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Unveiling Construction and Demolition Waste Dynamics: A Case Study of the Building Construction Sector in Sri Lanka

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Abstract: Construction and demolition waste (CDW) generation is an increasing global concern. Despite the significance of the construction industry to the economy of Sri Lanka, limited studies have been conducted on this topic, and no proper guidelines have been developed. Therefore, a comprehensive study on CDW is necessary to establish the required framework for developing guidelines for effective CDW management. This study aims to address this gap by investigating CDW generation in the building construction sector in Sri Lanka. The study examines the generation patterns and current management strategies of CDW in different phases at different conditions of significant construction projects in Sri Lanka. To ensure a representative sample, construction sites in the Colombo and Kandy districts were carefully selected, representing various project types and stakeholders, including public and private owners, commercial establishments, residential projects, and office structures. Data was collected by a rigorous questionnaire survey of stakeholders from 32 construction and demolition projects, complemented by face-to-face interviews with responsible higher officials. Key findings include high average wastage percentages for asbestos (7.4%) and ceramic tiles (7.1%), varying concrete wastage rates across building types (8.2% in high-rise structures, 5.2% in low-rise buildings, and 4.0% in medium-rise buildings), and potential inefficiencies in material use procedures. Substructure components show room for improvement in material consumption, with a wastage percentage of 6.3%, while superstructure components demonstrate relatively efficient material management, with a wastage ratio of 4.8%. Analysis of demolition waste composition reveals significant proportions of brick (25%), concrete (20%), timber (8%), and steel (6%), highlighting the importance of proper handling and disposal practices. Overall, finding of this study show that comprehensive waste management strategies are required, and the types of waste generated during building construction vary depending on factors such as construction stage, building size, contractor grade, etc.

Keywords: Construction waste, Demolishing waste, Building construction, Waste generation

1. Introduction

Construction and demolition waste (CDW) encompasses all non-hazardous solid waste stemming in the construction and demolition works, comprising materials such as concrete, bricks, steel, timber, asbestos, masonry, cement plaster, metal, asphalt, and more. Research indicates that these processes consume approximately 25% of raw wood and 40% of rough gravel and sand annually [1]. Notably, the demolition of buildings contributes significantly to global waste generation, accounting for 40% of the world's total waste [2].

This issue transcends local boundaries, affecting countries worldwide. For instance, in Australia, construction waste constitutes 15% of the total solid waste generated [3]; in Malaysia, it reaches 41% [4]. Similarly, Hong Kong and India experience significant proportions, with construction waste comprising 23% and 25% of their total waste, respectively [5]. Alarmingly, much of this waste ends up in landfills globally, highlighting a pressing environmental concern.

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Various activities within the construction sector contribute to waste generation, including construction, renovation, demolition, land clearing, responses to natural disasters, and other related processes [6]. When examining the causes of waste generation within building construction, it becomes evident that factors can be categorized into human-related and other external influences. Understanding these intricacies is crucial for developing effective waste management strategies and mitigating the environmental impact of construction activities.

This oversight is particularly concerning given the steady increase in construction activity over the past decade. With the construction industry emerging as a pivotal contributor to the country's GDP, experiencing a notable expansion of 1.4% in the latter half of 2018, its importance cannot be overstated [7]. Notably, the building construction sector stands out as the primary driver within the construction domain, accounting for 47% of all construction activities.

Despite the construction industry's robust growth and substantial economic impact, scant attention has been directed towards addressing the CDW generation and management issues in Sri Lanka. A few studies, such as those conducted by Jayewardene et al. in the early 1990s, have delved into this aspect, revealing alarming levels of material wastage on construction sites [8]. Further, a study was conducted in Sri Lanka to estimate construction material waste in local sites [9].

Unfortunately, a significant gap exists in Sri Lanka in accurately accounting for the volume of construction waste generated. Moreover, although the management of CDW is addressed under Sri Lanka's National Environment Act [10], there are no specific guidelines or recommendations developed to effectively tackle the CDW issue. Compounding this challenge is the absence of established procedures for implementing environmentally sound management systems for CDW in Sri Lanka. Tissera et al. (2022) reported the necessity of revised rules and regulations regarding the management of CDW [11].To alter or develop rules and regulations regarding the management of construction and demolition waste, a knowledge of CDW generation is essential. Therefore, this gap underscores the urgent need for comprehensive research to unravel the complexities of CDW management in the Sri Lankan construction sector and pave the way for developing practical guidelines.

