site sustainability and efficiency. Additionally, this code was created because of the negative impact of buildings on human health and the environment. This code proposes a set of standards, including efficient use of resources, site selection, planning and design, operation, maintenance, construction, and occupancy.

Additionally, it shares the following principles: (1) to help the government address climate change; (2) to meet the environmental needs of the present and future generations; and (3) to improve environmental quality by promoting higher productivity and comfort.

Accordingly, as claimed by Kedir and Hall (2021), improved resource efficiency in the construction industry is needed to balance sustainability requirements. In terms of resource efficiency in construction, the building life cycle should be industrialized to enable innovative manufacturing. Additionally, the creation of high-quality products with minimal waste should be increased in terms of methods and opportunities for improving construction efficiency [4].

When it comes to Resource Efficiency in the Philippines, the World Bank Group IFC (International Finance Corporation) awarded its First EDGE (Excellence in Design for Greater Efficiencies) resource efficiency to Imperial Homes, a local developer of both low-cost and high-end buildings. Imperial Homes has set a good example in the Philippines market by proposing green building regulations that will reduce energy and water consumption and embodied energy in building materials. Imperial Homes, a local builder of both affordable and luxurious structures, received the First EDGE (Excellence in Design for Greater Efficiencies) resource efficiency award from the World Bank Group's IFC for resource efficiency in the Philippines. By proposing a green construction standard that would lower energy, water, and embodied energy in building materials, Imperial Homes has provided an excellent example for the Philippines market.

Summary and Synthesis

The construction industry is increasingly transitioning to environmentally friendly building materials and sustainable construction methods, according to Construction Placement (2023), as excessive levels of pollution and waste are apparent in the environment. Additionally, there are three examples of sustainable solutions that may provide ideal temperature regulation, insulation for green roofs, stormwater management, and structural components made of renewable materials, such as cross-laminated lumber and bamboo. Furthermore, bamboo is one of the sustainable materials that may be utilized both now and in the future, according to Adier et al. (2023), because of its remarkable strength-to-weight ratio and ability to withstand heavy loads and pressures. In comparison to traditional materials, it also benefits from a decrease in carbon dioxide production. Although bamboo has advantages, its mechanical qualities differ depending on the species, age, location, technique, and treatment [1]. Nevertheless, according to ArchDesk (2021), there is no ideal answer, and there are no sustainable building materials that can be useful. However, the concept of green building is ineffective because the best course of action is to behave ethically and make changes to the resources that are now having a detrimental impact on the environment. Additionally, a substance should attempt to reduce its negative impact on the environment to qualify as sustainable.

The building sector generates a large amount of waste. In the United States, an estimated 251 million metric tons of solid waste is produced annually. Consequently, less than one-third of the solid waste produced is recycled or composted. One method that can reduce construction waste is to plan, choose vendors carefully, deconstruct rather than demolish, recycle non-recyclable items, donate materials that are in good condition, reduce packaging, be aware of local recycling programs, reuse scrap rather than cutting new materials, secure a contract with C&D recycling and waste, and finally organize the construction site. Similarly, controlling construction waste is a crucial step that may lead to the development of a sustainable building sector. Additionally, if you work in the construction business, you should be knowledgeable in this area because projects involving building and demolition can have a much smaller environmental impact if the firm is able to regulate waste. Additionally, there are suggestions on how to manage construction waste effectively, including the following: (1) establish a designated area on-site for waste sorting and separation; (2) identify and label various waste streams, including wood, concrete, metal, and plastic; and (3) form partnerships with nearby recycling and reuse organizations to guarantee that materials are recycled effectively [13].

According to the Grantham Research Institute (2015), the Philippine Green Building Code aims to increase efficiency by adopting measures that encourage resource management for site sustainability and efficiency. Additionally, the detrimental effects of structures on the environment and human health led to the creation of this regulation. This code suggests a set of guidelines for resource management, site selection, design, operation, maintenance, construction, and occupancy. It also adheres to the concepts of (1) helping the government combat climate change, (2) meeting the environmental demands of the current and future generations, and (3) enhancing environmental quality by encouraging greater comfort and productivity.

Knowledge Gap

There is a lack of knowledge in this study about the local literature related to the two sub-studies: sustainable materials, strategies for reducing waste, and resource efficiency in construction. Because some studies are already unreliable due to their year of publication, there is a lack of statistics regarding sustainable materials and resource efficiency used in Philippine construction. As a result, this study will focus on the three sub-studies relating internationally that are mentioned above.

METHODOLOGY

The research entitled “Sustainable Materials Management: Strategies for Reducing Waste and Enhancing Resource Efficiency in Construction” is a qualitative study that assesses current practices, challenges faced, and opinions on potential strategies for implementing SMM. The assessment will be based on waste management practices, resource utilization, and efficiency at various construction sites representing different scales and project types.

