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IMPACT OF MATERIAL WASTE MANAGEMENT ON CONSTRUCTION COST OF THE PROJECTS IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Material waste management plays an important role in the cost of a construction project. In Sri Lanka, inefficient material waste management significantly inflates project costs. Therefore, it is required to identify cost-significant inefficiencies in material waste management in Sri Lankan construction projects. Hence, this research carried out to identify cost-significant inefficiencies in material waste management in Sri Lankan construction projects. This research carried out a literature review which helped in findings the status of material waste management practices in construction projects. Mixed methods were adopted by combining qualitative and quantitative research approaches. The primary data for this study is collected through semi-structured interviews and questionnaire survey from the industrial experts purposely selected based on this research problem. The data collected were analyzed using manual content analysis and the Relative Importance Index method. As per this study, limited recycling facilities, design changes and variations and inefficient material handling are found out to be some of the major inefficiencies exist in the material waste management practices among building projects in Sri Lanka. This study further highlights inefficient design and planning process, insufficient regulations, inaccurate measurements and limited storage space as the major reasons for those inefficiencies. The best applicable strategies to overcome these inefficiencies were derived. Hence, this study highlights the major cost-significant inefficiencies in the material waste management practices specifically among the building projects in Sri Lanka, with the reasons for these inefficiencies and address on how to overcome these inefficiencies.

Keywords: *Building projects; Sri Lanka; Inefficiencies; Material waste; management; Strategies.*

1. INTRODUCTION

1.1 BACKGROUND

Construction waste generation is a significant issue in Sri Lanka, affecting the environment and the efficiency of the construction industry. Waste management involves managing resources such as site planning, transportation, storage, material handling, re-use, recycling, and disposal. The Western Province accounts for 60% of the total solid

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waste generation, amounting to 7000 metric tons per day. The construction industry in Sri Lanka faces challenges in disposing of waste properly, increasing project costs and causing long-term debt problems.

Building companies can save money by buying in bulk and using recycling stations to reuse materials. However, poor waste management methods, lack of strict laws, inadequate recycling centres, and tools further exacerbate the problem. The industry is highly fragmented, with material waste management companies, construction companies, and freelancers not working together to find effective ways to cut waste. Inefficient construction material waste management significantly contributes to increased project costs and environmental impacts worldwide (Osmani, Glass & Price, 2008; Yuan, Shen & Wang, 2011). In Sri Lanka, construction waste causes a serious challenge, yet research explicitly linking material waste handling to construction cost overruns remains limited. Existing studies tend to focus on waste generation rates and disposal methods rather than quantifying cost implications. The fragmented nature of Sri Lanka's construction industry further complicates effective waste management, as poor coordination among contractors, waste managers, and freelancers inhibits the adoption of efficient waste reduction practices. Globally, proactive waste management planning and stakeholder collaboration have proven essential to minimizing waste and controlling costs, but these strategies are underexplored in the Sri Lankan context. Additionally, weak enforcement of waste management regulations and inadequate recycling infrastructure exacerbate inefficiencies and increase project expenses.

This lack of comprehensive research and regulatory oversight underscores the need to investigate the cost impact of material waste management inefficiencies in Sri Lanka and develop customized solutions to improve sustainability and reduce construction costs. Despite differing social, economic, and environmental conditions, research is lacking on how waste management impacts construction costs. This highlights the need for effective waste management practices.

2. LITERATURE REVIEW

2.1 DEFINITIONS OF MATERIAL WASTE MANAGEMENT

Construction waste management involves material waste management, elimination, recycling, and reuse of materials (Hussain, 2016). The three most important steps in waste management are during the project phase, planning, and the completion phase. The construction industry employs various approaches; each specifically designed for its unique needs. Studies show that waste-conscious systems are crucial for handling waste effectively (Begum et al., 2007). In Malaysia, workers are not aware of waste management, while construction sites in the UAE lack proper attention. As per the studies done by Mohan et al. (2024), India's economy could benefit from less litter, and the 3R system (reduce, reuse, recycle) should be implemented. Indians should create less material waste when building and removing items, and schools should use previously used items. Pisuttu et al. (2024) advocate for the reuse of trash to reduce its environmental impact. Programs should be run to educate people about waste management and its contribution to the economy and environment.

