DEVELOPING AN EFFECTIVE WASTE MANAGEMENT PLAN FOR BUILDING CONSTRUCTION SITES

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Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree
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Declaration

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Abstract: Construction and demolition waste is a major problem to the environment as 40% of worldwide waste is generated from the construction industry. Waste material is generated in building construction sites as a result of construction, demolition, renovation, excavation, and site clearances. Construction waste constitutes reusable or recyclable materials such as concrete, steel, wood, ceramic tiles, bricks, cement blocks, cement mortars and paints. However, 35% of construction waste is directly dumped into the landfills without any further reusing or recycling due to the lack of onsite or offsite sorting. Since a considerable amount of waste materials is ended up as waste, management of the construction waste is very much a crucial economic and environmental challenge to project stakeholders. This research examined the applicability of various waste sorting methods that are essential before reusing and recycling. Three waste sorting methods were considered, namely: (i) onsite sorting based on material type (ii) onsite sorting based on economic value, and (iii) offsite sorting based on economic value. These methods were studied based on eleven influencing factors through a questionnaire survey on Construction Project Managers, Planning Engineers, Site Engineers, and Quantity Surveyors who were at 30 sites across Sri Lanka. Based on the responses, the most applicable sorting method was found as '(ii) onsite sorting based on economic value'. The most influencing factors for all sorting methods were 'management effort', 'market for recyclables', 'waste sortability', and 'site space'. 'Management effort', the most critical factor, was found to be a result of 'lack of waste sorting out process', 'high labour involvement in sorting process', and 'lack of market for recyclable products. This research therefore encourages the construction project stakeholders to leverage 'onsite sorting based on economic value' with increased "Management effort" to improve waste sorting for reusing and recycling and contribute towards reducing worldwide waste.

Key Words: Construction waste, Construction and Demolition waste; obstacle for waste sorting; Construction waste sorting techniques; waste

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Table of Contents

1: INTRODUCTION 1

1.2Aim & objectives of the research 2

1.3 Scope of the study 2

1.4 Significance of the study 3

1.6 Structure of the report... 3

2: LITERATURE REVIEW 5

2.1. Introduction to Construction Waste 5

2.2 Types of construction waste 5

2.3 Causes and sources for material wastage 6

2.3.1 Sources of construction waste.. 6

2.3.2 Waste generation in Pile construction 9

2.3.3 Practical measures adaptable for on-site waste minimization 9

2.4 Waste sorting methods in building construction 11

2.5 Efficient methods and techniques in waste management 12

2.5.1 The requirement for construction waste sorting on-site 12

2.5.2 Efficient waste sorting methods 14

2.6 Waste sorting influencing factor identification 17

2.7 Challenges in waste management & sorting 21

2.8 Proposals for effective waste sorting and management 24

2.9 Chapter summery 26

3. METHODOLOGY 28

3.1 General 28

3.3 Task I- Waste sorting methods 31

3.4 Waste sorting influencing factor identification 32

3.5 Task II-Challenges and opinions for waste sorting effectiveness & management 35
3.6 Proposing practices for effective waste sorting & management 36
3.7 Sample selection. 37
3.7.1 Target group 38
3.8 Method of data analysis 39
3.8.1 Descriptive Mean Testing 39
3.8.2 Reliability Analysis 39
4. DATA COLLECTION & ANALYSIS 41
4.1 General 41
4.2 Data collection 41
4.2.1 Current practices for the generated waste 43
4.2.2 Influencing factor ranking 45
4.3 Discussion- waste sorting options 53
4.3.1 Comparison of proposed construction waste sorting options 53
4.3.3 Minor factors for waste sorting 55
4.5 Discussion of management practices for effective waste sorting & management 57
4.5.1 Obstacles to waste management at sites 58
4.5.3 Relation between waste sorting practices and management practices 59
5. CONCLUSIONS & RECOMMENDATIONS 61
5.1 Conclusions 61
5.2 Recommendations 62
5.3.1 Waste Reduction through Precast Products 63
References 64
Bibliography 67

List of Tables

Table 1: Sources for generation of waste 7

Table 2: Construction waste composition in different countries 8

Table 3 Comparison of materials used for Piling in Vietnam (Thanh Long Ngo, 2011) 9

Table 4: Categorization of Respondents 38

Table 5: Proposed distribution of respondents 38

Table 6: Distribution of the research respondents 42

Table 7:Influencing index for each factor for each option of waste sorting 53

List of Figures

Figure 1:Formwork sorting at Angulana Site (State Engineering Corporation) 14

Figure 2:Waste refuser fabricated by GI barrels (Source: Angulana Site) 14

Figure 3: Waste Refusal after sorting (Source: Angulana Site) 15

Figure 4:Waste sorting methods (Hossain, Wu, & Poon, 2017) 16

Figure 5:Inadequate site space for waste sorting an storing (Borella site-SEC) 17

Figure 6: Mapping of waste handling (Shen LY, 2004) 19

Figure 7:Precast concrete product from recyclables (SEC-Ekala) 26

Figure 8:Research methodology adopted in the study 29

Figure 9:Construction waste management system through waste sorting 31

Figure 10: Distribution of respondents 43

Figure 11: Current practices for construction waste in the industry 44

Figure 12:Influencing Factors for Option I 47

Figure 13:Influencing Factors for Option II 49

Figure 14:Influencing Factors for Option III 51

Figure 15: Best management practices for waste sorting & management 57

Figure 16: Obstacles to effective waste sorting & management 58

List of Abbreviations

Abbreviation	Description
CIDA	Construction Industry Development Authority
COWAM	Construction Waste Management Project

List of Appendices

Appendix	Description	Page
Appendix A	Questions for the Survey	68
Appendix B	Evaluation of Responces	81
Appendix C	Project List	96

1: INTRODUCTION

Reaching the sustainable goals of the construction industry have become a huge challenge, since the high rate of waste generation is more than other industries. Also, the waste generation per year has doubled with the rapid development in the construction industry (Hossain, Wu, & Poon, 2017) since the application of waste management practices is in the primary stage. A considerable portion of waste is dumped into the landfills without any further process which cause severe damage to the ecosystem in the environment.

The construction sector is categorized into three sub-sectors as building, infrastructure, and industrial Among these, the building construction sector plays a vital role in the economy of Sri Lanka as the fourth largest sector, contributing 6-7% to the GDP (The Central Bank of Sri Lanka-2020). Because of that, all governments are highly focused towards the construction sector and invests in it to boost the economy.

The construction industry makes up a significant proportion of daily generated waste in Sri Lanka, and the primary factor of waste generation in the construction industry has been identified as design modifications during the construction stage and due to a shortage of interest in dimensions and poor workmanship (Kulatunga, Amaratunga, Haigh, & Rameezdeen, 2007).

Construction waste usually consists of a portion of inert materials (sand, concrete, cement block) and a portion of non-inert materials (Plastic, wood, paper, etc..) (Poon, Ann, & Ng, 2001). This waste is directly sent into landfills without any sorting method. In the Sri Lankan context, concrete and cement mortar hold the highest percentage of the waste percentage of 21% and 25% respectively (Rameezdean, Kulatunga, & Amaratunga, 2004) Hence, a considerable portion of funds invested are wasted .However, there is a portion of that waste that cannot be eliminated as well since that waste cannot be recycled or sorted to use for any other work. Moreover, less awareness of optimum resource-oriented methods and practices has led to the generation of a large quantity of waste and, the least awareness of the recycling methods for that waste.

As per the process of construction, direct waste and indirect waste are the two types of waste that can be sorted. Losing materials physically is named as direct waste and the loss of money due to payment for unsuitable material is called indirect waste (Skoyles & Skoyles, 1987). Direct waste is generated through all the construction processes and the first and foremost process is considered the cutting phase (Rameezdean, Kulatunga, & Amaratunga, 2004). Moreover, the cutting phase is the best process for adopting appropriate waste sorting practices.

1.2Aim & objectives of the research

This research aims to find out an efficient method of waste sorting and the obstacles to effective waste sorting in the management of the site. In addition to that, current practices have assessed the efficiency of the practices through a questionnaire developed for the industry experts. In addition, waste sorting practices, which are used in other countries are taken into consideration and surveyed to find out, what practices are fit local construction industry. Moreover, the proposals from the industry experts are evaluated and developed as the most efficient method for managing construction waste.

Accordingly, the following are identified as the objectives of this thesis.

I. To identify efficient methods of waste sorting and managing in building projects using literature review
   a) Assess the current situation and view of the site management towards waste sorting identified methods by literature review.

II. To develop the most efficient method of waste sorting considering the dominant factors affecting and its implementation

III. To assess the management effort in waste sorting and management.

1.3 Scope of the study

The scope of the study is limited to finding 120 participants in the building construction projects in Colombo & Gampaha, both private and public, who will be contacted by email. This recruitment phase will last no more than two months and will end when 120 volunteers have been identified or two months have elapsed. Each study participant will be asked to fill out a brief questionnaire based on the literature review to evaluate successful waste sorting systems and the factors that influence its applicability. Anyone who does not work in the construction projects but who is a project manager, a planning engineer, a site engineer, and a quantity surveyor in a consultancy firm or in Client representative will be excluded from the study.

1.4 Significance of the study

The initiative will reap enormous environmental and economic benefits now that the most determining criteria for effective waste sorting has been identified. This study is entirely focused on the aspects that contribute to effective waste sorting and adaptable waste sorting alternatives to any construction project based on the influencing factors. Furthermore, critical management practices which are needed for the success of waste sorting and management greatly influence the building construction projects in Sri Lanka.

1.5 Limitation of research

This study is only for construction company professionals which does not include clients or their representatives as consultants. However, the views of those groups in favor of effective waste sorting may help to improve the results even more.

1.6 Structure of the report

The following sections make up this study: (1) introduction, (2) literature review, (3) methodology, (4) data analysis, and (5) conclusion and recommendations. The following shows how each chapter would be summarized.

- Introduction – Chapter 1 The research's background is explained at the start of this chapter. This section provides an overview of the Sri Lankan construction industry, as well as construction waste generation and critical success factors for the implementation of an effective waste sorting system in a construction site. The research question is also justified by the empiric and practical gap. Then comes the formulation of a research problem, as well as research objectives and questions. Following that, the study's importance is communicated, and finally, chaptalization is concluded.

- Chapter 2 – Literature Review – Previous research is reviewed, and loopholes that have not been considered are used to design the questionnaire, theoretical data, and conceptual literature relevant to construction waste sorting and critical success factors affecting on-site waste sorting implementation.

- Chapter 3 – Approach – This section explains the study's methodology. The research philosophy, research approach, strategy, methodologies, and instruments are all explained. In addition, the development of questionnaires and data collection methods are also discussed.

- Data Analysis (Chapter 4) – This chapter contains the study's findings and analytical sections. SPSS software was used to conduct the relevant analysis.

- Chapter 5 – Conclusion and Recommendation – This chapter evaluates the analyzed data and builds a conclusion from it. Recommendations for future research are made based on the study's results and other findings.

2: LITERATURE REVIEW

2.1. Introduction to Construction Waste

Construction waste is made up of unusable or undesired raw materials produced by construction activity. Construction waste is also defined as any material that can be transported away from a construction site or used on-site for purposes other than the project's intended specific activity due to damage, excess, or non-use due to non-compliance with the material specification for the given activity due to non-compliance with the material specification for the given activity (Skoyles and Skoyles,1987). Another definition for construction trash has been described as "clean, diverse building materials created from numerous construction processes" The rapid growth of infrastructures is responsible for a significant quantity of trash creation. It has posed a significant threat, particularly to the environment and natural resources, depletion as well as energy waste, emission of greenhouse gases, and landfilling (M & Hettiarachchi P, 2002)

The literature review is mainly carried out under the following topics for convenience.