Therefore, this research aims to investigate the construction and demolishing waste generation in the Sri Lankan construction industry to gather preliminary information to develop environmentally sound waste management strategies. This study is focused on building construction projects as the primary construction sector.

This study investigated the generation, generation pattern, and the present management practices of CDW in various stages of the building construction projects in Sri Lanka through a comprehensive questionnaire survey.

2. Materials and Method

2.1 Study Area and Sample Selection

Building construction sites in the Colombo and Kandy districts of Sri Lanka were selected with various project types and stakeholders to ensure a representative sample. This included public owners, private owners, commercial establishments, residential projects, and office buildings. Additionally, various project values were considered to capture the full spectrum of construction activities in the respective districts by including a mix of public and private ownership and different types and scales of projects. The sample aimed to provide comprehensive insights into the construction landscape in Colombo and Kandy Districts in Sri Lanka.

2.2 Data Collection

A detailed questionnaire survey collected information from various stakeholders involved in 32 construction and demolition projects (24 construction sites and 8 demolishing sites). Face-to-face interviews were conducted with responsible higher officials such as site engineers, project engineers, and project managers. The questionnaire employed in this study was meticulously crafted to encompass various dimensions of waste generation in construction activities. It delved into critical aspects such as the type of construction being undertaken, ranging from low-rise to high-rise buildings, which enabled a comprehensive examination of waste generation across different building types. Additionally, the questionnaire explored the contractor grade involved in the construction process, shedding light on the correlation between contractor expertise and waste management efficiency. Furthermore, the stage of construction was analysed to understand how waste generation varies throughout the different phases of a construction project, from initial groundwork to finishing touches. Moreover, the questionnaire included participant's (i.e., construction company's) general information.

2.3 Estimating of Construction and Demolition Waste Generation

The estimation of waste generation percentages for various materials was conducted by comparing the delivered quantities with the amounts utilized and billed, as outlined in Eq. 1 below.

$$\textbf{Average wastage generation}(\%) = \frac{(\mathbf{X_1} - \mathbf{X_2})\mathbf{x100}}{\mathbf{X_1}} \qquad (\textbf{Eq. 1})$$

where X_1 = delivered quantity of materials
X_2 = materials against those utilized for billed quantities

The percentages of demolishing waste were determined through an estimation process, relying on the volumes of waste identified at demolishing waste storage sites. This estimation involved approximate volume calculations to gauge the proportion of waste generated during demolition activities.

2.4 Determination of Contractor Grades and Types of Building Projects

Respondents provided the classification of contractor grade depending on the National Registration and Grading Scheme for Construction Contractors [12]. Moreover, the types of buildings were categorized as low-rise, medium-rise, and high-rise according to the general guidelines of the Urban Development Authority Sri Lanka [13].

2.5 Data Analysis

The data were analysed by comparing the mean and standard deviation values across the different datasets. The mean provided a measure of central tendency, indicating the average value of the data, while the standard deviation offered insights into the variability and dispersion of the data points around the mean. This approach allowed for a comparison, highlighting both the central trends and the degree of variation within the datasets, thereby ensuring a comprehensive understanding of the observed differences.

3. Results and Discussion

3.1 Construction Waste Generation from Different Materials

Table 1 summarises the average construction wastage percentage of construction waste of buildings surveyed. When it comes to construction waste management, understanding the typical percentages of waste for different materials generated is essential to developing strategies that reduce environmental impact and maximize resource efficiency. Materials that require careful handling and usage procedures include asbestos and ceramic tiles, which have comparatively high average waste percentages of 7.4% and 7.1%, respectively. On the other hand, materials such as plastics show lower waste rates, with an average of only 2.6% being thrown away. These numbers offer insightful information about the areas that may need immediate interventions to maximize resource use and lessen the adverse environmental effects of building operations.