2.2 STATUS OF MATERIAL WASTE MANAGEMENT

The construction industry is increasingly concerned about environmental protection and resource efficiency. Old methods of waste production, such as wood, concrete, and metal, end up in landfills over 75% of the time (Akanbi et al., 2018). The waste management process involves project teams, contractors, and suppliers, and circular economy ideas play a crucial role in cutting waste. Design choices and proper storage and handling are essential for meeting global sustainability goals and reducing waste production and disposal costs. Recycling and reusing old bricks, such as the REBRICK process, can help reduce litter and landfill waste. End-of-life trash can be disposed of through recycling, reusing, or landfilling (Akanbi et al., 2018). The goal is to recover as many resources as possible and minimize the impact on the world. Reusing building materials can save money, as shown by a BIM-based whole-life performance prediction (Akanbi et al., 2018). New ways to buy items for a circular economy, such as barcodes and tracking systems, can also help manage waste and save money. Circular economy ideas, new technologies, and good policies have been shown to reduce building costs and promote environmentally friendly practices (Karavezyris, 2007; Chen et al., 2021). Proper waste management requires using new tools, following rules, and thinking creatively about reuse. These tips can help construction companies save money and make the world a better place when used together.

2.3 IMPACT MATERIAL WASTE ON CONSTRUCTION COSTS

Builders play a crucial role in economic growth, but they also generate significant material waste, which increases building costs. This literature review highlights the importance of material waste management and the circular economy in reducing construction costs. Further Akanbi et al. (2018) emphasized the need for reusing construction materials, while Bao et al. (2019) mentioned procurement innovations for a circular economy. Begum et al. (2006) study the benefits and drawbacks of waste reduction in Malaysia. Bao et al. (2019) have suggested barcode systems can help reduce construction waste and save money. Bilal et al. (2020) have discussed the challenges in implementing the circular economy in the construction sector and propose solutions. Esa et al. (2017) have incorporated ideas on reducing waste disposal costs. Mahpour (2018) highlights the main issues preventing waste management from using circular economy methods. Chen et al. (2021) have highlighted that construction waste can be turned into useful materials, reducing costs. Simulations and good planning can help reduce costs. Changes in rules, waste management, circular economy, new technologies, and construction industry policies are key factors affecting building prices.

2.4 STRATEGIES FOR EFFECTIVE MATERIAL WASTE MANAGEMENT

To be sustainable, the accumulation of material waste must be eliminated. This is particularly true now as people are more concerned about resource depletion and environmental harm. This analysis examines research from a variety of disciplines, including engineering, finance, and environmental technology, to determine the most effective waste management strategy. Through many studies, they have discussed the significance of handling garbage in a way that promotes a circular economy. A financial system that operates circularly must reuse building materials (Akanbi et al., 2018). BIM stands for construction Information Modelling. It makes it easier for people to monitor how well a structure will function over time. Bao et al. (2019) have demonstrated the

significance of Suzhou's retail options for expanding China's economy in all directions. The cost of reducing building waste must be considered. Begum et al. (2006) examined the advantages and disadvantages of landfilling in Malaysia to determine whether it makes sense economically. This demonstrates how crucial it is to identify affordable and effective techniques. For the same reason, Mahpour (2018) has emphasized the challenges that arise when implementing circular economy concepts to manage waste from building and demolition while finding solutions to overcome challenges.

2.5 CHALLENGES AND OPPORTUNITIES OF THE CONSTRUCTION INDUSTRY IN MATERIAL WASTE MANAGEMENT

Around the world, the act of disposing of and dumping material waste affects businesses, individuals, and the environment (Akanbi et al., 2018). Some economies are beneficial because they aim to make goods more useful and spend less. This literature review examines the challenges and possibilities in handling construction and demolition trash by utilizing several research studies. Waste elimination becomes challenging in a revolving economy, as items undergo repeated construction. According to Bao et al., (2019), the construction industry must have several ways to buy materials to have the transition to a circular economy. They discovered that issues are unique everywhere and need various approaches to resolution in Suzhou, China.