1. Type of Construction waste

2. Causes and Sources for material wastage

3. Quantification of Waste generation

4. Waste sorting methods in building construction

5. Efficient methods and techniques in waste management

2.2 Types of construction waste

Waste from construction projects is separated into two categories: finishing waste and structural waste. Most of the structure waste is made up of concrete fragments, reinforcements, and abandoned wooden plates, whereas the majority of the finishing trash is made up of extra cement mortar, broken raw materials, tiles, ceramics, paints, and plastering supplies (Poon et al.,2001).

Construction process waste can be divided into two categories, direct waste which is produced during the construction progress and another category which is defined as indirect waste which is not physical waste, but the payments are made for non-usable end products (Skoyles and Skoyles,1987).

2.3 Causes and sources for material wastage

2.3.1 Sources of construction waste

Direct waste can be produced at any activity of construction and can be identified as follows (Skoyles & Skoyles, 1987).

- Delivery Waste

Loss of supplies or products during delivery to the building site, unloading, and storage to the stores' initial position.

- Stockpile waste

Wastage of materials in stockpiles due to rain or exposure to other natural hazards, such the pedestrian, and vehicular movement.

- Cutting waste

Material waste because of cutting into diverse sizes or uneconomical forms.

- Fixing Waste

Wastage or losses due to dropping, spoiling or discarding materials during fixing.

- Waste from Residue

Remained part of the materials are in the bins or containers which are not sealed to use after. It also includes the hardened material in bins and containers.

- Waste Caused by other trades

Damages occurring by the succeeding activities of the work

- Criminal Waste

Waste to be considered in theft

- Management Waste

Materials lost or damaged owing to a lack of oversight, improper decisions, alteration, or managerial negligence

- Waste due to improper use
- Losses of materials due to wrong selection

Construction waste generation is unavoidable at any site during the construction process, and it generates a variety of waste depending on how the material is used. As a result, reducing waste generation at the source is the most desirable factor.

To achieve the project objectives, it is necessary to manage the waste efficiently and effectively. To achieve it is necessary to determine the most important sources of waste for waste generation. The following table gives a better understanding of the causes of waste (Kulatunga, Amaratunga, Haigh, & Rameezdeen, 2007)

Table 1*:* Sources for generation of waste

Source	**Causes of Waste**
• Operational Waste	Poor Workmanship
	Poor Communication among the designer and contractor
	Inadequate Supervision
	Damages caused by succeeding activities
	Quantity calculation error due to improper planning
	Unfavorable weather
	Use of incorrect materials
	Dropping and spoiling
	Malfunctioning of equipment
	Site Accidents
• Design waste	Design changes during construction
	Dimensional coordination becomes unnoticed.
	Drawings with insufficient information
	The contract document is incomplete and contains inaccuracies.
	Alternative products are unfamiliar to designers.

	Materials and items of poor quality were chosen.
	The market's conventional sizes are not being paid attention to because of a lack of attendance.
	Complexity of drawings
• Waste in Material Handling	Inappropriate storage facilities
	Damages during transportation
	Materials are delivered in a loose state.
	The project team and personnel have a hostile attitude.
	Theft
• Waste in the procurement process	Materials that may not be up to standard
	Ordering Errors
	Lack of possibility to order small quantities

Table 2: Construction waste composition in different countries

Construction Material	Sri Lanka (Rameezdean, Kulatunga, & Amaratunga, 2004)	Hong Kong (Poon C S, 2004)	Malaysia (Mei, 2017)
Sand	25	1.7	19.5
Lime	20		
Cement	14		10
Concrete		19	17
Bricks	14	5	10
Ceramic Tiles	10		8
Timber	10	10.53	7
Rubble	7	14.13	
Steel	7		
Cement Blocks	6		
Paints	5		
Other	3		

2.3.2 Waste generation in Pile construction

Pile construction costs, both actual and anticipated, have been found in a case study of Vietnam.

Table 3 Comparison of materials used for Piling in Vietnam (Thanh Long Ngo, 2011)

Type of waste	Item	Actual Amount	Used Amount	Waste (%)
Defects and Overproduction	Concrete (m^3)	16,255.26	18,822.35	9.32
	Steel D<=18mm (Ton)	166.602	171.067	2.59
	Bentonite liquid (Ton)	19,806.17	20,387.80	2.85
Over-processing	Drilling work, soil moving work, and other works ($)	$32,655,611,180	$38,418,366,100	15
Excess inventory				
Unnecessary transport				
Unnecessary movement of people and equipment				
Delays				

Accordingly,9 % of concrete is consumed excessively which is may not estimated for payments due to lack of techniques to get accurate measurements. Also, during the washing stage, loose soil is washed out and it leads for bulging of concrete makes excessive volume. Further, about 2m top part of the pile is removed till the required strength is receiving (Pile hacking).

2.3.3 Practical measures adaptable for on-site waste minimization

Waste management is becoming more widely acknowledged as a strategy for accomplishing construction project objectives. This is so that important project performance metrics, such as time, cost, quality, waste, and safety, among others, may be met. It is known that good waste management is required. Numerous research and policy recommendations have been prompted by the need to reduce the quantity of waste produced by industry. As a result, numerous construction methods that are crucial in reducing construction waste have been identified (Saheed O.Ajayi & Muhammadi Bilal, 2016).

Followings have been identified as the key management factors to reduce waste generation in a construction project.

- Identify construction activities that may result in the release of reusable materials from the construction site. (Uzzal Hossain, Zezhou, & Poon, 2017)
- Waste reduction target for sub-Contractors
- Use of secure storage facilities for materials
- Prevent over-ordering
- Prevention of double handling of materials
- Reuse of off-cut materials (Reinforcement, tiles, etc...)
- Landscaping with demolished or excavated materials
- Prefabrication space on the site for proper construction waste sorting/Management
- Stick to the Project drawings & specifications
- Monitors the use of construction waste containers regularly.
- Avoiding generated waste mixing with soil
- Providing each subcontractor with waste collection bins
- Reduce the number of changes during construction
- Erecting temporary bins at each construction zone
- Ensure sufficient access to the site for material supply and movement
- On-site waste auditing to track records
- Dedicated area for cutting & Storages
- Waste skipping technique for pre-defined activities
- Reuse of scrap materials
- Waste sorting for reuse and recycling
- Dedicating the responsibility to the subcontractor for waste disposal
- Maximizing the reuse of raw materials
- Procurement waste minimization strategies
- Improving attitude towards construction waste minimization
- Deployment of waste data collection model (Mapping flow of waste). (Shen LY, 2004)

Waste sorting for reuse and recycling, as well as adherence to project drawings and designs, are the most highly ranked waste management practices for reducing waste (Saheed O.Ajayi & Muhammadi Bilal, 2016). Construction waste minimization refers to sticking to design drawings and avoiding errors and variations in the document. According to the findings, one of the site management team's most important responsibilities is to assess design compliance and verify that activities follow the design specification. As a result, today's site managers, like today's designers, must be well-versed in design interpretation to reduce waste, just as designers must be well-versed in construction activities and sequence (Faniran & Cabon, 1998).

Furthermore, logistics management contributes to increased waste reduction. Materials ordering and procurement, as well as inward and on-site materials transportation and storage, all necessitate planning and preparation. According to the factor component, waste reduction involves precise estimation of materials needed at various stages of a project to avoid the risk of material overordering and subsequent residues, which are a major cause of waste. In addition to ordering the right materials, poor site access for material delivery and on-site mobility might lead to material damage and waste (Hossain, Wu, & Poon, 2017).

2.4 Waste sorting methods in building construction

Numerous benefits are there to any construction project if on-site waste sorting practice can be adapted in the site since it is considered a more effective approach to minimization and recovery of materials. Emerging technology helps immensely to perform efficiently and can increase the rate of reuse, and recycling as well as reduce waste generation, transportation, and disposal.

Waste is divided into two groups, inert waste and non-inert waste, to improve sorting efficiency. For land reclamation, inert waste (such as mud, sand, bricks, and concrete) is disposed of at public landfills and is distinguished from non-inert waste. (e.g.wood and timber, bamboo, plastics, glass, paper, and other materials) (Poon, Ann, & Ng, 2001). Construction waste is often a combination of inert and non-inert construction materials, therefore separating it before dumping it in landfills or public fills is important. Off-site sorting, on-site sorting, and direct landfilling are three options for CWM (without sorting) (Lu, 2012).

The decision is taken when the inert waste is sorted. That process is started before the use, during the use, and after the use.

For construction waste sorting, a building should have two waste chutes, one for inert waste and the other for non-inert waste. This system then collects the waste individually, clears it using different trucks, and transports it to various public landfilling sites and landfills (Poon, Ann, & Ng, 2001). This method is very much suitable for a large building project which has adequate space to erect two refuse chutes.

When Precast concrete elements are taken from off-site, there is no necessity to allocate additional space for material sorting. As a result, there is no need to make any additional arrangements for material management on the job site. This could result in little material waste on the construction site. Thus, using precast elements is a better alternative for waste reduction, though the consultants and contractors in the Sri Lankan Construction industry are not interested (Silva & Vithana, 2008).

The most effective three strategies in waste sorting in building construction sites can be accommodated to the waste management plan as off-site sorting, on-site sorting, and directly dumping in landfills. Accordingly, the waste recovery rate is high in the onsite sorting system (Hossain, Wu, & Poon, 2017).

2.5 Efficient methods and techniques in waste management

There are five main categories in construction waste management such as reuse, avoidance, reduction, recycling, and disposal. (Faniran & Cabon, 1998).

2.5.1 The requirement for construction waste sorting on-site

There have been numerous studies done on managing construction waste, covering everything from source reduction through waste reuse, recycling, and disposal. As was previously said, an integrative hierarchy of construction waste management can be used to explain all of these solutions (Peng, Scorpio, & Kitbert, 1997).

The "3Rs" concept of construction waste management is based on the top three priorities in the waste management hierarchy, and it ranks waste management methods according to their acceptability (Reduce, Reuse, and Recycle). Reduction, as one of the three strategies for reducing construction waste generation and has two key advantages.

a) decreasing the cost of greater waste recycling, transportation, and disposal charges; and

b) preventing the development of construction waste.

As a result, it is regarded as the most effective way of reducing construction waste generation and avoiding many wastes disposal and environmental issues. (Poon, Ann, & Ng, 2001). When it becomes impossible to reduce construction waste, reusing and recycling will take precedence to reduce the amount of waste that ends up in landfills. Construction waste, on the other hand, should be sorted on-site before it is further processed to ensure a higher rate of reuse and/or recycling, because it is frequently a mixture of inert and organic materials, and mixed and contaminated waste which is not suitable for reuse or recycling and is instead disposed of directly at landfills (Shen LY, 2004).

Furthermore, putting in place an effective on-site sorting technique for building waste will significantly minimize the vast amount of pollution and environmental impact of construction waste. The results of a quick on-the-spot trial by a Shenzhen, China-based study team revealed the positives of handling construction waste, particularly in terms of reducing expenses and construction waste volume, and the benefits to the contractor's bottom line. During an investigation, certain project operatives assisted in sorting materials on the building site, including steel, formwork, concrete, bricks, and mortar. Investigated was the amount of waste produced in buildings with and without sorting systems. The findings demonstrated that waste sorting raises the overall proportion of waste materials for reuse and recycling from 14 per cent to 24 per cent by volume and from 8 per cent to 19 per cent by weight. This data would have been enough to persuade the construction industry to encourage thorough on-site sorting of construction waste to reduce waste (Shen LY, 2004).As per figure 1,the collected waste of timber and plywood is stacked in a location till it deliver for Off-site sorting since the site space is not adequate.

