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ASSESSMENT OF EFFECTIVE WASTE RECYCLING PRACTICES TO MINIMISE CONSTRUCTION AND DEMOLITION WASTE IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

The construction industry, a vital sector driving global development, simultaneously contributes significantly to waste generation. This research delves into the assessment of effective waste recycling practices to minimise Construction and Demolition (C&D) waste in the Sri Lankan Construction Industry. The study aims to evaluate the most applicability waste recycling practices, identify implementation barriers, and provide recommendations for overcoming these barriers. A comprehensive literature review highlights the global significance of the construction industry and its substantial contribution to waste production. Effective waste management is crucial for cost, quality, time, and environmental impact. It advocates for scientific consultation to determine appropriate waste management practices, considering extended producer responsibility, Waste-to-Energy, material recovery facilities, source separation and landfill options. C&D waste production is linked to ecological consequences, necessitating sustainable waste management practices. Recycling C&D waste emerges as a viable mitigation strategy, offering benefits such as landslide risk reduction, greenhouse gas emission reduction, and natural resource protection. The research methodology used in this study is mixed-method approach combining quantitative and qualitative methods. Major findings include appropriate waste recycling practices, implementation barriers, and recommendations for overcoming barriers. Waste management policy regulation and enforcement being the most applicable waste recycling practice according to RII analysis. The identified most significant barrier was the absence of rules and enforcement. Recommendations focus on awareness programs, incentivising through the tendering process, education and training, seeking international guidance and technology and government support programs. The study provides valuable insights for policymakers, industry stakeholders, and researchers in advancing waste recycling practices in the Sri Lankan Construction Industry.

Keywords: *Construction and Demolition Waste; Sri Lankan Construction Industry; Waste Management; Waste Recycling Practice.*

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1. INTRODUCTION

The construction field exemplifies one of the world's most exciting and complicated industrial developments (Kabirifar et al., 2020). C&D waste refers to the materials produced from construction or demolition activities. Construction sites generate waste from raw materials with monetary value. Excessive waste can lead to financial losses and environmental damage (Wahi et al., 2016). Waste resulting from C&D encompasses a wide range of operations, such as clearing sites, excavating land, constructing buildings and other structures, carrying out demolitions, constructing roads, and renovating existing structures. The problem of C&D waste is currently a big concern in Sri Lankan construction in environmental, economic, and social, which must be addressed immediately in an effective way through waste management practices.

A number of ecological consequences, such as pollution, land depletion, environmental harm, and resource limits, are directly related to the production of C&D waste (Alsheyab, 2021). C&D waste, a significant environmental issue, is not properly managed in Sri Lanka, unlike most developed countries where effective waste management practices are established (Tissera et al., 2022). Stakeholders must implement effective waste management practices to control and prevent financial losses and environmental harm. Proper C&D waste management is critical within construction sector, with studies mostly concentrating on waste reduction and recycling (Lawson, 2020; Napier, 2023). Key objectives of this study encompass applicability of suitable waste recycling practices to Sri Lankan construction industry, barriers to implement to Sri Lankan construction industry and recommendations to overcome the barriers.

2. LITERATURE REVIEW

C&D waste is solid waste generated during constructing, repair, and demolition operations (Lu & Yuan, 2011). Nagapan and Rahman (2011) classify the causes of C&D wastes into six categories i.e., (i) design, (ii) procurement, (iii) material handling, (iv) operation, (v) residual associated, and (vi) others. Waste from C&D may be split into two major categories i.e., (i) inert waste, and (ii) non-inert waste. Large amount is made up of inert material, which is further separated into soft and hard inert materials (Yeheyis et al., 2012). Rocks and shattered concrete are examples of hard inert materials, whereas soil, earth, silt, and slurry are examples of soft inert materials. Conversely, non-inert materials include metal, plastic, wood, and packaging waste (Yuan & Shen, 2011). Due to rising C&D waste amounts, a lack of waste dumps, and the extended time negative consequences of eliminated waste from construction and demolition, the environment, and society, sustainable management of construction and demolition debris is becoming increasingly important to protect public wellness and natural ecosystems (Kourmpanis et al., 2008). Yeheyis et al. (2012) stated that C&D waste has a more clearly recognised source and a rather well-established composition. This clear classification helps in the effective management and disposal of waste from C&D (Karunasena & Rathnayake, 2014).