In 2017, Nasir et al. conducted another study that examined the distinctions between direct and circular supply chains in the construction industry. It appears that using circular approaches reduces waste and improves resource utilization. Concepts from the circular economy can be helpful, but addressing the construction and demolition of trash with them is challenging for several reasons. These issues include inadequate infrastructure, a lack of knowledge, and a lack of government monitoring, according to Mahpour (2018). Some states, like Malaysia, also have clear regulatory problems. In their benefit-cost analysis, Begum et al. (2006), for instance, concluded that waste reduction techniques were both economically feasible and challenging to manage. According to Akanbi et al. (2018), a BIM-based whole-life performance estimate can be used to save construction resources. This demonstrates how digital tools can accomplish more with less. This trend is further reinforced by the utilization of system dynamics models to analyze the management of various kinds of waste (Hao et al.,2010). They have used this information to determine ways to enhance on-site waste management. Factors like income also have an impact on trash management, particularly in developing nations. In his investigation, Manowong (2012) has emphasized the significance of involving stakeholders and assisting them in developing their abilities. They have emphasized the necessity of interdisciplinary approaches that consider wealth disparities. It has been noted that managing waste from construction and demolition in a circular economy is challenging and can be approached in a variety of ways.

3. RESEARCH METHODLOGY

This chapter elaborates on the methodological framework adopted to achieve the research objectives. To achieve the research objectives, the mixed method approach was followed. Thus, it was decided that a mixed-method approach could give a more comprehensive understanding of the research, which qualitative and quantitative methods could offer separately.

This research emphasized the construction material waste management solutions in building projects in Sri Lanka. To identify the effect of inefficiencies on the construction cost of projects, semi-structured interviews were conducted among professionals. Table 01 shows the profile of the respondents of semi-structured interviews. Utilizing content analysis, the information gathered from the interviews was analysed. A simple content analysis method was used to conduct the analysis.

Table 1: Profile of Interviews

Respondents	Designation	Years of experience
R1	Material Engineer	6
R2	Chartered Civil Engineer, Program Director	37
R3	Chartered Quantity Surveyor	22
R4	Free Lance Consultant - Design Engineer	35
R5	Civil Engineer in Central province Engineering office	18
R6	Civil Engineer	12

Following the interviews, a questionnaire survey was conducted to collect quantitative data on the inefficiencies of existing material waste management strategies and practices in Sri Lankan building construction projects. The survey aimed to identify the most significant inefficiencies, their underlying causes, and possible strategies for improvement. A purposive sampling approach was used to select industry professionals such as project managers, site engineers, quantity surveyors, and architects, as these roles have direct involvement in material handling, procurement, and waste reduction activities

The questionnaire consisted of three sections: identification of inefficiencies, reasons contributing to these inefficiencies, and strategies to address them. A five-point Likert scale was used to measure the perceived level of impact or importance of each factor. The survey was distributed via both electronic platforms and printed copies to ensure accessibility, with clear instructions provided to respondents and follow-up reminders to encourage completion.

In this study, the Relative Importance Index (RII) was adopted as a principal analytical technique to prioritise the identified inefficiencies in material waste management within the Sri Lankan construction industry. The method facilitated the conversion of expert evaluations into quantifiable measures, enabling the systematic comparison of factors based on their relative significance. Through this approach, inefficiencies were ranked according to their impact on construction project costs, thereby providing a rigorous, evidence-based framework for formulating targeted interventions to enhance waste management practices.

$$RII = \frac{\sum W}{AxN} = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{5 * N} \qquad Equation\ (1)$$

- W – weighting given to each factor by the respondents
- nx = Number of respondents rate on each choice
- N = Number of respondents (40 for this study)
- A = Highest weight (5)

The Relative Importance Index, $0 \leq RII \leq 1$

4. DATA ANALYSIS

4.1 QUALITATIVE DATA ANALYSIS

4.1.1 Inefficiencies and Reasons for those Inefficiencies in Material Waste Management Practices in Sri Lanka

The respondents indicated that material waste contributed between 5% and 30% to the total cost of construction. Additionally, most materials include steel, pipes, electrical wires, cement, sand, and tiles. Thus, Sri Lanka's material waste management practices include the following significant inefficiencies.