Figure 1:Formwork sorting at Angulana Site (State Engineering Corporation)

2.5.2 Efficient waste sorting methods

I. most applicable waste sorting technique is considered as, using two waste refusers per every construction project is reserved for inert waste, and another one is reserved for non-inert waste. Also, collected inert waste is directly dumped into the landfills and non-inert waste is sent to recycling process centres (Poon, Ann, & Ng, 2001).Figure 2 demonstrates a single waste refuser.

Figure 2:Waste refuser fabricated by GI barrels (Source: Angulana Site)

II. Another method of waste sorting is identified as the categorization of waste as per economy such as collecting only reinforcement to a fixed place and the rest is removed as a mixture of materials (Kang & Jia Yuan Wang, 2006).Figure 3 shows the remains after sorting is dumped through a waste refuser to the ground floor for loading to trucks.

Figure 3: Waste Refusal after sorting (Source: Angulana Site)

III. Separation of waste as per the type of material and collect those in reserved bins for each category and remove them from the site separately to the vendors or collective locations (Kang & Jia Yuan Wang, 2006).

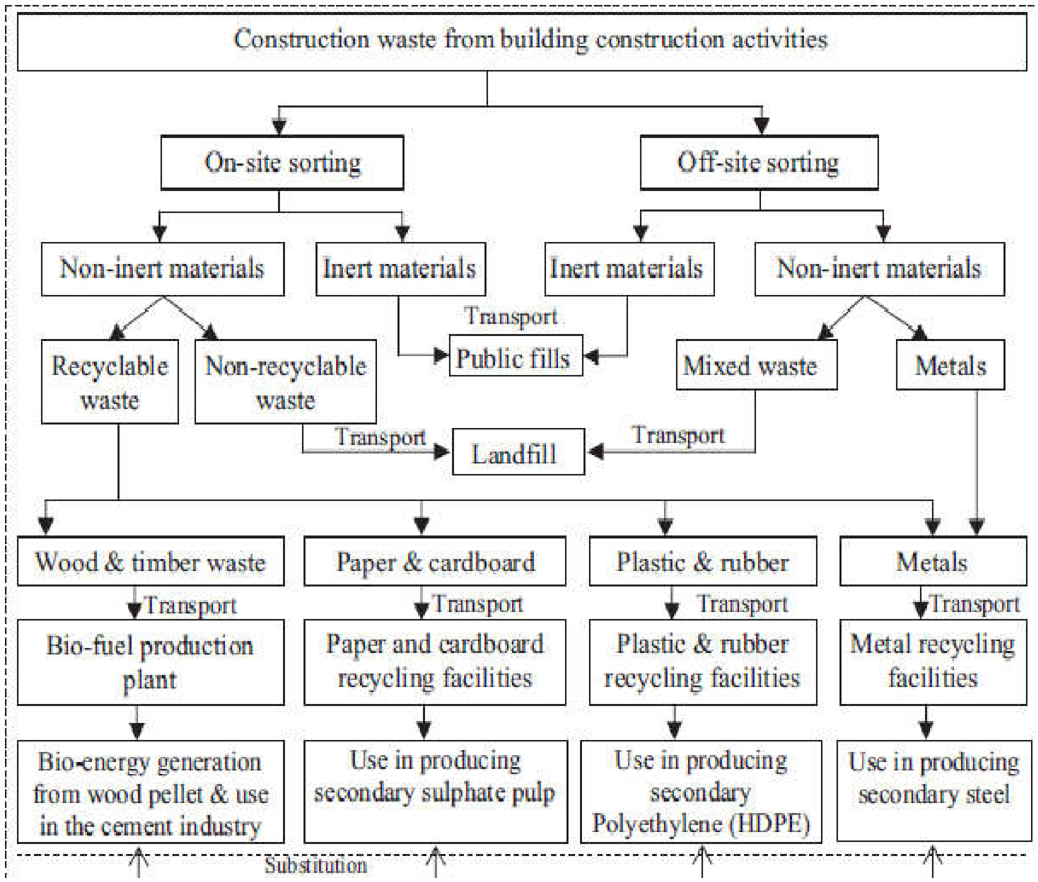

Figure 4:Waste sorting methods (Hossain, Wu, & Poon, 2017)

IV. Separation of hazardous or poisonous waste as per guidelines of the environmental authority and remove the rest of waste as a mixture of material to dumping yards.

V. The results show that off-site sorting will be significantly more constrained than on-site sorting by cost, labor demand, facility requirements, waste sorting capacity, and management effort. The lease of a separate sorting facility is required for off-site sorting; this cost must be added to the sorting cost, which is always substantially more than on-site sorting. Another issue is that the waste sent to the new location is mixed; workers find it difficult to separate the various waste, and sorting takes a lot of time and effort. Off-site sorting is typically less applicable than sorting at the source it generates and therefore requires more managerial involvement (M & Hettiarachchi P, 2002).

2.6 Waste sorting influencing factor identification

I. **Site space**: This element refers to the waste sorting limitations at building sites for all waste types, including domestic waste, inert waste, non-inert waste, and hazardous waste. The discrepancy is most likely caused by the fact that construction waste sorting operations require a lot more space on Hong Kong building sites. As a result, Hong Kong's construction waste sorting will have greatly depended on the level of site space that was available for these operations. Although no area is officially pre-arranged for on-site sorting of building debris in Hong Kong (Hossain, Wu, & Poon, 2017).

Figure 5:Inadequate site space for waste sorting an storing (Borella site-SEC)

II. **Management effort**: Chinese contractors are unlikely to be persuaded to reconsider the significance of enhancing management capability by the attraction of on-site construction waste sorting. In fact, they might think about strengthening managerial capability in order to enhance public awareness, increase competitiveness, or lower project costs. It should be recognized that increasing construction waste management capabilities, particularly on-site building waste sorting, is a protracted process. It will not be completed, without the cooperation of both managerial and operational employees. (for example, Project Managers, Supervision staff, and site engineers) (Hossain, Wu, & Poon, 2017).

As a management endeavor the following key responsibilities would be assigned to the site staff.

- Working with organizational short- and long-term goals
- Gathering and analyzing information related to waste sorting and implementation of those
- Employee engagement to solicit comments and develop recognition and award programs.
- Monitoring of waste sorting progress
- Other staff should be made aware of the program and encouraged to take part.
- Obtaining management support for performance objectives and implementation, conveying the value of waste reduction across the company, directing, and sustaining the program, and promoting and rewarding employee dedication and involvement are all tasks that really should be addressed.

III. **Manpower & Cost**-It is not typical for manpower to be viewed as the most important factor affecting the construction industry's capacity to efficiently sort construction waste on-site (Poon, Ann, & Ng, 2001). This shows the high operating costs of waste sorting and securely storing sorted waste, as well as the additional cost of waste sorting instruments or types of machinery (Jiayuan Wang & Xiangping Kang, 2009). In this sense, if the objective was to reduce construction waste through onsite sorting, more manpower would be necessary to complete the task. Furthermore, in the Chinese construction sector, the environment is often ranked lower than other project objectives such as cost, quality, length, and safety (Poon, Ann, & Ng, 2001). Contractors' main concern with construction waste sorting is whether it is a value-added investment, in other words, whether it will provide them with additional benefits.

In addition, the gathered waste had to be carried to a sorting facility and then stored due to a lack of space. As a result, it needs a large manpower requirement for handling.

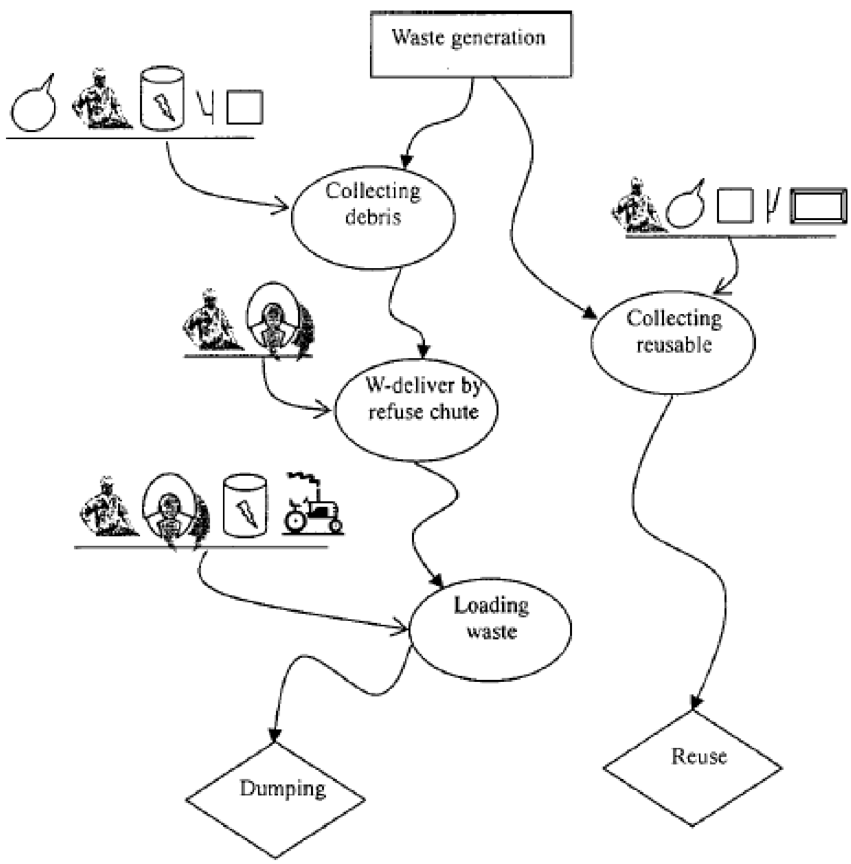

Figure 6: Mapping of waste handling (Shen LY, 2004)

IV. **Interfering with normal site activities**: On-site waste sorting necessitates a significant amount of site space, skilled manpower, and additional transportation to transport the sorted waste. The site's normal operations would be interrupted. The most likely reason is that sorting activity is typically done away from the site's main activities, allowing site activities to proceed with minimum interruption (Poon, Ann, & Ng, 2001).

V. **Waste sortability**: After the waste materials have been mixed, it is difficult to separate them. Separating the contaminated material from the mixture so that the rest can be processed for reuse and recycling is the most difficult problem. However, because it is too inconvenient to use, no contractor in China has applied such a method (Poon, Ann, & Ng, 2001).

VI. **Market for recycled materials**: The lack of a market for receiving recycled items slows the development of on-site sorting systems. Contractors cannot earn from selling recycled materials in the market without such a market, thus there would be no motivation for contractors to promote on-site sorting techniques.

VII. **The attitude of project stakeholders toward implementing on-site waste sorting**: Stakeholders in the project are significant players who can affect site management in terms of waste sorting. Because they weigh their financial impact and the company's image.

VIII. **Attitude of the site Contractors**: Attitudes are a key component in helping people comprehend their social environment. Because the construction industry is labor-intensive, contractors' attitudes and views have an impact on waste sorting methods adoption. On-site waste sorting reduces the amount of construction waste that must be disposed of in landfills while simultaneously increasing the amount of waste that may be recycled. Whether or not the contractors are environmentally conscious will have a big impact on how on-site waste sorting is implemented.

IX. **Project duration**: Because manpower and cost are correlated to project duration, adapting on-site sorting would cause the project to be delayed.