The management of construction and demolition waste has become a major problem across the world, particularly in developing nations where construction is a major economic activity (Yuan, 2017). There are several ways to consider in managing waste from C&D. It involves more than simply disposing of the waste but rather implementing a comprehensive plan to make the most of construction resources. The objective is to

reduce waste production and discover efficient methods to use whatever waste that is generated. Although it is a widely used practice, dumping construction waste in landfill sites is not the only approach to waste management (Dania et al., 2016). The goal of managing waste from C&D is to decrease waste and properly dispose of it, which both serve to prevent negative environmental consequences and favourably influence social, economic, and economic performance (Karunasena & Rathnayake, 2014).

In Sri Lanka, waste management related to C&D must be improved, per a survey report by Nifal (2023). A study of the literature conducted by Nifal (2023) looks at the situation of C&D waste management in Sri Lanka now and highlights both potential and obstacles for better waste recycling practices. The authors contend that improved waste management policy regulation and enforcement are necessary, as well as greater public knowledge and education regarding the advantages of waste recycling ("Central Environmental Authority", 2000). According to Senarathna and Perera (2021) nonetheless, the Sri Lankan Construction Industry may find use for several C&D waste recycling practices. Extended Producer Responsibility (EPR), Waste-to-Energy (WTE), Material Recovery Facilities (MRFs), and source separation are some of these approaches (Senarathna & Perera, 2021). Robots are said to be more accurate and precise than humans at placing materials such as bricks or concrete. As a result, there may be reduced material waste from mistakes or improper positioning. By precisely measuring and cutting materials, as well as by minimising waste from overuse or cutting errors, robots can maximise material utilisation (Thompson et al., 2016). These methods are the new applicable waste recycling practices to the Sri Lankan construction industry.

Overall, the Sri Lankan construction industry might profit from certain waste recycling practises, even though there is still space for improvement in the country's C&D waste management system. The industry can lessen the quantity of waste dumped in landfills and help local economies by Vijayaragunathan and Renukappa (2017). In this study, finding most suitable applicable recycling practices according to above mentioned practices is the primary objective.

Jain (2012) outlines barriers to implement waste recycling practices that prevent waste management from being widely used. One of the barriers is the dearth of skilled workers in the sector. It has also been demonstrated that worker errors that necessitate reworking, the absence of skilled labour and subcontractors, and, particularly, worker errors that led to this, have the greatest influence on the development of C&D waste (Wahi et al., 2016). Furthermore, when duties are performed, a lack of basic competency will lead to waste that is both non-physical and physical (Jain, 2012).

Lack of knowledge is another barrier when implementing waste recycling practices. It may be challenging to adopt waste recycling practices since many stakeholders in the building sector are unaware of their advantages. Another insight is absence of rules and enforcement which is Sri Lankan waste recycling practices are not subject to any rules or enforcement mechanisms, which makes it challenging to ensure that waste management policies are being followed (Senarathna & Perera, 2021).

According to Senarathna and Perera (2021), lack of infrastructure can be challenging to gather, sort, and process waste materials due to a lack of infrastructure for waste recycling. The lack of incentives makes it challenging to justify the costs involved with waste recycling practices, as there aren't enough motivations for stakeholders in the building sector to adopt them. According to Wijewansha et al. (2021), Sri Lanka still has

a long way to go before meeting the requirements of international sustainable construction. Due to the industry's lack of flexibility, the circular economy idea is still seen as unique even though it has been applied in Sri Lanka by several scholars (Bekchanov et al., 2018; Liyanage et al., 2019).

3. RESEARCH METHODOLOGY

The main aim of this research is to identify applicability waste recycling practices to the Sri Lankan Construction Industry, barriers to implement and suggestions to overcome the barriers. The Mixed Methods Research (MMR) approach used in this study's research involves combining quantitative and qualitative data collection and analysis methods.

Primary data is information gathered by researchers directly from primary sources, such as conducting semi-structured interviews and questionnaire surveys. The questionnaire was developed using the information gathered during the literature review. A Likert type scale with a maximum of five points was used in the questionnaires. This scale was used to determine how much the respondents agreed or disagreed with the factors that were presented to them.