Thus, the following are Sri Lanka's main inefficiencies in material waste management practices.

Through semi-structured interviews, inefficiencies in material waste management were investigated. Poor regulations and enforcement, limited recycling facilities, unstable market for recycled products, inaccurate material estimation / ordering more materials than required to avoid shortages, inefficient material handling, damage to materials, inefficient transport methods, uneconomical design, design changes and variations, poor quality control, poor workmanship, not enough salvaging and reviewing, limited technology adoption, poor cutting and fabrication practices, limited standardization of materials, limited research and knowledge, not good security measure and ineffective communication are identified inefficiencies of from the semi structured interviews.

Furthermore, this study also found the major reasons for inefficiencies. There were Not enough regulations, inaccurate measurement, limited storage space, inefficient design and planning processes, weather and environmental effects, poor communication among project stakeholders, lack of awareness of material handling and proper material waste management, insufficient training practices, no proper guidance, cultural factors, delays in delivering, use of outdated tools, unforeseen site conditions, focus on speed over accuracy and overlooking minor defects that lead to later rework were identified through interviews.

4.2 DEMOGRAPHIC FACTORS ANALYSIS

Out of 55 professions, 40 respondents completed the questionnaire survey to determine the impact of inefficiencies on project construction costs in Sri Lanka. Accordingly, the response rate is 72.72%.

In this study the majority of the respondents 32.50% were Project Managers with a frequency of 13 Professionals and minority of the respondents of the 7.50%, were Site Engineers and Engineers with a frequency of 3 Professionals.10%(4) of the respondents were Senior Quantity Surveyors, 22.50% (9) of the respondents were Senior Engineers, 10% (4) of the respondents were Quantity Surveyors and 10% (4) of the others respondents participated in the questionnaire.

40% (16) of the respondents in this survey belong into the category of construction contracting, 37.50% (15) belong into the category of construction consulting, 17.50% (7) belong into the category of developer or client organization, and 5% (2) belong into the other organization categories. This indicates that the Contracting category had the most responses. This indicates that the Contracting category had the most responses.

The experience of the survey respondents was categorized into different periods of experience. 10% of respondents have four or more years of experience in the construction industry. 7.50% (3) of the 55 respondents have 6–10 years of work experience, which is the least amount in any category. Of the 55 responders, 9 (22.50%) have 11–15 years of construction sector job experience. Ten of the 25.00% of respondents have 16–20 years of experience in the building sector. It has also been determined that, out of the 55 respondents, 35.00% (14) have greater knowledge and skill in the construction business, having worked for more than 20 years. Experts with over 20 years of experience in the building business make up a larger percentage of those who completed the questionnaire.

4.3 QUANTITATIVE DATA ANALYSIS

4.3.1 Impact of the Inefficiencies in the Material Waste Management on Construction Cost of the Projects in Sri Lanka (Buildings)

Results of this study provide an indication of the Relative Importance Index (RII) and rank of identified inefficiencies of the material waste management in the construction industry of Sri Lanka. Here, each inefficiency was ranked considering the impact on the project cost.

- The **Mean** value ($\bar{X}$) of the RII values is,

  $\bar{X}$ = **Σ RII / No. of Inefficiencies** $\bar{X}$ = 13.085/18

  $\bar{X}$ = 0.727

Table 2: Ranking of inefficiencies of highest impact

Inefficiencies	RII (X)	(X-$\bar{X}$)	Rank
Limited recycling facilities	0.830	0.103	1
Design changes and variations	0.800	0.073	2
Inefficient material handling	0.785	0.058	3
Poor workmanship	0.780	0.053	4
Poor quality control	0.765	0.038	5
Unstable market for recycled products	0.750	0.023	6
Limited technology adoption	0.735	0.008	7
Inaccurate material estimation /ordering more materials than required to avoid shortages	0.730	0.003	8
Poor regulations and enforcement	0.730	0.003	8

Based on the Relative Importance Index (RII), the inefficiencies affecting material waste management and construction costs in Sri Lankan building projects were ranked as follows:

Limited recycling facilities were rated as Very High in their negative impact, making them the most critical inefficiency. Design changes and variations followed with a high ranking, indicating a significant effect on costs. Inefficient material handling was also considered High, ranking third in impact. Poor workmanship received a Neutral ranking, reflecting a moderate influence on project expenses.