Table 1 - Average Construction Waste Percentages of Different Construction Materials (n = 24)

Material	Average wastage (%)		Material	Average wastage (%)
Asbestos	7.4 ± 5.1		Cement	5.1 ± 0.4
Ceramic tiles	7.1 ± 4.5		Sand	4.9 ± 0.3
Blocks	6.9 ± 0.6		Electric wires	4.7 ± 2.6
Soil	6.7 ± 5.8		Paints	4.6 ± 3.0
Timber	6.1 ± 2.1		Steel	4.3 ± 1.1
Bricks	5.8 ± 0.1		Rubble	4.2 ±0.7
Concrete	5.6 ± 1.9		Aluminum	3.9 ± 0.6
Lime	5.3 ± 2.9		Plastics	2.6 ± 0.3
Glass	5.2 ± 3.3			

According to past studies, Jayawardene (1994) found that concrete and mortar wastage constitute a significant portion, accounting for up to 21% and 25% of total wastage on construction sites. Moreover, Rameezdeen et al. (2004) carried out studies in Sri Lanka to quantify construction material waste in local sites [9]. Their findings revealed that sand is the primary material with the highest wastage, comprising 25% of the total waste collected. Additionally, lime waste (20%), cement waste (14%), brick waste (14%), ceramic tile waste (10%), and timber waste (10%) were identified as significant contributors to overall waste. However, the waste generation percentages in the present study were significantly lower than those reported by Rameezdeen et al. (2004). This is probably due to applying new and developed strategies in modern construction processes.

Using this data, stakeholders may adjust waste management initiatives to concentrate on items with excellent waste rates, encouraging resource stewardship and sustainability within the construction industry.

3.2 Waste Generation from Different Building Categories

As shown in Table 2, the study of construction waste generation across different building types reveals exciting differences in wastage rates for various materials.

Table 2 - Constrcution Waste Generation in Different Types of Buildings (n = 24)

Material	Average wastage generation (%)		
	Low rise buildings	Medium rise buildings	High rise buildings
Concrete	5.2 ± 2.8	4.0 ± 1.4	8.2 ±2.0
Bricks	5.3 ± 2.5	4.3 ± 0.8	8.1 ±0.4
Blocks	6.4 ± 4.4	5.4 ± 3.0	9.2 ±1.4
Cement	4.6 ± 0.5	5.4 ± 1.4	5.1 ±0.4
Rubble	5.8 ± 0.4	2.7 ± 1.9	5.2 ±0.2
Soil	8.7 ± 8.1	7.6 ± 6.5	4.3 ±3.2
Steel/Reinforcement	5.1 ± 1.8	4.6 ± 1.4	3.2 ±1.2
Timber	10.1 ± 4.1	5.6 ± 2.8	3.8 ±0.5
Sand	4.2 ± 0.6	4.7 ± 1.0	5.0 ±1.4
Plastics	4.0 ± 1.4	1.5 ± 0.7	3.5 ±0.7
Aluminum	4.9 ± 0.4	3.1 ± 2.7	3.2 ±0.2
Lime	5.0 ± 0	4.5 ± 4.0	7.0 ±0
Glass	6.3 ± 3.5	3.1 ± 3.5	6.0 ±3.0
Ceramic tiles	7.3 ± 4.7	5.6 ± 3.8	9.1 ±5.1
Electric wires	6.3 ± 2.5	3.5 ± 2.9	5.6 ±1.8
Paints	4.2 ± 3.1	4.5 ± 3.6	4.4 ±2.4
Asbestos	9.0 ± 6.6	5.0 ± 0	N/A

Concrete, a construction mainstay, varies significantly in waste across building types, with high-rise structures producing the highest average wastage of 8.2%, compared to 5.2% in low-rise buildings and 4.0% in medium-rise buildings. The lowest waste generation in medium-rise buildings compared to low-rise buildings can be attributed to more efficient design and construction practices often employed in medium-rise projects, which aim to maximize space utilization and reduce material usage. The waste types such as bricks and blocks follow a similar pattern, with higher-rise buildings resulting in more significant wastage percentages. Interestingly, materials such as steel and timber exhibit a different pattern, with low-rise buildings having the most critical waste percentages, indicating possible inefficiencies in material use procedures for such structures. This data stimulates a discussion on the elements that influence waste creation in construction, such as design complexity, construction methods, and project scale.