X. **Equipment for waste sorting**: Although on-site sorting of construction waste is primarily done manually in China, the equipment utilized to do so has a considerable impact on the operation's efficiency (Hossain, Wu, & Poon, 2017). Both the manpower and waste sorting equipment factors will result in a significant rise in project costs. The waste sorting equipment component mainly relates to two things: the usage of professional construction waste sorting equipment and storage equipment for sorted construction waste. Construction waste sorting activities in China are now mostly manual, with only a few machines employed to store the waste materials (Uzzal Hossain, Zezhou, & Poon, 2017).

XI. **Environmental benefits**: Dumping waste directly into the landfill is a burden on the environment. When considering waste and its composition, the waste sorting process is greatly beneficial to the environment.

However, each of the above factors is needed to be compared concerning the selected waste sorting options which can be adapted to the local construction industry.

2.7 Challenges in waste management & sorting

The following practices were identified as key management practices for effective waste sorting from literature review.

- **Lack of waste sorting out Process.**

Construction waste created on construction sites is often mixed in the current environment. Municipalities and contractors pay little attention to waste sorting during construction. Surveys show that no building waste is separated; it is all gathered. As a result, recycling and reuse of construction waste will be less effective and more expensive for the construction industry. Furthermore, waste collection companies do not consider the material's toxicity and simply dump it all into a landfill without separating it. More pollution of the environment and land will follow, as well as detrimental repercussions to health and safety of people (Ranjan, Karunasena, & Rathnayake, 2014).

- **Less concern for waste recycling or reuse.**

Building projects have been developed as a result of research. Many architects and designers are not aware of the necessity for waste reduction throughout the planning and design stages because construction waste management is a relatively new area in the Sri Lankan construction industry. Because architects are unaware of the necessity of waste management, lack of awareness of waste minimization design and construction alternative approaches, as well as design changes made during the building stage, is a major role in waste generation. Due to a poor site waste management plan, a large amount of waste might be generated during the construction stage (Ranjan, Karunasena, & Rathnayake, 2014).

- **Intensive labor Work involved in handling waste**

It is not typical for labor to be considered the most essential component affecting the construction industry's ability to effectively sort construction waste on-site. This showed the overall operational costs of waste sorting and secure storage of sorted garbage, as well as the added expenditures of waste sorting equipment or types of machinery. In this respect, more people would be required to operate if the goal was to reduce construction waste by onsite sorting. Contractors' main concern with construction waste sorting is whether it is a value-added investment, in other words, whether it will provide them with additional benefits (Hossain, Wu, & Poon, 2017).

- **Limited market for recycled products**

A lack of understanding of the recycling market for construction waste is a significant impediment to the growth of recycling in Sri Lanka. Furthermore, Construction waste recycled product market values are low, with low customer satisfaction with recycled product quality, and companies are likely to switch to new products (Ranjan, Karunasena, & Rathnayake, 2014).

- **Limited facilities for waste recycling or sorting**

There aren't enough facilities in Sri Lanka to recycle construction waste. The only factory that has been operational in the COWAM. Due to a shortage of workers and a finite supply of construction waste, the COWAM facility is only operational 14 days each month. Contractors are reluctant to send generated waste to the Center due to the high cost of waste transportation. The local authority in Galle, which owns the plant, is unwilling to go to the sites and collect the waste for the same reason (Ranjan, Karunasena, & Rathnayake, 2014).

- **Lack of Knowledge of staff & Workers in waste sorting**

Construction workers' skill levels have a significant impact on the quality of construction waste. Many of the hired labor are not permanent, and many of them were farmers before joining the project, with no training or experience in building procedures, materials, or material handling. More waste in plastering and formwork are generated due to poor competency of their trades.

- **Lack of communication among stakeholders**

There is no communication system in place in Sri Lanka for stakeholders to communicate information on construction waste. In this situation, the government should create a database on construction waste management systems, which would include innovative demolition techniques, reuse, and recycling procedures, and information on stakeholders involved in the process. Clients, contractors, and waste collection companies will all be connected through the communication systems. As a result, communication between parties involved in construction waste management is achieved (Kulatunga, Amaratunga, Haigh, & Rameezdeen, 2007).

- **Fewer landfills to handle construction waste**

Due to the rapid development of the construction sector in Sri Lanka, the amount of construction waste generated is constantly increasing, and municipal authorities are responsible for waste collection and disposal as well as site management. There are just a few permanent landfills owned by municipal authorities in Colombo and the suburban areas, and they are insufficient to handle all the waste created by construction sites. Foreign nations reportedly have common building waste disposal sites where they can run an appropriate construction waste disposal system, according to the literature. Due to a lack of landfills, people in Sri Lanka used to dump construction waste everywhere, which resulted in environmental and social issues. As a result, insufficient landfill capacity in Sri Lanka is a major impediment to construction waste management (Ranjan, Karunasena, & Rathnayake, 2014).

- **Limited research on waste sorting or management**

Lack of understanding of the necessity of construction waste sorting & management, as well as a lack of funds allocated, has resulted in a shortage of waste management researchers. Because of these factors, only a few studies on construction waste management have been done. It is widely agreed that study is required to better the field of construction waste sorting management.

- **Unavailability of national policy**

The findings revealed that the challenge of developing a national policy due to time and expense restrictions has resulted in its unavailability. Furthermore, the government's and relevant ministry's failure to address construction waste issues has aggravated the issue.

- **Lack of Commitment of authorities**

The government and local authorities should take the lead on construction waste management. In general, the government imposes rules and regulations, while local authorities impose municipal laws. Municipal councils are responsible for waste management. Furthermore, the central government is responsible for many large-scale construction projects. As a result, the government can provide more assistance in managing construction waste. However, given the current situation, the government and local authorities indicate a lack of commitment to construction waste management (Ranjan, Karunasena, & Rathnayake, 2014).

2.8 Proposals for effective waste sorting and management

Following practices are proposed by the literature for the effectiveness of waste sorting and management of sorted waste.

- **Definite space allocation for waste sorting**

  It is necessary to set up a specific location to collect waste for sorting, and then appropriately storing of the sorted waste, with special consideration for toxic waste. This will help to keep normal construction activities from being disrupted. Because contractors manually sort waste after finishing their work at noon or in the afternoon and then bring the sorted waste in plastic bags to the ground-floor store location, this issue has a considerable impact (M & Hettiarachchi P, 2002).

- **Incentive Schemes or Rewarding for waste sorting workers /subcontractors**

  The management of construction waste is directly influenced by the skill levels of construction workers. However, despite the shortage of skilled workers, the incentive scheme motivates the workers as well as sub-contractors to adopt waste management in the project (Ranjan, Karunasena, & Rathnayake, 2014).

- **Subcontracting waste sorting activities.**

  The associated cost for waste sorting and management is high due to high labor demand and machinery requirements. By subcontracting the waste sorting through competitive bidding, the estimated cost can be reduced by controlling labor demand and facility demands.

- **Waste sorting needs to be done at the time of generation**

  Having sorting facilities on site will improve the percentage of construction waste that is reused and recycled and lower the environmental effect. Hence the sorting can be performed at the location where the waste originated.

- **Ensure the implementation and compliance of the waste management plan**

  Typically, this includes scheduling waste removal, coordinating collection, and planning transportation to approved disposal locations.

- **Training program for the staff and works for waste management**

  The efficiency of waste management is directly influenced by staff & workers' awareness of construction waste management. As a result, it is critical to establish waste management awareness programs for contractors, technical employees, and workers as well as clients. These programs should educate the staff about the environmental, social, and economic benefits of managing construction waste. This will help enhance construction waste management. With the help of non-governmental organizations, the top management of a company can play a major role in this by incorporating experienced personnel in construction waste management (M & Hettiarachchi P, 2002).

- **Development of industry norms for waste management**

  The conceptual framework for strategic planning of construction waste management emphasizes a few things that the governing body of construction can employ to ensure that construction waste management is implemented successfully. It is a combination of regulation, policy, technology, and guidance. These four criteria are used to ensure that the 3R approach is carried out effectively or the development of a new framework for the contractors who register with this governing body.

Figure 7:Precast concrete product from recyclables (SEC-Ekala)

2.9 Chapter summery

There is a lot of research on construction waste management in construction industries all around the world, but just a few research on construction waste management in Sri Lanka. It obviously implies that more research is needed to examine waste management procedures in the Sri Lankan construction industry and improve their practicability to construction projects.

According to observations and findings from the literature, waste management in Sri Lanka's construction industry is a relatively underdeveloped field of knowledge, and the majority of projects do not give significant consideration to waste reduction and waste sorting, having a negative impact on construction projects. As a result, the current research is being carried out to answer the questions of "what are the critical factors impacting waste sorting" and "what are the management practices to be followed for waste sorting performance."

Waste reduction is the most successful strategy, and construction companies have been using it for a long time. However, waste generation is unavoidable, and sorting the waste generated will be a perfect option because it can be reused for subsequent activities on a construction site. To seek solutions to these issues, the current research will focus on the current practices in construction waste sorting strategies and the factors that influence their performance. Furthermore, the suitability of those options to a specific project is evaluated based on those relevant factors.

In addition to the construction industry in terms waste management and sorting challenges were identified, and proposals for effective waste sorting and management should implement to overcome those challenges were proposed in the literature.

3. METHODOLOGY

3.1 General

This study focused on how to close the gaps in waste sorting procedures that are most appropriate for the Sri Lankan construction sector using qualitative and quantitative analysis of data collected from the industry, as well as a literature survey. The literature survey was used to determine the existing practices for waste sorting methods for generated waste during construction, their efficiency, and which elements have the most influence on waste sorting.

The practical features of waste sorting were developed at site levels, in addition to the preceding researchers. Individual discussions with industry specialists who are currently engaged and managing waste sorting procedures in significant building development projects in the Colombo area provided the practical knowledge gained through the construction.

Accordingly, the study has been divided into three sections as per the research objectives as shown in figure 8.

I. Conduct a literature review to identify waste sorting options used in other countries, as well as the factors that influence the effectiveness of such options.

II. Identification of most influencing factors for adaptable waste sorting options to a building construction project and comparing them to identified influencing factors by descriptive mean analysis and recommendation of the applicability of the best option by the overall influencing factor mean scores (Refer appendices I).

III. Determine the severity of the main difficulties that are influencing the execution of waste sorting processes in any building site based on the responses. Also, the best opinions for waste sorting process implementation on a construction site are ranked by responses (Refer appendices II).