Table 1 presents the population and sampling methods employed in data collection using questionnaire survey. Various professional disciplines were included, selected randomly from construction projects in Sri Lanka, to generate findings through content analysis.

Table 1: Population and sampling using questionnaire survey

Profession	Frequency	Sample
Project Manager	14	
Civil Engineer	23	5
Quantity Surveyor	10	
Technical Officer	3	

Table 2 presents the frequency and proportion of respondent's years of experience in the construction industry are illustrated in the following statistical format,

Table 2: Results of respondents - experience in industry

Years of Experience	Frequency	Sample
Less than 1 year	2	
1-5 years	20	50
5-10 years	18	
More than 10 years	10	

Table 3 provides a breakdown of interviewee frequencies categorised by profession.

Table 3: Breakdown of interviewee frequencies

Profession	Frequency	Sample
Project Manager	3	
Civil Engineer	3	10
Quantity Surveyor	4	

Table 4 provides a breakdown of the interviewee's years of experience in the industry.

Table 4: Breakdown of interviewee's experience

Years of Experience	Frequency	Sample
10 – 20 years	6	
More than 20 years	4	10

The Relative Importance Index (RII) method was used to analyse and present the data from the questionnaire survey in graphs, tables, and figures. Interview data was recorded, and content analysis was used to examine it.

4. ANALYSIS

For the questionnaire survey, 60 questionnaires were distributed, and 50 were returned with valid responses with a response rate of 83.3%. Out of the responses, 46% was Quantity Surveyors, 28% was Project Managers, 20% was Civil Engineers, and 6% was Technical Officers. Subsequently, ten semi-structured expertise interviews were conducted to identify barriers to implement and suggestions to overcome the identified barriers.

Seven waste recycling practices were identified through a literature survey, and their applicability to the Sri Lankan construction industry was evaluated through a questionnaire survey. The identified practices encompass Extended Producer Responsibility (EPR), Waste-to-Energy (WTE), Material Recovery Facilities (MRFs), waste management policy regulation and enforcement, source separation of waste, creating a model to forecast average waste generation, and utilising robots to measure and cut materials. These identified practices were incorporated into this study and formed the basis for a questionnaire survey to gauge the level of agreement using RII.

Table 5: RII Analysis of waste recycling practices

Practices	Total Weight	Relative Index	Rank
Extended Producer Responsibility (EPR)	190	0.7600	3
Waste-to-Energy (WTE)	172	0.6880	5
Material Recovery Facilities (MRFs)	179	0.7160	4
Waste Management Policy Regulation and Enforcement	213	0.8520	1
Source Separation of Waste	193	0.7720	2
Create a model to forecast average waste generation	171	0.6840	6
Using robots to measure and cut materials	**151**	**0.6040**	7

According to Table 5, waste management policy regulation and enforcement was ranked in the first place which means it is the most suitable waste recycling practice according to identified waste recycling practices in the literature review. Developing countries including Sri Lanka do not have much capacity to implement most initial costing waste recycling practices. The country's current economic problems and lack of financial

resources are major contributors to this. Source separation of waste is the second-ranked waste recycling practice according to the above analysis. Source separation of waste practice can be implemented in Sri Lanka practically because there is no high cost. The third most applicable waste management practice is EPR. Implementing EPR practice in the construction industry motivates minimising environmental impact and promotes waste recycling. The fourth-ranked practice is material recovery facilities. In simple terms, this plant specialises in receiving, separating, and preparing recyclable materials for manufacturers to use. This is a popular waste recycling practice in developed countries. However, when implementing this to Sri Lankan construction industry barriers may arise. Because of this reason, this waste recycling practice came up in fourth place in the questionnaire. Waste to Energy is the fifth most suitable waste recycling practice to implement Sri Lankan construction industry. This waste recycling practice is another better solution to minimise waste in the construction industry. This has a high initial cost to implement. The sixth and seventh most suitable waste recycling practices are creating a model to forecast average waste generation and using robots to measure and cut materials. It is not practical to implement in Sri Lanka because of high initial cost and lack of technology. Because of these reasons these practices came up the last option from respondent.