This data inspires a debate on the elements that influence waste generation in construction, such as design complexity, construction processes, and project scale, and emphasizes the significance of tailoring waste management systems to different building types [14]. Further study should focus on identifying measures to reduce waste in high-rise buildings, where environmental and economic consequences of material inefficiencies are particularly severe.

Furthermore, investigating the possibility of integrating prefabrication and modular construction techniques may provide opportunities for decreasing material waste across all building types [15].

Table 3 - Average Construction Waste Percentages of Different Materials in Different Construction Phases (n = 24)

Material	Average wastage generation (%)		
	Substructure	Superstructure	Finishes
Concrete	6.9 ± 6.3	6.4 ± 6.2	3.4 ± 3.2
Bricks	5.7 ± 3.1	5.8 ± 4.0	5.9 ± 5.2
Blocks	7.4 ± 8.5	6.9 ± 6.8	6.3 ± 5.6
Cement	4.8 ± 4.0	5.0 ± 3.8	5.6 ± 4.2
Rubble	4.7 ± 3.4	3.7 ± 3.3	2.7 ± 1.5
Sand	5.2 ± 3.8	4.5 ± 2.6	5.1 ± 3.7
Steel	4.3 ± 3.0	5.4 ± 3.4	3.3 ± 2.7
Timber	7.6 ± 6.1		4.6 ± 3.3
Plastic		2.4 ± 1.5	2.9 ± 1.2
Soil	10.8 ± 8.6		
Aluminum		3.5 ± 3.0	4.4 ± 3.3
Glass			5.2 ± 3.3
Ceramic tiles			7.1 ± 4.5
Electric wires			4.7 ± 2.6
Asbestos			7.4 ± 5.1
Paints			4.6 ± 3.0
Lime			5.3 ± 2.9

3.3 Construction Waste Generation at Construction Phases

Analysis of typical waste generation percentages across various construction materials gives fascinating insights into the dynamics of material consumption across distinct construction phases, substructure, superstructure, and finishes (Table 3). Notably, concrete, a key component in construction, varies significantly in waste percentages between building types, with finishes having the lowest average wastage of 3.4% compared to

6.9% in the substructure and 6.4% in the superstructure. Materials such as bricks and blocks, on the other hand, show very similar waste rates throughout building types, implying that material inefficiencies persist independent of building height [16]. However, certain materials, such as timber and plastic, exhibit considerable swings in waste percentages, indicating potential prospects for improving material use procedures, particularly in the superstructure and finishes phase.

Further studies should focus on identifying particular treatments targeted at different construction phases to maximise material use and reduce waste creation in construction projects.

3.4 Overall Construction Waste Generation during the Different Construction Phases

Figure 1 shows the average waste generation percentage under different stages of the building construction projects from substructure to finishes. Examining waste percentages across various components of building construction provides valuable insights into prospective waste reduction and resource optimization opportunities. Substructure components, which comprise foundational materials, have a waste percentage of 6.3%, indicating the potential for more effective material consumption and construction procedures during this crucial period of building development. Meanwhile, superstructure components, which cover the building's primary structural elements, have a waste ratio of 4.8%, indicating relatively excellent material management in this construction phase. However, finishes with surface treatments and decorative features have a higher waste ratio of 5.6%, suggesting possible inefficiencies in material selection, procurements, installation, or disposal processes [17].

3.5 Contribution of Factors for Construction Waste Generation in Different Construction Phases

The contributions of various factors were analysed to investigate the significant causes of construction waste generation. Table 4 shows the contribution of five critical factors to construction waste generation during the different stages of building projects.