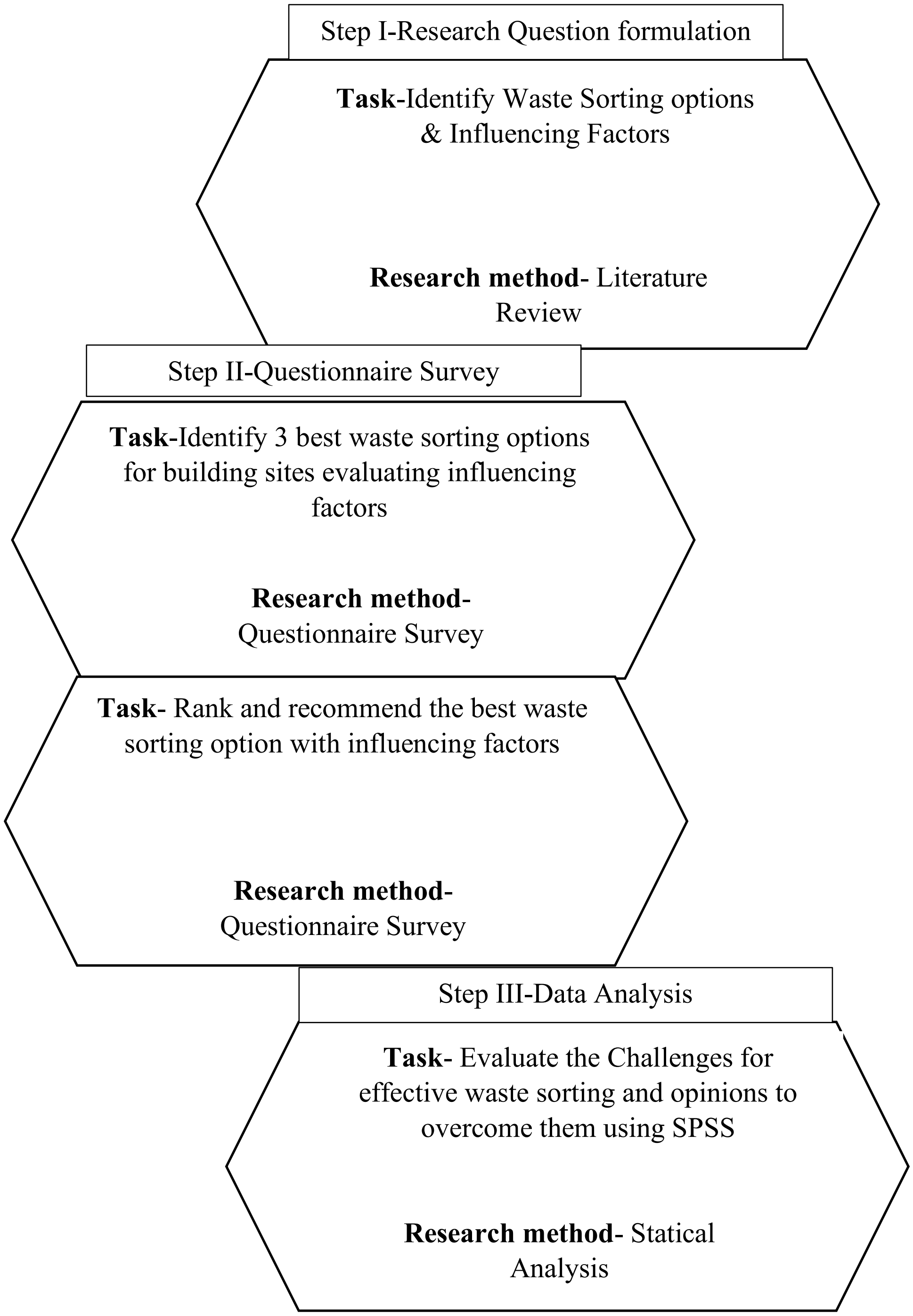

Figure 8:Research methodology adopted in the study

3.2 Literature review for problem identification

Waste interrupts the efficiency, effectiveness, value, and profitability of construction activities, so identifying the sources and controlling waste is essential. To adopt successful waste management techniques, it was essential to recognize the basic sorting methods

There are a variety of waste sorting procedures that have been adopted in different countries' construction sites. As a result, 15 research publications that were pertinent to this research and review were studied. Those papers were then categorized as per the region, to determine the best practices that would apply to each region. Then the selected best practices were used to formulate the questionnaire.

3.2.1 Identification of waste generation

The identified Sources & Causes of waste generation and materials which were used for the construction activities through the literature review were listed as the first part of the questionnaire to identify the topmost sources and causes for waste generation and which raw materials have the highest vulnerability to become waste. To rank those, 1-5 Likert scale was used as follow.

The questionnaire was sent to the respondents where material reconciliation reports are generating. The selected sites were practicing this method to identify the allowable material waste percentage and actual wastage from the material reconciliation report, produced every month. The details of the reports were distributed among the key staff of the project for their information and further improvement. The identified construction activities, which materials have a high tendency to become waste, and causes for the waste generation in said activities were identified and ranked.

3.3 Task I- Waste sorting methods

From the literature review, three feasible waste sorting methods which can be effectively used in the Sri Lankan Building Construction projects were identified as in figure 9.

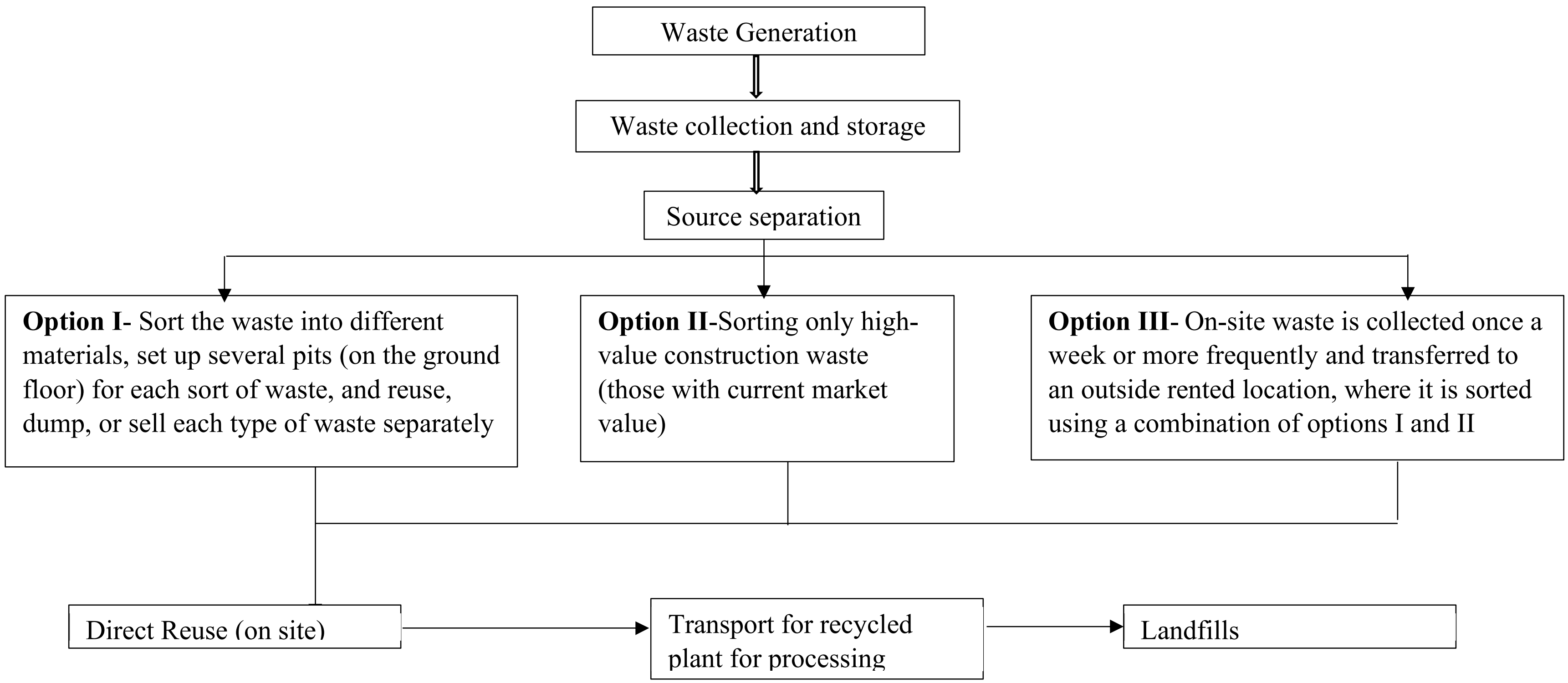

Figure 9:Construction waste management system through waste sorting

- **Option I**-Sort the waste into different materials, set up several pits (on the ground floor) for each sort of waste, and reuse, dump, or sell each type of waste separately (Hongping Yuan & Hao, 2013).
- **Option II**-Sorting only high-value construction waste (those with current market value), such as steel reinforcing and wood; the rest (mixture) should be collected to a fixed site (usually on the ground floor) and cleaned up every other day or weekly (Uzzal Hossain, Zezhou, & Poon, 2017). Separating of positions waste under legal requirements (ISO 9000, or any other standard or as per country law. Hazardous waste generated by the construction industry includes lead, asbestos, plasterboard, paint thinners, strippers, mercury, fluorescent bulbs, and aerosol cans, to name a few (Lu, 2012).

- **Option III**- On-site waste is collected once a week or more frequently and transferred to an outside rented location, where it is sorted using a combination of options I and II, where workers will sort the waste according to options I & II (Jiayuan Wang & Xiangping Kang, 2009).

3.4 Waste sorting influencing factor identification

A comprehensive literature review for onsite waste sorting was done to develop the questionnaire to identify the main factors affecting onsite waste sorting in a building construction project. Accordingly, the following 11 critical factors have been identified as principal factors for effective waste sorting.

I. **Site space**: This factor references the building site's limitations on waste sorting practices for all waste including, domestic waste, inert waste, non-inert waste, and hazardous waste (Hongping Yuan & Hao, 2013).

II. **Management effort**: To practice any waste sorting options, it is very important to have support and commitments from the site management and fund allocation for it. As a management endeavor, leveraging the existing team for waste management, creating a new team responsible for effective waste management, and recruiting officials from a different perspective for waste sorting are the key influencing factors (Uzzal Hossain, Zezhou, & Poon, 2017).

As a management endeavor following key responsibilities would be assigned to the site staff.

- Working with organizational goals in terms of short term and long term
- Gathering and analyzing information related to waste sorting and implementation of those
- Employee engagement to solicit comments and develop recognition and award programs.
- Monitoring of waste sorting progress
- Other staff should be made aware of the program and encouraged to take part.
- Obtaining management support for performance objectives and implementation, conveying the value of waste reduction across the company, directing, and sustaining the program, and promoting and rewarding employee dedication and participation.

III. **Manpower & Cost**: This shows the high operating costs of waste sorting and storing sorted waste in a secure manner, as well as the additional cost of waste sorting instruments or types of machinery (Uzzal Hossain, Zezhou, & Poon, 2017).

IV. **Interfere with site normal activities**: When employees or instruments are assigned to site operations, the waste sorting process will have an impact on typical site activities. As a result, there is a negative impact on waste sorting selection because site activities are paramount (Shen LY, 2004).

V. **Waste Sort ability**: It refers to the ease with which a material can be manually sorted from a mix (Wu & Jian Zuo, 2019).

VI. **Market for recycled materials**: When waste sorting practices are improved, a market for recyclable materials should emerge. Otherwise, the procedure's only aim will be lost, and the waste sorting process will fail (Hongping Yuan & Hao, 2013).

VII. **Project stakeholders' attitude toward implementing on-site waste sorting**: Stakeholders in the project are significant players who can affect site management in terms of waste sorting. Because they weigh their financial impact and the company's image (Hossain, Wu, & Poon, 2017).

VIII. **Attitude of the site Contractors**: Attitudes are a key component in helping people comprehend their social environment. Because the construction industry is labor-intensive, contractors' attitudes and views have an impact on waste sorting methods adoption. On-site waste sorting is an efficient way to reduce the quantity of construction waste that must be disposed of in landfills while also increasing the amount of waste that may be recycled. Whether or if the contractors are environmentally conscious will have a major impact on the execution of on-site waste sorting (Jiayuan Wang & Xiangping Kang, 2009).

IX. **Project duration**: Because manpower and cost are correlated to project duration, adapting on-site sorting would cause the project to be delayed (Uzzal Hossain, Zezhou, & Poon, 2017).

X. Equipment for sorting waste: Appropriate equipment will substantially assist in sorting waste at a reasonable cost; nonetheless, cost allocation is a critical aspect in such processes because the project objectives will not be met without it (Poon C S, 2004).

XI. Environmental benefits: Dumping waste directly into the landfill is a burden to the environment. When considering waste and its composition, the waste sorting process is greatly beneficial to the environment (Saheed O.Ajayi & Muhammadi Bilal, 2016).