The ten barriers to implementing waste recycling practices were identified through a literature survey, and their most significant barrier to the Sri Lankan construction field was evaluated through a questionnaire survey. These identified barriers were incorporated into this study and formed the basis for a questionnaire survey to gauge the level of agreement using RII.

Table 6: RII analysis of barriers to implementing waste recycling practices

Barriers	Total Weight	Relative Index	Rank
The dearth of Skilled workers in the sector	172	0.6880	10
The absence of subcontractors	180	0.7200	7
Worker errors	173	0.6920	9
Lack of basic competency	179	0.7160	8
Lack of Knowledge	192	0.7680	3
Absence of rules and enforcement	209	0.8360	1
Lack of infrastructure	189	0.7560	5
Lack of incentives	191	0.7640	4
Poor communication and coordination among parties involved	185	0.7400	6
Poor qualities of recycled products and their limited applications	196	0.7840	2

The five most significant barriers identified in the above table will be analysed and discussed. According to Table 6, the absence of rules and enforcement was ranked in the first place which means it is the most significant barrier to implementing waste recycling practices in SL construction field according to the identified barriers listed in the literature survey. There are statutes and regulations in SL regarding trash management and recycling practises, but they are inactive or non-efficiency. Effective implementation of

recycling practices in industry requires strict penalties for non-compliance and incentives for adoption. In the absence of such measures, some companies may not prioritise recycling efforts in their waste management practices. The second most significant barrier is the poor quality of recycled products and their limited applications. In the construction industry, stakeholders have not given much attention to the use of recycled products. Many people are sceptical about the quality of recycled products. According to the above-mentioned challenges, the third most important obstacle to adopting waste recycling practises within the construction business is a lack of knowledge. Among the above-mentioned waste recycling practices implementation of robotic technology and the creation of a model to forecast average waste generation are difficult to implement in the Sri Lankan construction industry because of lack of knowledge and technology, lack of high cost, and lack of industry experts in relevant fields. Lack of incentives is the fourth significant barrier identified according to the above table. Construction projects often work within tight budgets and timelines, leading to a short-term focus on project costs. This can hinder the integration of recycling practices into project planning and execution. As economic considerations, construction companies may prioritise economic factors. Without financial incentives, the cost-effectiveness of waste recycling practices may not be immediately apparent. Investing in recycling initiatives may be discouraged by the perceived high initial costs of recycling infrastructure and processes. The fifth most significant barrier is the lack of infrastructure. In lack of infrastructure includes transportation challenges, insufficient collection systems, limited public-private partnerships, and inadequate storage facilities. Insufficient collection systems are a major barrier to lack of infrastructure.

Apart from the above-identified barriers through the literature survey, some barriers were identified through open-ended questions included in the questionnaire survey and from the semi-structured interview. A total of 28 responses out of 50 responses answered open-ended questions regarding barriers. Implementation barriers were identified as lack of cost, behaviour of the people, disagreement of skilled workers, professional to change the styles of their activities, lack of a culture in favour of waste management and economy problem.

Based on the answers provided to the open-ended questions of the questionnaire survey, the highest frequency was obtained which is lack of cost on implementation of waste recycling practices. In the prevailing situation of the construction industry, there is a lack of cost when implementing waste recycling practices. In the above-mentioned waste recycling practices using robots to measure and cut materials, Material Recovery Facilities (MRFs) and waste-to-energy (WTE) practices have high initial costs.

Numerous varied suggestions to overcome the barriers to implement waste recycling practices to industry were derived from the open-ended questions in the questionnaire survey. These recommendations, supported by insights gained from semi-structured interviews, were not only substantiated but also expanded upon. The same set of recommendations was echoed by professionals during the semi-structured interviews, where they provided additional details and perspectives. A comprehensive compilation of the recommendations to overcome implementation barriers, as identified through the questionnaire survey responses, is presented as conducting awareness programs, enforce strong rules and regulations, encourage through the tendering process, provide proper education and training, seek international guidance and technology, identify the root

cause and propose alternative methods, integrated regulatory framework, government support programs.