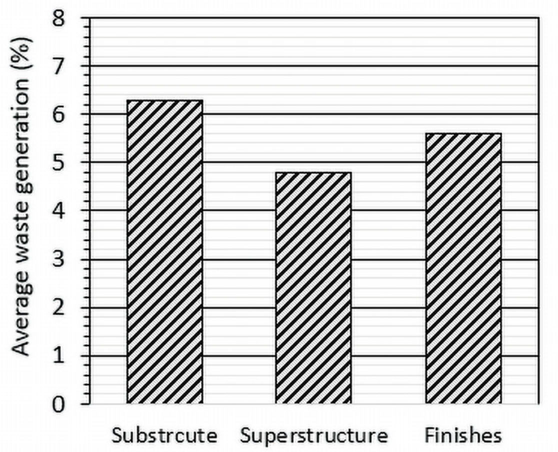

Figure 1 - Average Wastegate Percentages of Different Construction Phases

Analyzing the causes of waste generation across different construction components sheds light on key factors influencing inefficiencies in the construction process. Design changes significantly contribute to waste generation, with a medium impact observed across all components—substructure, superstructure, and finishes. This suggests that alterations in design plans during the construction phase can lead to material wastage, highlighting the importance of robust planning and coordination [18]. On the other hand, procurement errors exhibit a varying impact, with low levels observed in substructure and superstructure but a medium impact in finishes, underscoring the need for meticulous attention to detail in material sourcing and procurement processes. Improper handling of materials emerges as a notable cause of waste across all components, with an exceptionally high impact observed in finishes, indicating potential inefficiencies in material transport, storage, and installation practices.

Operational errors, including faults in construction execution, influence all components moderately, underscoring the significance of solid quality control procedures throughout the construction process. Bad weather also contributes to waste formation, albeit to a lesser level, with medium influence on the substructure and low impact on the superstructure and finishes [19].

Table 4 - Contribution of different Factors for Waste Generation in Various Construction Phases

Causes of waste generation	Substructure	Super structure	Finishes
Design changes	Low	Medium	Medium
Procurement errors	Low	Low	Medium
Improper handling of materials	Medium	Medium	High
Operational errors	Medium	Medium	Medium
Bad weather	Medium	Low	Low
Other	Low	Low	Low

3.6 Effect of Contractor Grades on Construction Waste Generation

Analyzing construction waste generation across different contractor classes indicates no notable differences in typical waste-generating percentages, as depicted in Figure 2. However, lowest-grade contractors (C3) have excellent average waste generation rates, whereas other contractors generate less waste. Further research may need to examine particular techniques higher-performing contractors use and allow knowledge sharing to promote industry-wide sustainability efforts [20].This helps to develop a relationship between contractor grade and waste management efficiency, with higher-grade contractors possibly implementing more effective waste reduction techniques, or the attitude and behavioral factors in waste management may vary among the grades of the organizations [20].

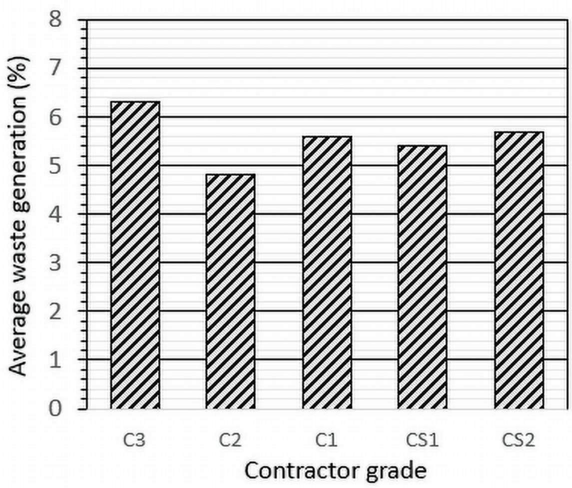

Figure 2 - The Construction Waste Generation Across Different Contractor Classes

3.7 Compositions of Building Demolishing Waste

As shown in Figure 3, the analysis of demolition waste composition reveals significant proportions of various materials, with brick constituting the highest percentage at 25%, followed by concrete at 20%, timber at 8%, steel at 6%, asbestos and aluminum each at 4%, and glass at 3%.