Each factor influencing each option in on-site waste sorting is assessed using the prepared questionnaire, based on the selection of impact factors for each option with their experience and knowledge in the construction industry. Respondents would rate the constraints of the influencing factors on a scale of 1 to 5, as shown below, to assess the practicality of each on-site waste sorting option.

1- Least Influence
2- Less Influence
3- Moderate Influence
4- High influence
5- Very High influence

A mean constraint score was calculated using the descriptive mean calculation formula with the help of SPSS software. The factors were arranged with the highest mean at the top rank and the lowest mean at the bottom rank. In addition, an overall influence score was determined, and the overall applicability score of onsite waste sorting alternatives was compared. Besides that, the influencing score of each component is compared to see whether one alternative is more relevant in a specific area. Accordingly, the dominant factors and minor factors for waste sorting were discussed and the best onsite waste sorting option was identified. To validate the reliability analysis using Cronbach Approach was performed for each option. The key findings were also cross-referenced with the findings of related literature.

3.5 Task II-Challenges and opinions for waste sorting effectiveness & management

However, before implementing any waste sorting strategy on the site, it important to understand the barriers and challenges of waste sorting and the best different approaches. The following elements have been highlighted as problems for it based on the literature review.

- Lack of Waste Sorting out Process: Previous research has found that all types of construction waste is collected without being separated but only a few materials are sorted, and this leads to discouragement in implementation hence, management decisions are made as per previous approaches (Wu & Jian Zuo, 2019).
- No consideration for Recycling or Reusing waste after sorting: The lack of commitment from site management to reuse or recycle, as well as the development of recycled products from sorted waste, has a negative impact (Osmani, 2012).
- Intensive labor work involved in handling waste for sorting: Sorting waste is a time-consuming operation that requires additional handling to sort and store. Contractors put a priority on project time, quality, and cost control, and are unwilling to sort waste due to high labor demand (Hossain, Wu, & Poon, 2017).
- Limited market for recycled products:
- Limited facilities for waste recycling or sorting

- Lack of Knowledge of staff & Workers of waste sorting
- Lack of Knowledge of staff & Workers about waste sorting: Because of the lack of knowledge about waste sorting processes, project staff or workers are hesitant to adopt any waste sorting approach, which could tarnish their reputation.
- Lack of communication among stakeholders
- Poor Coordination and supervision of waste handling staff
- Limited research on waste sorting or management.
- Unavailability of a national policy
- Lack of Commitment of local authorities

The effectiveness of the waste sorting procedure has been demotivated because of the aforesaid challenges. As a result, rather than focusing on all the difficulties, it is essential to prioritize and handle the most significant matters. Hence descriptive mean testing is done for all factors and analyses based on the respondent's role in the project and their experience. To calculate the mean, the following marks are given for each constraint of the respondents.

- Strongly Disagree -2
- Disagree -1
- Neutral 0
- Agree 1
- Strongly Agree 2

All the positive means were the principal determinants preventing the implementation of effective waste sorting practices and ranked them for reference to the construction industry.

3.6 Proposing practices for effective waste sorting & management

Following practices were identified as the critical management practices for effective waste sorting (Kang & Jia Yuan Wang, 2006), (Uzzal Hossain, Zezhou, & Poon, 2017).

- Definite space allocation for waste sorting
- Incentive Schemes or Rewards for waste sorting workers /subcontractors
- Subcontracting waste sorting activities
- waste sorting needs to be done at the time of generation
- Ensure the implementation and compliance of the waste management plan
- Training program for the staff about waste sorting practices
- Development of industry norms for waste management

The highest-ranking procedures are deemed the most effective waste sorting management approaches among the practices. In addition, these practices are assessed based on the respondent's experience and work position.

3.7 Sample selection.

The questionnaire is designed for the engineering staff both government and private-owned local construction companies. Sri Lanka has a few major construction companies such as the Central Engineering Consultancy Bureau, State Engineering Corporation, Department of Buildings, National Housing Development Authority, and Urban Development Authority owned by the state sector. From those companies, randomly draw two construction companies for the survey, and the questionnaire is issued at their sites, which are under construction, and taken randomly from their list of construction project sites.

Similarly, the private-owned construction company list is taken from the CIDA website, who have registered in it and they have the grade between CS2 to C1 for the building construction sector. There are 65 Contractors registered as C1 contractors in CIDA. From that list, 8 Construction companies randomly selected and send the questionnaire sent 120 participants who working for those companies in their building construction projects (Refer appendices III). The survey is designed to be conducted over 2 months in 2022.

The questionnaire was divided into three sections, all include 16 key questions and respective subjects covering a wide range of issues related to construction waste generation and waste sorting methods, as well as their effective implementation.

3.7.1 Target group

The questionnaire is mainly designed for professionals who are currently involved in the construction organizations as highlighted in table 4 and directing a construction project. Consultant Managers or Engineers of any consultancy firm are not responsible for the waste management process in their site.

Table 4: Categorization of Respondents

A sector of the respondent's company
• Public • Private • Consultancy firm
Years of Experience
• Up to 5 Years • 5-10 Years • More than 10 Years
Project Type
• Institutional or Social Beneficial Construction Project • Housing and Apartment Construction Project • Commercial Building Construction Project

Using the CIDA directory and Government companies as a sampling frame,19 sites were selected from those companies and 120 questionnaires sent through email for professionals in those sites as in the table 5 based on the criteria mentioned in table 3.

Table 5: Proposed distribution of respondents

Profession/Job role	Designed Sample Size
1. Construction Project Manager	30
2. Construction Planning Engineer	30
3. Quantity Surveyor	30
4. Site Engineer	30

All the respondents are categorized into three groups as per their experience in the construction industry to correlate the case study options for construction waste sorting hence it is very much important to identify the career background of respondents to validate the results. In addition, the sample is categorized by the organization they are working for, the project type, and the category of client. Project type is very much important to identify the questionnaire is covering all the building types.

3.8 Method of data analysis

3.8.1 Descriptive Mean Testing

Descriptive mean testing is a central tendency measure used by statisticians to determine the means and relative relevance of a set of statistical variables. The key site management approaches that can result in construction waste minimization were identified using descriptive analysis in this study. In this example, a greater mean value suggests that the management metric is significant. This is based on the Likert scale's relevance index, which spans from 1 to 5, with 1 being the least important and 5 representing the most significant.

W_j =influencing factor 1-5

Number of respondents

$$D\ (\text{Influencing Index}) = \frac{\sum_{1}^{5} Wj \times fi}{\sum_{1}^{5} fi}$$

3.8.2 Reliability Analysis

Reliability is the measure of consistency between different measurements of a concept or variable. Furthermore, dependability relates to the consistency of a latent construct's multiple measurement items. Estimates of a measurement's freedom from random or unstable error are referred to as reliability. The construct is said to be reliable if the respondent's response remains constant or steady across time. The Cronbach alpha test was performed to determine the study's scale reliability. This value conveys information about the relationship between a group of items.

In many social science studies, a Cronbach alpha of greater than 0.6 is considered acceptable, indicating that the study questionnaire's reliability for measuring variables is acceptable. Higher alpha values suggest that the scale's items are more internally consistent. Internal consistency is measured using the following rules: >.9 – Excellent, >.8 – Good, >.7 – Acceptable, >.6 – Questionable, >.5 – Poor, and.5 – Unacceptable. As a result, all the variables' internal consistency is acceptable, according to the analysis.

4. DATA COLLECTION & ANALYSIS

4.1 General

The findings of the literature review for waste sorting alternatives are discussed in this chapter, as well as the influencing factors that determine the success of each option.

Specifically, this chapter comprises the discussion of a questionnaire created based on the literature and data acquired to rate and develop applicability scores for each alternative and its adaptability using SPSS software to calculate descriptive mean values of each influencing factor.

Also, the critical challenges for effective waste sorting factors and best practices for effective waste sorting to be implemented in a construction project as per data collected from respondents are ranked based on the descriptive mean values. Accordingly, the recommendation is made for its adaptability to the current construction industry.

4.2 Data collection

A pilot survey was conducted with a small group of respondents to ensure that the questions were appropriate for the larger research population, to rule out any incompatible results, to get a clear understanding of the research's outlines, and to ensure that the survey type adopted in this research was effective. To determine the requirements, seven respondents were given a draft questionnaire.

The results of the pilot survey revealed that some of the questionnaire responses were inconsistent. The reason for this was that the questions were not framed correctly, and the respondents may not have fully comprehended the inquiries. Another explanation for the disparity was that the questions were not developed with the project's scope in mind. As a result of the results of the pilot survey, the questions had to be restructured.

About 120 copies of the questionnaire were sent to selected professionals through emails, working at the places listed in Appendix I for the main survey. A total of 73 replies were received, with a 61 per cent response rate as in the table 6. Those who are in consultancy firms were disregarded for the analysis.

Table 6: Distribution of the research respondents

	Sample size	**Percentage %**
Profession/Job role		
Construction Project Manager	20	27.4
Construction Planning Engineer	15	20.5
Quantity Surveyor	17	23.3
Site Engineer	21	28.8
Type of organization		
Public Construction	26	35.6
Private Construction	41	56.1
Years of Experience		
Up to 5 Years	19	26
5-10 Years	30	41.1
More than 10 Years	24	32.9
Project Type		
Institutional or Social Beneficial Construction Project	22	30.1
Housing and Apartment Construction Project	28	38.4
Commercial Building Construction Project	23	31.5
Client Type		
GOSL (Public)	32	43.8
Private	41	56.2

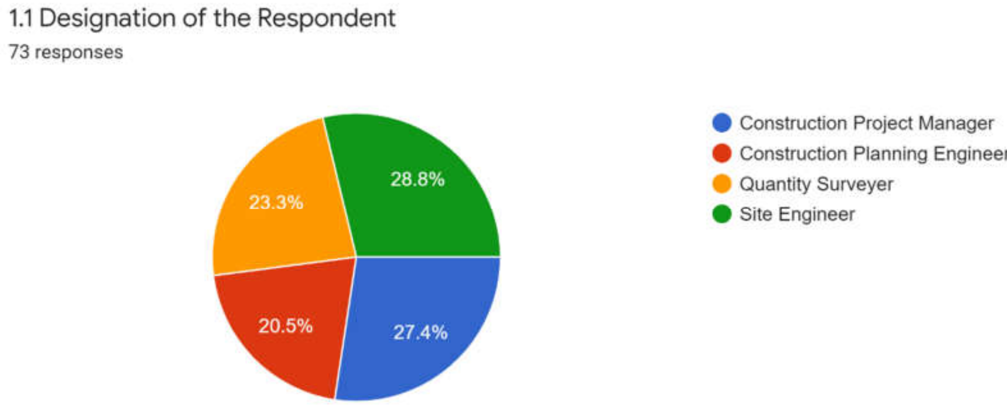

Figure 10: Distribution of respondents

The following is a cross-section of the selected respondents in terms of their practicing disciplines.

4.2.1 Current practices for the generated waste

As shown in figure 10, In terms of waste management, the industry's existing methods for construction management in building projects were identified, and the following are the industry's present practices: Out of 73 respondents, 62 use on-site waste sorting for their generated waste with the intention of reuse, and the remainder going straight to landfills as shown in figure 10. However, in figure 10, only a few projects are practicing off-site waste sorting, hence the limited space available at site premises.

As a result, it is needed to identify on-site waste sorting options and off-site waste sorting strategies, as well as to compare them to influencing factors, to determine how these waste sorting methods should be implemented in every construction project.