Relying on the answers to the open-ended questions of the questionnaire survey, conducting awareness programs is the most common answer in questionnaire surveys and interviewers. Emphasise the environmental and economic benefits of waste recycling in a manner that resonates with the target audience and organise workshops and seminars to facilitate in-person interaction and engagement. The second suggestion is encouraged through the tendering process. The one interviewer stated that, "*During my time working on the HSBC project, the client asked for a certificate to ensure proper waste disposal from the site. They also requested the associated costs through a variation. However, the client did not approve the cost and mentioned that they did not have any additional funds to spend on this matter. In my opinion, if there are regulations that can be added to the tender, it would be beneficial*". The third suggestion is providing proper education and training on waste recycling practices. Conduct practical training sessions that give participants a real-world understanding of waste recycling processes. This could include on-site demonstrations and interactive exercises. The problem of these types of education and training programs is the language barrier for stakeholders. Ensure that educational materials and training sessions are accessible in multiple languages to cater to the diverse linguistic backgrounds of the construction workforce. International seek guidance and technology is the fourth suggestion. Facilitate the transfer of advanced waste recycling technologies from countries with established practices to the Sri Lankan construction industry and collaborate with technology providers to customise solutions that are suitable for local conditions and requirements are included for. The fifth suggestion is to identify the root cause and propose alternative methods. Conduct a comprehensive analysis to identify the underlying factors contributing to challenges in waste recycling practices.

5. DISCUSSION

The first objective is to identify which identify the extent to which waste recycling practices apply to the Sri Lankan construction industry. Seven waste recycling practices were identified through a literature survey, and their applicability to the Sri Lankan construction industry was evaluated through a questionnaire survey. These identified practices were incorporated into this study and formed the basis for a questionnaire survey to gauge the level of agreement. The study used the RII method to rank the identified practices. In second objective identified barriers were incorporated into this study and formed the basis for a questionnaire survey to gauge the level of agreement. In third objective fulfil from open-ended questions in the survey questionnaire and the interview that was semi-structured were used to identify recommendations.

The discussion section underscores the research's key findings on waste recycling practices in the Sri Lankan construction industry. Notably, the survey results indicate a pronounced preference for waste management policy regulation and enforcement, emphasising the industry's recognition of the importance of regulatory frameworks. Additionally, the integration of innovative technologies such as robotic assistance for material measurement reflects a forward-looking stance towards sustainable construction practices. However, identified barriers, with the absence of rules and enforcement at the forefront, present significant challenges. The study's recommendations, encompassing awareness programs, education initiatives, government support, and international

collaboration, collectively aim to address these barriers, fostering a culture of environmental responsibility and propelling the industry towards effective waste recycling practices for a more sustainable future.

6. CONCLUSIONS

In conclusion, this study has provided valuable insights into the assessment of effective waste recycling practices to minimise construction and demolition waste in the Sri Lankan construction industry. The identification of key waste recycling practices, such as EPR, WTE, MRFs, and others, has been crucial in understanding the applicability of these practices in the local context. The study's major finding indicates that waste management policy regulation and enforcement emerged as the most suitable practice, emphasising the importance of regulatory frameworks in promoting effective waste recycling.

However, the study also uncovered significant barriers hindering the implementation of waste recycling practices in the Sri Lankan construction industry. The absence of rules and enforcement was identified as the most substantial barrier, highlighting the need for regulatory strengthening and enforcement mechanisms. In response to these findings, the study proposes a set of actionable recommendations, including enforce strong rules and regulations, awareness programs, encouragement through the tendering process, education and training initiatives, seeking international guidance and technology, and the development of an integrated regulatory framework with government support programs. These recommendations serve as a roadmap for overcoming the identified barriers and fostering a more sustainable and environmentally conscious construction industry in Sri Lanka.

While this study contributes significantly to the understanding of waste recycling practices in the Sri Lankan construction sector, it is essential to acknowledge its limitations, particularly its focus on building construction and exclusion of labour and plant waste. To advance the field, future research should explore technological advancements in construction and demolition waste recycling, conducting feasibility studies for implementation in the Sri Lankan context. This will provide a comprehensive understanding of emerging technologies and their potential integration into the industry, ensuring a more holistic approach to waste management in construction practices.

7. LIMITATIONS

The study focuses on present waste management practices in the construction sector, with a particular emphasis on waste recycling practices. This research is confined to building construction in Sri Lanka. This research emphasises waste from construction and demolition on the construction site, ignoring labour and plant waste.

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