Notably, a substantial portion, accounting for 30%, comprises plastering and other miscellaneous materials. These findings prompt a discussion on the factors contributing to the composition of demolition waste and comparisons with past literature. Possible reasons for the high percentages of brick and concrete waste may include the prevalence of these materials in older structures and the labour-intensive nature of their removal during demolition [21]. Similarly, the relatively high percentages of timber and steel waste may be attributed to their everyday use in construction and their recyclability, which can result in salvaging efforts during demolition. Due to their hazardous nature, asbestos and aluminium waste underscores the importance of proper handling and disposal practices.

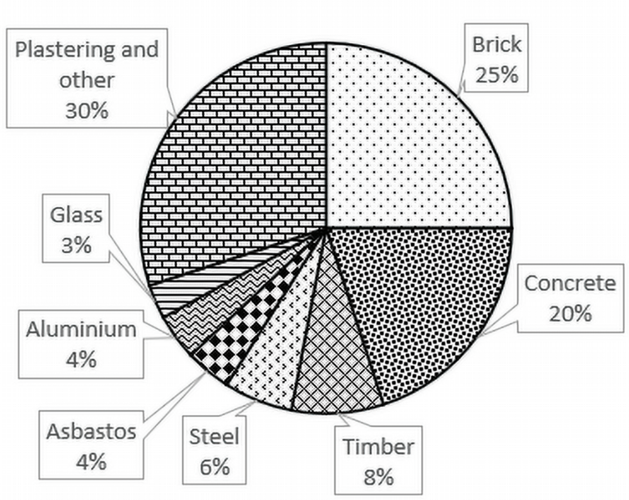

Figure 3 - Average Materials Wastegate Percentages of Demolishing Works (n=8).

The results of this study stimulate a debate on the elements that contribute to waste development in construction, such as building processes, project scale, and material management procedures. Furthermore, investigating measures to reduce material waste, such as enhanced inventory management and on-site material recycling, may provide exciting opportunities for increasing resource efficiency and lowering environmental impact across all construction phases. Further research could delve into the effectiveness of waste management strategies in mitigating the environmental impact of demolition activities and identifying opportunities for improving recycling and reuse practices to reduce the overall volume of demolition waste.

4. Summary and Conclusions

Key discoveries about the distribution and possible mitigation of waste are highlighted by analysing CDW generation across building construction stages. Substructure components, in particular, have a waste rate of 6.3%, indicating potential for improvement in material consumption and construction techniques throughout the foundational phases. On the other hand, superstructure parts have a reduced waste ratio of 4.8%, suggesting that material management of fundamental structural elements is reasonably practical. Finishes, which include surface treatments and decorative elements, exhibit a waste ratio of 5.6%, which suggests that there may have been inefficiencies in the processes of material selection, installation, or disposal. When the leading causes of CDW generation are investigated, it becomes clear that elements like poor material handling, design modifications, poor procurement, operational mistakes, and unfavorable weather play a crucial role.

These results emphasise the significance of careful planning, strict quality control procedures, and rigorous procurement procedures in minimising waste in the building process. Additionally, it seems that contractor grade affects the effectiveness of waste management; contractors with higher grades may employ more efficient waste reduction techniques.

When demolition waste is compared to earlier research, significant materials, including brick, concrete, timber, and steel, ignite debates about factors influencing trash composition and opportunities for better waste management practices. Overall, results of this show that comprehensive waste management strategies are required, and the nature of the waste generation in building construction varies with various factors such as construction stage, building size, contractor grade, etc.

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References

1. Hobbs, G., "The Smartway to Reduce Construction Waste". *Wastes Management*,2000, pp.20-40.

2. Roach, I., "Diverting Lightweight CandD Waste from Landfill". *Wastes Management*,2001, p.23.

3. McDonald, B. and Smithers, M., "Implementing a Waste Management Plan during the Construction Phase of a Project: A Case Study". *Construction Management and Economics*, Vol. 16, No 01,1998,pp. 71–78.

4. Mei, M.C., "The Construction and Demolition Waste Management in Malaysia: the Life Cycle Assessment Analysis Approach to Sustainability". 2017.