Conceptual Framework

The conceptual framework showcases the interconnected nature of construction processes, waste generation, resource utilization, and their impacts on economic, environmental, and social spheres. It emphasizes the significance of strategies aimed at reducing waste and enhancing resource efficiency within the context of construction, considering inputs, processes, and outputs. The dynamic nature of the framework supports the need for ongoing evaluation, adaptation, and innovation in sustainable material management practices within the construction industry (Figures 1 and 2).

Data Gathering Procedure

The researchers will collect comprehensive data on current construction practices, waste management, and resource efficiency within the construction industry to identify effective strategies for reducing waste and enhancing resource efficiency. The researchers will provide structured questionnaires with closed- and open-ended questions, conduct interviews to gather in-depth insights and opinions, and conduct site visits to evaluate on-site waste management procedures and assess efficient practices. The combination of surveys, interviews, and site visits allows for a comprehensive understanding of current practices and perceptions related to sustainable material management in the construction industry.

The data gathered through these methods will provide valuable insights for identifying effective strategies to reduce waste and enhance resource efficiency. The researchers will use *t*-tests and mean standard deviation to compare waste generation, resource efficiency, or other metrics between different categories, such as companies implementing sustainable practices and those that do not. The *t*-test provides straightforward results that are easy to interpret. Researchers can directly assess whether the observed differences in means are likely due to chance or are statistically significant (Tables 1–11).

A total of 27 respondents were included in the study, who are mostly from the 36–40 years old or 40–45 age group (22.2%). Other 18.5% are from 31–35 years old, while 14.8% are from 46–50. The youngest age group of 26–30 comprised 11.1%, while the oldest age group of 51–55 also comprised 11.1% of their total.

Sustainable materials management: Strategies for reducing waste and enhancing resource efficiency in construction.

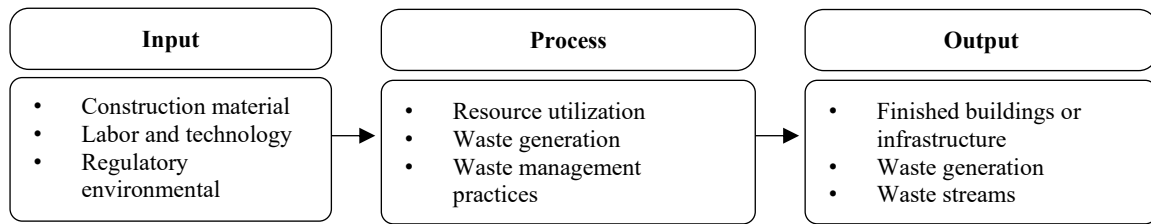


Figure 1. Conceptual framework of sustainable materials management in construction.

Sustainable materials management: Strategies for reducing waste and enhancing resource efficiency in construction