The unstable market for recycled products was rated as Neutral, though still important, with potential cost implications that could be reduced by improving local availability and use of recycled materials. Limited adoption of technology was ranked Low, showing less but still relevant impact on construction costs. Lastly, inaccurate material estimation (leading to over-ordering) and poor regulation and enforcement were rated Very Low, indicating a minor effect on construction costs according to respondents. RII values clearly show that there is high impact on construction costs of those inefficiencies.

Each inefficiency identified contributes to increased construction costs in specific ways. Limited recycling facilities and an unstable market for recycled materials force contractors to rely on new materials, which raises both procurement and disposal expenses. Design changes, inaccurate estimations, and inefficient material handling result in rework, material wastage, and project delays, all of which increase labour and material costs. Poor workmanship and inadequate quality control also lead to frequent defects and the need for corrective work. Furthermore, limited adoption of technology and weak regulatory enforcement hinder effective planning, monitoring, and coordination. These factors collectively increase overall project costs and reduce operational efficiency.

4.3.2 Reasons Applicable for the Inefficiencies in the Material Waste Management on Construction Cost of the Projects in Sri Lanka (Buildings)

Results of this study provide an indication of the Relative Importance Index (RII) and rank of identified reasons applicable to the inefficiencies in the material waste management in the construction industry of Sri Lanka.

- The **Mean** value ($\bar{X}$) of the RII values of these reasons is

  $\bar{X}$ = **Σ RII / No. of Reasons** $\bar{X}$ = 11.320 / 15

  $\bar{X}$ = 0.755

Table 3: Ranking of reasons applicable for the inefficiencies

Inefficiencies	RII (X)	(X-$\bar{X}$)	Rank
Inefficient design and planning processes	0.825	0.070	1
Lack of awareness of material handling and proper material waste management	0.820	0.065	2
Not enough regulations	0.815	0.060	3
Inaccurate measurement	0.805	0.050	4
Insufficient training practices	0.785	0.030	5
No proper guidance	0.765	0.010	6
Limited storage space	0.760	0.005	7

Inefficient design and planning processes were ranked as first major reason of applicable for the inefficiencies in the material waste management on construction cost of the projects in Sri Lanka (Building). Design errors and changes have severe impact on the project cost. Lack of awareness of material handling and proper material waste management was ranked as the second reason for the inefficiencies. By using Relative Importance Index, not enough regulations were found for the third reason applicable for the inefficiencies. Inaccurate measurement was identified as the fourth reason applicable to the inefficiencies of material waste management in the construction industry of Sri

Lanka. If any item is missed during construction phase, even if it can be constructed by supplementary work, it will cost higher than the first cost due to market fluctuations. Insufficient training practices was ranked fifth by respondents. The overall rank shows that no proper guidance was ranked as the sixth reason. Limited storage space was ranked as the seventh reason.

4.3.3 Strategies to Overcome the Inefficiencies in the Material Waste in the Construction Industry of Sri Lanka (Buildings)

The identified main strategies for overcoming the inefficiencies in material waste were identified based on the ranks made according to the results of the RII.

- The **Mean** value ($\bar{X}$) of the RII values of these inefficiencies is

  $\bar{X}$ = **Σ RII** / **No. of Inefficiencies** = 8.050 / 10

  $\bar{X}$ = 0.805

Table 4: strategies for overcoming the inefficiencies in material waste

Inefficiencies	RII (X)	(X-$\bar{X}$)	Rank
Invest in proper material storage facilities and recycling facilities	0.850	0.045	1
Use of strict and rigorous waste management policies and practices at site level and creating some motivational and incentive schemes for workers and staff working towards these goals	0.850	0.045	1
Carry out the material waste management plans for every project into the initial planning and design phase	0.840	0.035	3
Develop comprehensive awareness programs and training programs about material waste management	0.830	0.025	4
Implement quality control measures to reduce material defects and waste	0.820	0.015	5

The analysis reveals that the top strategies for overcoming inefficiencies in material waste management in the construction industry of Sri Lanka include investing in proper storage and recycling facilities, using strict waste management policies and practices at the site level, and creating motivational and incentive schemes for workers and staff. The government should implement a construction material waste reduction plan policy, outlining permissible amounts and management techniques, along with incentives and penalties for construction companies.