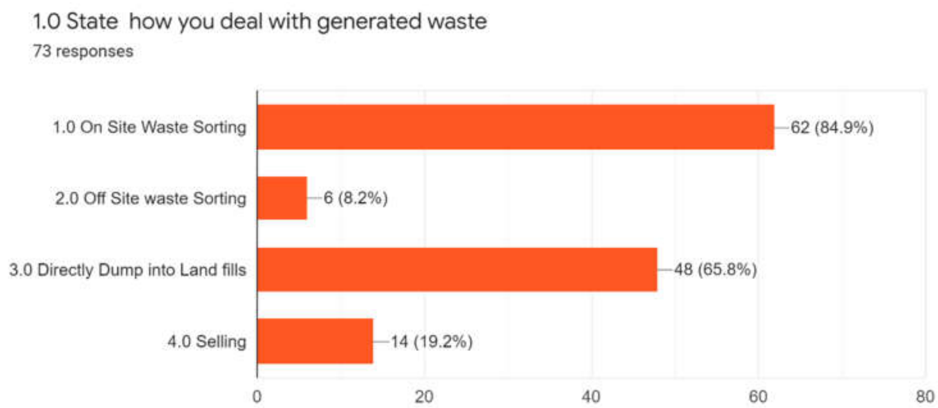

Figure 11: Current practices for construction waste in the industry

Accordigly,84.9% from respondents stated that on site waste sorting methods are practicing and then the balance waste is sent to the landfills as shown in figure 8.

Following waste sorting practices were identified in the literature review which are practicing in industries locally as well as in other countries.

- Sort the waste into different materials, create several pits (on the ground floor) for each sort of waste, and reuse, dump, or sell each type of waste separately.
- Sorting only high-value construction waste (those with current market value), such as steel reinforcing and wood; the rest (mixture) should be collected at a fixed site

Based on the literature review the following factors were identified Factors as the influencing factors for effective waste sorting in identified options in the literature review,

1.0 Site Space

2.0 Management effort

3.0 Manpower & Cost

4.0 Interference with site normal activities

5.0 Waste storability

6.0 Market for recyclables materials

7.0 Project stakeholder's attitude toward implementing on-site waste sorting

8.0 Attitude of the site Contractors

9.0 Project duration

10. Equipment for sorting waste

11. Environmental benefits

The objective of this research was to develop an efficient method of sorting construction waste in building projects through influencing factors for those options. The above waste sorting options can be adapted on-site as well as off-site. Regarding each option including offsite waste sorting by adapting both options together to evaluate influencing factors were evaluated as follows.

4.2.2 Influencing factor ranking

Waste cannot be avoided completely but can be reduced. However -the generated waste should be dealt with to achieve the sustainable goals in any construction project. But per most respondents, they directly dump waste to landfills before any sorting methods. Accordingly, there is a necessity to avoid being waste dumped into landfills and adapt waste sorting methods in the construction site.

But every site is practicing sorting methods for steel reinforcements before they send the waste to landfills and a few sites are practicing sorting for tiles to get reusable off-cuts for the balance work.

Due to the lack of waste sorting practices in most construction sites, it is necessary to identify what would be the influencing factors for different waste sorting practices if adapted, Accordingly, the respondents have stated their opinion and the significant index is calculated from SPSS software and ranked as follows.

Option I-Waste Sorting-Separation of materials as per the type (Domestic waste, inert waste, non-inert waste, and chemical waste are examples of waste types)

From the literature review,11 basic influencing factors have been identified for each type of waste sorting practice and the summary of the respondent is analyzed on descriptive mean scores with the Likert scale of 1-5 from least influence on highest influence using SPSS software and summary is as in the figure 9. The higher the index correspond to the higher rank as per the mean value.

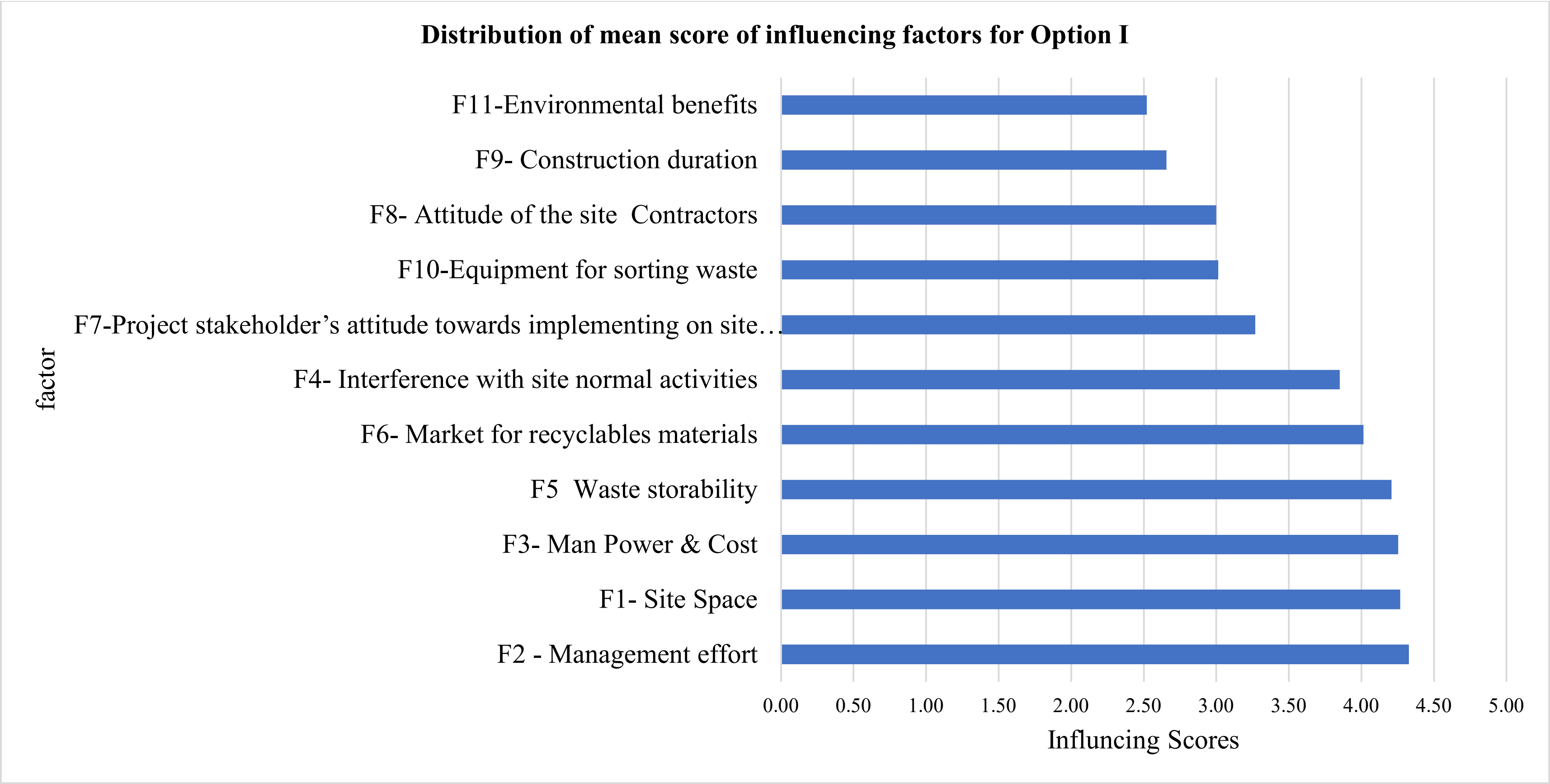

Figure 12:Influencing Factors for Option I

Figure 12 illustrates the descriptive mean scores of influencing factors for waste sorting of materials as per the type of material (Ex- Domestic waste, Inert waste, non-Inert waste, and chemical waste) selected as waste sorting option I.

Accordingly, the influencing factors such as 'management effort', 'site space', manpower & cost for waste sorting', and 'waste sortability' have taken maximum descriptive mean scores of more than 4, and hence it illustrates those are the crucial factors affecting the selection of this option as the waste sorting practice. Therefore, to implement this option, the management effort of the site is crucial, and their commitment is highly important since they should pay attention to this as major construction activity. Furthermore, this option is more appropriate to the projects which have lesser markup, since rates have allowed only a very low percentage for waste and the sorted waste that can be used for the succeeding construction activities is comparatively high

However, if influencing factors such as ‘construction duration of the project', the attitude of the site contractors', 'equipment of waste sorting', and 'project stakeholders' attitude towards waste management' were not considered as the major concerns for the implementation of this option. Accordingly, this option is more appropriate for construction projects, has less construction duration, and less equipment since its influence is very low.

Furthermore, if this method is adopted, it is moderately influenced by the site's normal activities due to obstruction while waste sorting. Hence, it may lead to extending the project duration due to delays in construction activities. Because of that, the cooperation, or commitments from project management as well as the Client or project consultant will be the crucial factor to select this alternative.

Option II -Separation of materials as per the economic value (Separate steel or Reinforcement and the rest collect to sell)

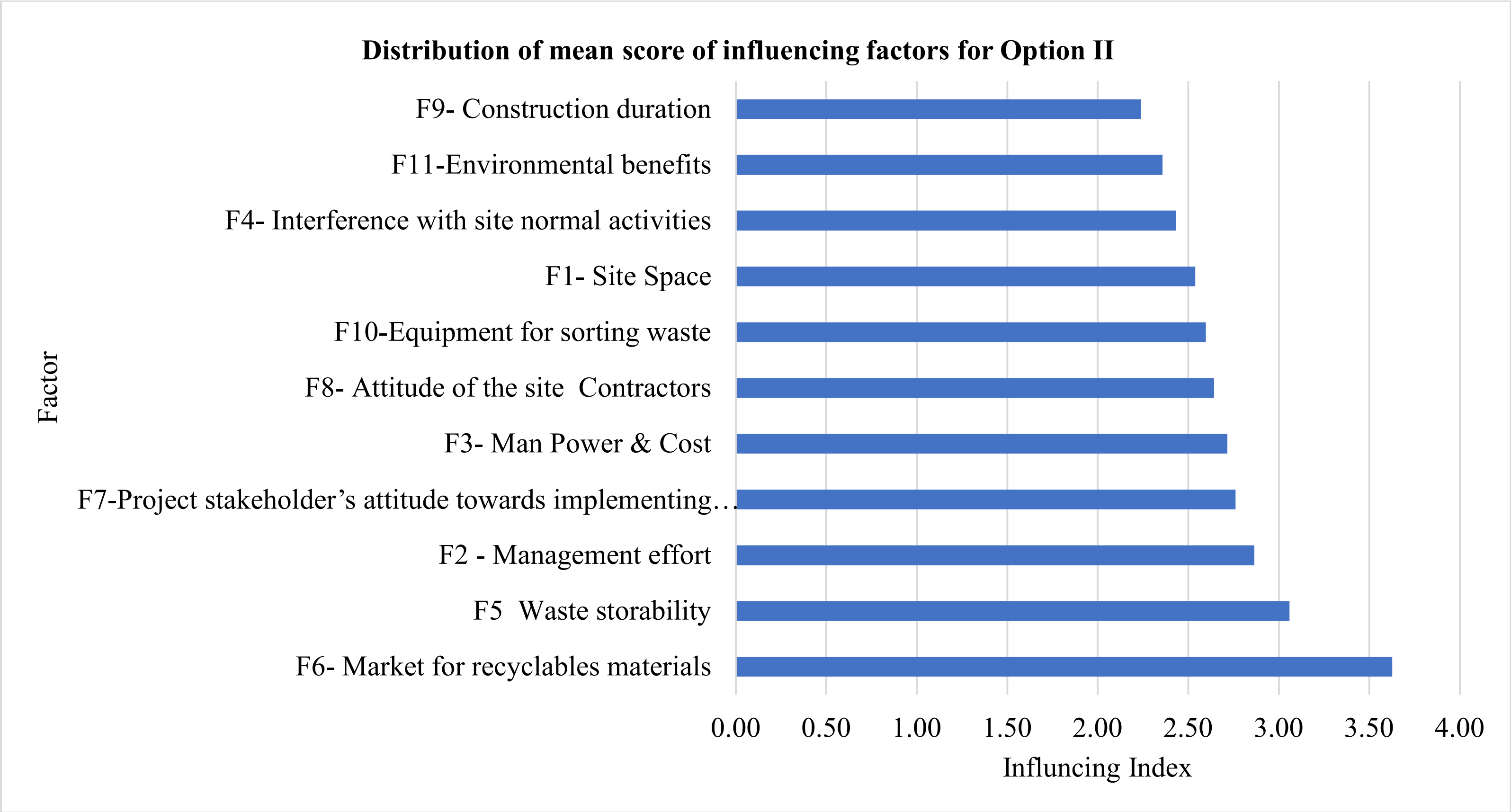

Figure 13:Influencing Factors for Option II

Figure 13 illustrates descriptive mean scores for influencing factors that affect to select waste sorting option II of Separation of materials as per the economic value (Separate steel or Reinforcement and the rest collected to sell).