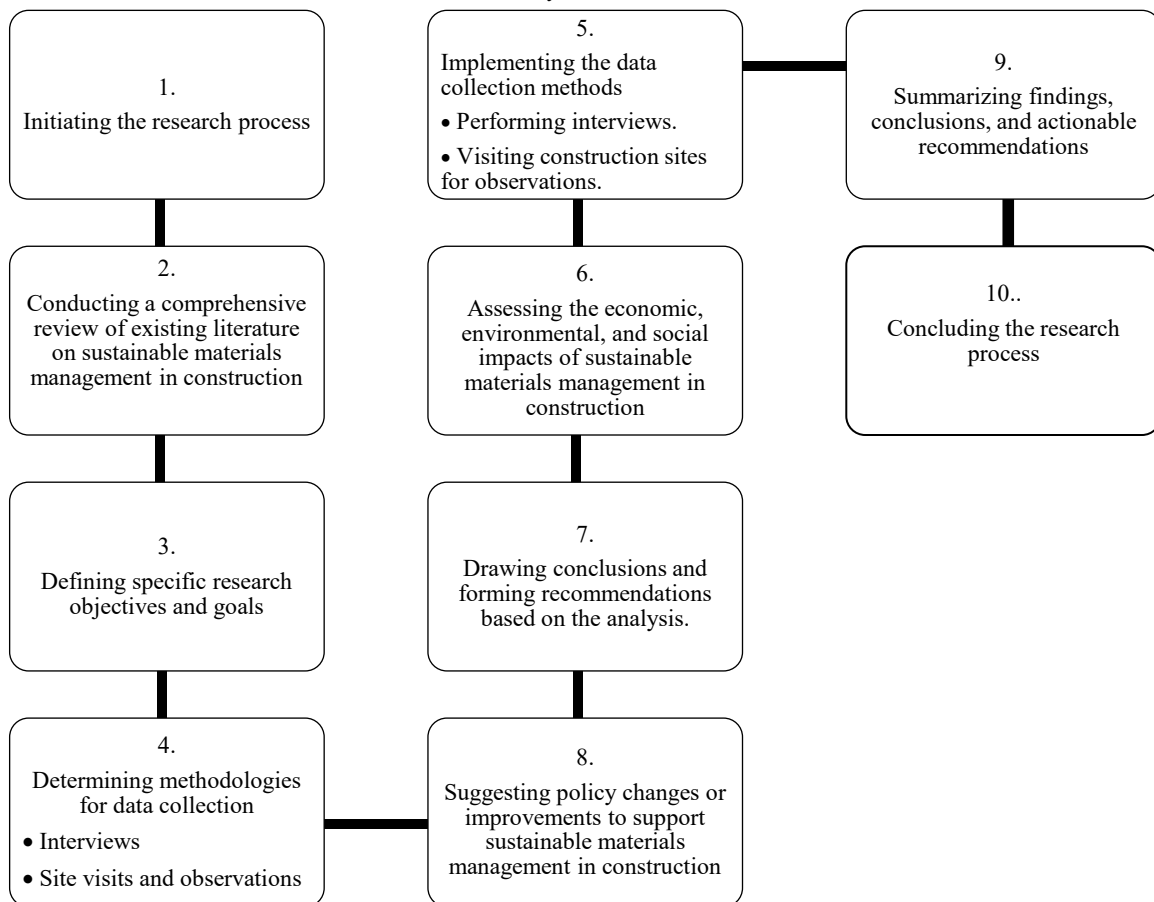


Figure 2. Research flowchart of sustainable materials management in construction.

The majority of them are male (66.7%), while the remaining 33.3% are female.

Three departments are represented in the study. Specifically, most of them are from operations (55.6%), followed by 22.2% each from engineering and finance administration.

More than half (55.6%) of the respondents were at the support level, while 14.8% were at the executive level. Other 18.6% are at the managerial level, while the remaining 11.1% are at the Board level. After years of service, 44.4% of employees have been working 11–15 years, while 18.5% either work for 6–10 or 16–20 years. Other 7.4% are working from 1–5 years or from 26–30.

Most of the businesses have 1–5 employees (37%), while 22.2% have 6–10 employees. Other 18.5% have employees of 26–30, while 11.1% has 11–15. Other 7.5% has 21–25 employees, while 3.7% has 16–20.

Table 1. Company profile and decision maker profile.

Age	Frequency	Percent
26–30	3	11.1
31–35	5	18.5
36–40	6	22.2
40–45	6	22.2
46–50	4	14.8
51–55	3	11.1

Table 2. Gender.

Gender	Frequency	Percent
Male	18	66.7
Female	9	33.3

Table 3. Department.

Department	Frequency	Percent
Engineering	6	22.2
Finance administration	6	22.2
Operation	15	55.6

Table 4. Position.

Position	Frequency	Percent
Board level	3	11.1
Executive level	4	14.8
Manager level	5	18.5
Support level	15	55.6

Table 5. Years of service.

	Frequency	Percent
1–5 years	2	7.4
6–10 years	5	18.5
11–15 years	12	44.4
16–20 years	5	18.5
21–25 years	1	3.7
26–30 years	2	7.4

Table 6. Number of employees handling.

	Frequency	Percent
1–5	10	37.0
6–10	6	22.2
11–15	3	11.1
16–20	1	3.7
21–25	2	7.4
26–30	5	18.5

Table 7. Sustainable materials management practice and strategies for reducing waste.

Treatment and disposal	Mean	SD	Interpretation
Prior to the disposal of waste. We used treatments such as shredding, incineration, anaerobic digester, etc., to reduce the volume and toxicity of waste.	4.44	0.70	Always
We used landfills for waste disposal to facilitate an integrated waste management system.	4.81	0.48	Always
We collaborate with different municipalities regarding the solid waste disposal regulated by the state and local governments.	4.78	0.58	Always
We ensured that our employees are monitored with strict compliance regarding the federal regulations of waste management disposal.	4.70	0.61	Always
Our company implements control measures when it comes to pollution prevention, waste management, product life cycle, and eco-friendly materials that can be disposed of.	4.22	0.89	Always
Overall mean.	4.59		Always (very high)

Table 8. Energy recovery.

Energy recovery	Mean	SD	Interpretation
We convert non-recyclable waste materials into electricity and heat.	3.81	1.00	Often
We incorporate solar panels, green roofs, and energy-saving materials to reduce the construction project's energy consumption.	4.56	0.75	Always
We used energy recovery facilities as an offer for an innovative solution to minimize the environmental impact of construction waste.	4.30	0.67	Always
Large volumes of diesel are used for machinery, as well as electricity for powering buildings and tools.	4.93	0.38	Always
We always used to be "Active Energy Efficiency", measuring, monitoring, and controlling energy usage in construction.	4.26	0.76	Always
Overall mean.	4.37		Always (very high)

Table 9. Recycling/composting.