The third strategy is to implement material waste management plans for every project during the initial planning and design phase, ensuring efficient designs and strict rules on construction sites. The fourth strategy is to develop comprehensive awareness programs and training programs about material waste management, promoting education and research for construction workers and staff.

The fifth strategy is to implement quality control measures using the Relative Importance Index (RII = 0.820) to reduce material defects and waste. Quality management software can be used to control quality throughout the project.

Other strategies include using suitable material and waste management software systems, adopting proper stock balance procedures, enabling flexible delivery schedules, improving mathematics knowledge, and using new technologies like Building Information Modelling (BIM) for waste management.

We should use and try to adopt more efficient new technologies, such as AI-based tools and modules like BIM and Revit. These advanced technologies can greatly enhance our project management, improve accuracy, and streamline various processes, ultimately leading to better outcomes and reducing inefficiencies. Establishing a proper ERP system for the construction industry would help overcome this issue. It will facilitate linking each department to ensure minimal wastage and optimal use of materials. Additionally, using a mobile app to update relevant details linked to the ERP system can further improve the process. Implementing the Lean Six Sigma methodology would also help run the project smoothly and minimize waste by addressing every bottleneck in the process.

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This section provides a concise overview of the entire study, highlighting key findings and how the research objectives were addressed. Effective material waste management is crucial for reducing construction costs and minimizing environmental impact. Traditional construction methods often result in excessive waste, but the integration of circular economy principles, precise planning, and technologies like Building Information Modelling can significantly reduce these inefficiencies. Reusing materials, improving on-site handling, and engaging all stakeholders contribute to better outcomes. With innovative strategies, regulatory compliance, and a focus on sustainability, the construction industry can achieve both environmental responsibility and cost efficiency.

The Sri Lankan construction industry faces significant inefficiencies in material waste management, affecting project performance. These include limited recycling infrastructure, frequent design variations, and poor on-site material handling. Systemic issues like inadequate design processes, lack of regulatory enforcement, and inaccurate estimation methods further contribute to these inefficiencies. The sector needs a paradigm shift embracing digital transformation, institutional accountability, and continuous improvement. Key recommendations include investing in site-level infrastructure, institutionalizing strict waste management policies, and leveraging advanced digital tools. This holistic transformation can lead to greater cost-efficiency, resource optimization, and environmental sustainability.

5.2 RECOMMENDATIONS

The following recommendations are given on the impact of material waste management on construction costs of projects in the Sri Lankan construction sector based on the findings and results of this study. Recommendations for the Sri Lankan Government

The government should implement a construction material waste minimization plan, highlight acceptable amounts and management methods, and offer incentives and penalties for inefficiencies. On-site appointments of a material waste officer can help control waste inefficiencies. Regulations should be passed to manage construction waste materials, and adherence should be closely monitored. A recycling market should be

established through policies that support this. Mandatory workshops on waste management inefficiencies and their impact on construction costs should be mandatory for all parties involved. Regular material specifications in contract documents should be changed to reduce the need for regular materials in government buildings.

5.2.1 Recommendations for the Sri Lankan Construction Industry

Construction sites should invest in weatherproof storage facilities and hazardous material storage to prevent pollution and waste. Engage with local communities to develop recycling programs and partner with recycling companies. Adopt advanced technologies like AI-based tools and waste management software to improve project management and reduce inefficiencies. Establish an Enterprise Resource Planning (ERP) system to link departments and minimize wastage. Implement Lean Six Sigma methodology to address bottlenecks and minimize waste.

Workers and staff should work together, and awareness campaigns, education, and research on waste management are essential. Employees should receive ongoing training on material handling and installation. Designers should carry out efficient designs, and contractors should enforce strict rules to minimize waste. Motivational and incentive schemes can motivate workers and staff towards waste management goals. Close supervision and material availability monitoring are crucial for achieving these goals.

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