5. Poon, C. S., and Chan, D., "The Use of Recycled Aggregate in Concrete in Hong Kong". *Resources, Conservation and Recycling,* 2007, Vol.50, pp.293–305.

6. Laquatra, J., and Pierce, M., "Waste Management at the Construction Site". *Integrated Waste Management*, Vol. 1, 2011, pp.281-300.

7. National Accounts of Sri Lanka 2nd Quarter of 2018. "Department of Census and Statistics. Ministry of National Policies and Economic Affairs Sri Lanka", 2009.

8. Jayawardane, A. K. W., Are We Aware of the Extent of Wastage on our Building Construction Sites?, *Engineer*, Vol. 20, No 2, 1994,pp. 41-45.

9. Rameezdeen, R., Kulatunga, U. and Amaratunga, D., "Quantifying Construction Material Waste in Sri Lankan Sites". *Proceedings: International Built and Human Environment Research Week*, 2004, pp. 1-9.

10. Basnayake, B. F. A., Ariyawansha, R. T. K., Karunarathna, A. K., Werahera, S. M. and Mannapperuma, N., "Sustainable Waste Management Challenges in Sri Lanka" *In Sustainable Waste Management Challenges in Developing Countries* 2020, pp. 352-381. IGI Globale.

11. Tissera, W. D. A. C., Dahanayake, R. and Edirisinghe, V., 2022. "The Applicability of Regulations for the Disposal of Construction and Demolition Waste in Sri Lanka". *Proceedings of the 10th World Construction Symposium*, Sri Lanka. pp. 821-832.

12. National Registration and Grading Scheme for Construction Contractors. https://www.cida.gov.lk/sea_con/pages_e.php?id=124 (Visited on 30th March 2023).

13. General Regulation (Part 1), Urbuam Development Authority, Sri Lanka (2018), https://www.uda.gov.lk/attachments/devplan_detailed/for_public_comments/General%20Regulation-%20Report_2018.11.08.pdf (Visited on 30th March 2023).

14. Luangcharoenrat, C., Intrachooto, S., Peansupap, V. and Sutthinarakorn, W., "Factors Influencing Construction Waste Generation in Building Construction": *Thailand's Perspective. Sustainability*, Vol. 11, No 13, 2019, p.3638.

15. Lu, W., Lee, W. M., Xue, F. and Xu, J., "Revisiting the Effects of Prefabrication on Construction Waste Minimization: A Quantitative Study using More Extensive Data". *Resources, Conservation and Recycling*, Vol. 170, 2021, pp.105579.

16. Meng, T., Shan, X., Ren, Z. and Deng, Q., "Analysis of Influencing Factors on Solid Waste Generation of Public Buildings in Tropical Monsoon Climate Region". *Buildings*, Vol. 14, No 2, 2024, p.513.

17. Ajayi, S. O., Oyedele, L. O., Akinade, O. O., Bilal, M., Alaka, H. A. and Owolabi, H. A., "Optimising Material Procurement for Construction Waste Minimization: An Exploration of Success Factors". *Sustainable Materials and Technologies*, Vol. 11, 2017,pp.38-46.

18. Alaloul, W. S., Liew, M. S. and Zawawi, N. A. W. A., "Identification of Coordination Factors Affecting Building Projects Performance". *Alexandria Engineering Journal*, Vol. 55, No. 3, 2016, pp.2689-2698.

19. Nagapan, S., Rahman, I. A. and Asmi, A., "A Review of Construction Waste Cause Factors. In Asian Conference on Real Estate": *Sustainable Growth Managing Challenges* (ACRE) 2011, pp. 967-987.

20. Begum, R. A., Siwar, C., Pereira, J. J. and Jaafar, A. H., "Attitude and Behavioral Factors in Waste Management in Malaysia's Construction Industry". *Resources, Conservation and Recycling*, Vol. 53, No 6, 2009, pp.321-328.

21. Mah, C. M., Fujiwara, T. and Ho, C. S., "Construction and Demolition Waste Generation Rates for High-Rise Buildings in Malaysia". *Waste Management & Research*, Vol. 34, No. 12, 2016,pp.1224-1230.