Recycling/composting	Mean	SD	Interpretation
We used raw materials (cement, gravel, etc.) in construction rather than recyclable materials (metal, formworks, wood, etc.).	4.41	0.64	Always
We collect, recycle, and reuse materials such as steel, timber, etc., to reduce construction waste consumption.	4.81	0.48	Always
We sort and process recyclable products into raw materials and remanufacture them.	4.44	0.75	Always
Asphalt, concrete, and rubble are often recycled into aggregate or new asphalt and concrete products.	4.52	0.70	Always
We extract raw materials and cut carbon emissions.	4.48	0.64	Always
Overall mean.	4.53		Always (very high)

Table 10. Source reduction and reuse.

Source reduction and reuse	Mean	SD	Interpretation
We preserved existing buildings rather than constructing new ones.	3.85	0.95	Often
We purchased items in bulk or economy sizes.	4.89	0.42	Always
We invest in long-lasting, high-quality, durable, and repairable materials.	4.89	0.42	Always
We obtain only those items that we need.	4.89	0.32	Always
We sell materials that are in oversupply.	4.59	0.75	Always
Overall mean.	4.62		Always (very high)

Table 11. Perceived impact of practicing sustainable materials management.

	Mean	SD	Interpretation
Sustainable construction practices can help to create a more sustainable, resilient, and healthy built environment.	4.74	0.45	Strongly agree
Sustainable practice in construction can establish effective disposal methods and waste management for resource efficiency.	4.93	0.27	Strongly agree
Practicing sustainable materials management can help to reduce energy consumption in construction.	4.81	0.40	Strongly agree
Construction waste can lead to toxic air and water pollution, which impacts wildlife and public health.	4.59	0.50	Strongly agree
Proper sustainable practices ensure legal compliance, protect the health and safety of workers and the public, reduce the environmental impact, achieve cost savings, and enhance the reputation of construction.	4.89	0.32	Strongly agree
Overall mean.	4.79		Strongly agree (very high)

An overall mean of 4.59 implies that treatment and disposal are highly practiced by businesses. Among the five positive attributes, all were rated as always. The highest mean was 4.81, which denotes that they always used landfills for waste disposal to facilitate integrated waste management systems. The lowest mean was 4.22, which still implies that their company always implements control measures when it comes to pollution prevention, waste management, product life cycle, and eco-friendly materials that can be disposed of.

An overall mean of 4.37 implies that energy recovery is highly practiced by businesses. Among the five positive attributes, four are rated as always, while the remaining one is rated as often. The highest mean is 4.93, which denotes that large volumes of diesels are always used for machinery, as well as electricity to power buildings and tools. The lowest mean is 3.81, which denotes that they often convert non-recyclable waste materials into electricity and heat.

An overall mean of 4.53 implies that recycling and composting are highly practiced by businesses. All five positive attributes were rated as always. The highest mean was 4.81, which denotes that they always collect, recycle, and reuse materials such as steel and timber to reduce construction waste consumption. The lowest mean was 4.41, which also denotes that they always used raw materials (cement, gravel, etc.) in construction rather than recyclable materials (metal, formwork wood, etc.).

An overall mean of 4.62 implies that source reduction and reuse are highly practiced by businesses. Among the five positive attributes, four are rated as always, while the remaining one is rated as often. The highest mean is 4.89, which is tied for three attributes: always purchasing items in bulk or economy sizes, always investing in long-lasting, high-quality, durable, and repairable materials, and always obtaining only the items that are needed. The lowest mean is 3.85, which implies that they often preserve existing buildings rather than constructing new ones.

The overall mean was 4.79, which denotes that the perceived impact of practicing sustainable material management is very high. All five attributes received a rating of always. The highest mean was 4.93, indicating strong agreement that sustainable construction practices can establish effective disposal methods and waste management for resource efficiency. Respondents also strongly agreed that proper sustainable practices ensure legal compliance, protect the health and safety of workers and the public, reduce environmental impact, achieve cost savings, and enhance the reputation of construction.

CONCLUSION

In conducting the research study, the researchers will ensure that all participants, including construction company representatives, stakeholders, and workers, understand the purpose, nature, and potential implications of the research, and ensure the confidentiality of participant data and responses.

During site visits, minimize disruption to ongoing construction activities, ensuring that the research process does not interfere with the regular workflow or safety protocols, and the researchers will not request or encourage participants to engage in practices that could be potentially harmful to their health, safety, or the environment. By adhering to these ethical considerations, the research on SMM in construction maintains integrity, respects participant rights, and contributes responsibly to the betterment of the construction industry's practices.

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