Accordingly, the most influential factor to select this option is considered as 'Market for recyclables. If there is a better market for recyclable products, implementing this option may give high benefits to the projects. On the other hand, the sorted waste is also reused for succeeding activities and can be benefit it by reducing the project cost. In addition to that 'waste sortability', 'management effort', and 'attitude of project stakeholders to implement waste sorting methods' have been identified as the other utmost influencing factors, hence those have a high descriptive mean score of more than 2.5.

However, the 'Interfere with site normal activities' factor has a less influence than option I and it has been recognized as the third lowest. Also, the factor 'site space' is very less influential in the selection of this option. Also the influencing factor ‘project duration’ is not crucial to implement this option II.

- **3.0 Option III- Waste generated on-site is collected once a week or even more frequently transported to the outside rented location, and sorting it using a mix of options I and II, where workers will sort the waste according to options I & II.**

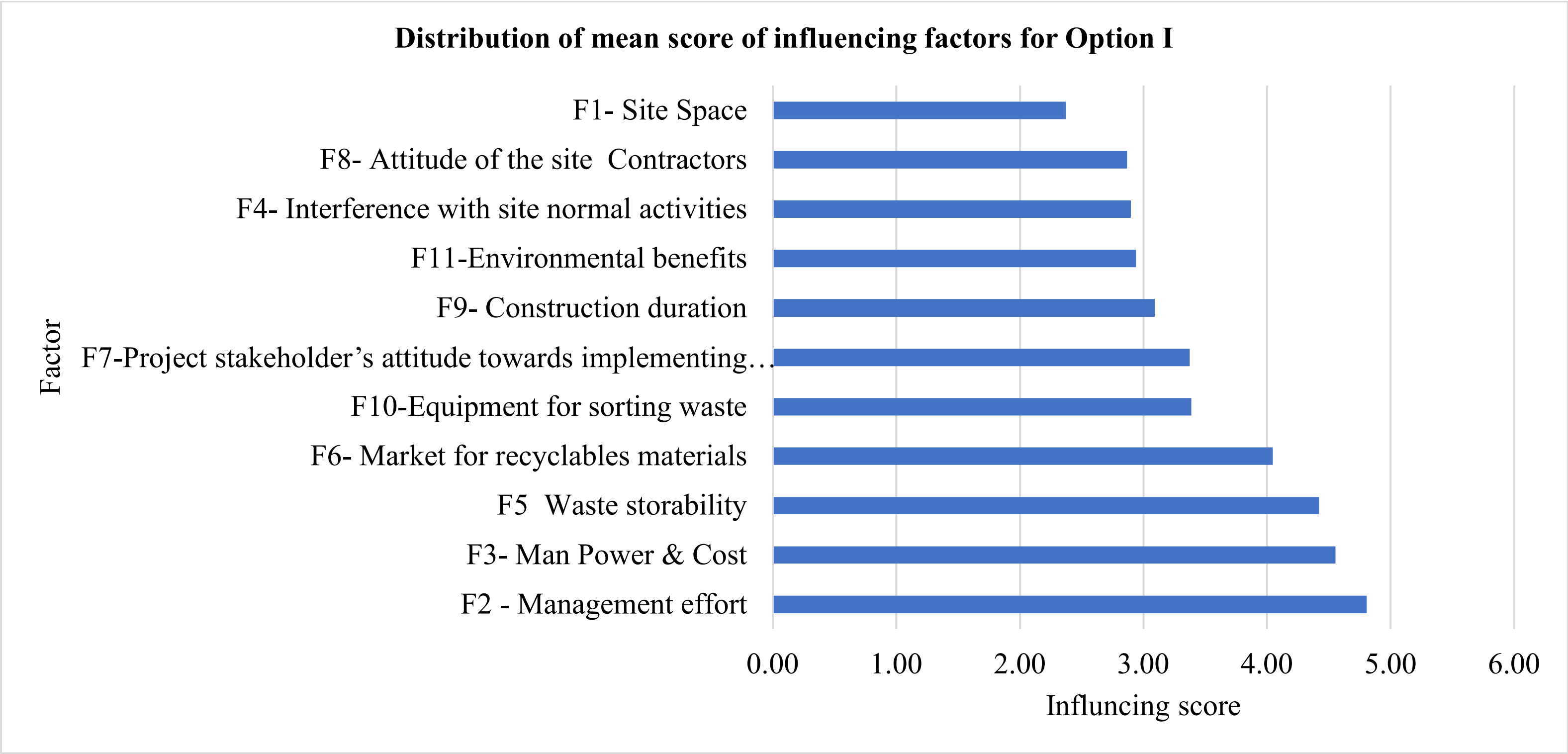

Figure 14:Influencing Factors for Option III

Figure 14 shows the descriptive mean scores for the influencing factors that influence the decision to be using Option III for offsite waste sorting. On-site waste is collected once a week or more frequently and delivered to an outside rented location, where it is sorted using a combination of options I and II, with labor separating the waste according to options I and II.

The 'Site Space' factor refers to the original site layout, as well as storage and sorting space for building debris. According to respondents, the availability of site space has the least impact on option III since only a small quantity of site space is necessary for keeping waste until it is delivered to the sorting location. The sorting area, on the other hand, will require sufficient space to keep waste that is brought daily or weekly.

The most significant component has been shown to be "management effort," followed by the cost of hiring a different area and transportation. The process' practitioners must collaborate in order to sort building waste offsite as efficiently as possible. Greater construction management is therefore necessary. Furthermore, respondents noted that the ‘manpower and cost' aspect is also important when choosing option III because extra work is required for waste collection, storage, transportation, sorting, and return to the market as well as to the site for reuse. On the other hand, it will require storage equipment for sorted waste as well as professional equipment for construction waste sorting off-site.

Because of the selection of option III, interference with normal construction activities will reduce, but during collection and storing it will interfere with other site activities.

4.3 Discussion- waste sorting options

The table 7 demonstrates the total constraint score of the waste sorting options: As a result, the most critical influencing factor for all waste sorting options was 'management effort'.

Table 7:Influencing index for each factor for each option of waste sorting

No	Influencing Factor	Option I/Mean	Rank	Option II/Mean	Rank	Option III/Mean	Rank
F1	Site Space	4.27	**2**	2.54	**8**	2.37	**11**
F2	Management effort	4.33	**1**	2.87	**3**	4.81	**1**
F3	Man power & Cost	4.25	**3**	2.72	**5**	4.55	**2**
F4	Interference with site normal activities	3.85	**6**	2.43	**9**	2.90	**9**
F5	Waste storability	4.21	**4**	3.06	**2**	4.42	**3**
F6	The market for recyclables materials	4.01	**5**	3.63	**1**	4.04	**4**
F7	Project stakeholder's attitude toward implementing on-site waste sorting	3.27	**7**	2.76	**4**	3.37	**6**
F8	The attitude of the site Contractors	3.00	**9**	2.64	**6**	2.87	**10**
F9	Construction duration	2.66	**10**	2.24	**11**	3.09	**7**
F10	Equipment for sorting waste	3.01	**8**	2.60	**7**	3.39	**5**
F11	Environmental benefits	2.52	**11**	2.36	**10**	2.94	**8**
	Overall influencing Score	**39.39**	**-**	**29.84**	**-**	**38.75**	

4.3.1 Comparison of proposed construction waste sorting options

As per the table 7, the total applicability score was computed based on the above computation for both onsite and offsite waste sorting options. Option II received the lowest overall influencing index score of 29.84, followed by option III with a score of 38.75 and option I with a score of 39.39. Accordingly, the lowest influencing score holds the option II of waste sorting as per separation of materials as per the economic value (Separate steel or Reinforcement and the rest collect to sell), hence this option is the most applicable for effective waste sorting. If, the market for the sorted waste, waste sort ability, and management effort to implementation, this option is the best for any project for waste sorting.

Most crucially in the second option respondents selected offsite waste sorting since it needed site space for waste sorting and seems to have the least influence on on-site activities, resulting in less interference with site activities. Furthermore, the findings suggest that onsite waste sorting by separating all waste by type, is the least applicable option for any site in the Colombo area due to a lack of site space for waste sorting and a high manpower demand, increasing cost.

Along with the overall influencing scores, the influencing scores of the various sorting alternatives were also compared. This was done to determine if there were any solutions that would be more suitable in a particular situation. Individual influencing ratings at "Management Effort," "Site Space," "Manpower & Cost," and "Waste Sort ability" are often higher for Option I. The project stakeholder's attitude for implementing on-site waste sorting receives the highest influencing scores for Option II at "Market for Recyclables," "Waste Sort ability," "Management Effort," and "Project stakeholder attitude." The highest individual influencing ratings, however, go to Option III for "Management Effort," "Labor Demanding & Cost," "Waste Sort Ability," and "Market for Recyclables Materials.". In addition, "Environmental benefits" and "Construction length" have been regarded as the elements with the least impact on Option III, as opposed to "Attitude of site Contractors.". Accordingly, those influencing factors were categorized as the dominant factors and minor factors for waste sorting and following figure15 illustrates the mean scores for each factor as per the options chosen.

4.3.2 Dominant factors waste sorting

I. **Management effort**

As per table 6, Management Effort' has the highest influence score of the two options except Option II. Because it frequently entails planning waste clearances, collection, and transportation to approved disposal destinations. Option II demands the least amount of management effort in this regard. This could be explained by the fact that only materials with significant market demand are sorted since such sorting is required at all sites. However, in Option III, extra effort with the commitment is needed since this option involves high cost and labor as well as a separate management team for waste transporting and storing.

II. **Manpower & Cost**

Contractors would always assign their workers to construction tasks rather than waste management. The most significant restraint is the COVID 19 Pandemic, which made it difficult for contractors to obtain the labor for construction rather than waste sorting for the first time. As a result, the cost of waste sorting is automatically added because the contractors do not place a high value on waste sorting but rather prioritize construction duration, quality, and cost management.

III. **Site Space**

When selecting both on and off-site waste sorting when site space is insufficient, this is one of the most important issues assessed by the respondent also as per the perception of (Poon C S, 2004). Option II from onsite waste sorting has a relatively low impacting index score, indicating that it requires the least amount of site area. This could be because the mass of sorted waste can be reused or recycled in subsequent actions, leaving less waste in the sorted site in Option I.

4.3.3 Minor factors for waste sorting

I. **Construction Duration**

Offsite waste sorting takes a lot of time and work because it necessitates a lot of transportation, as well as storing, sorting, and storing sorted waste before returning it to the site for reuse or sending it out to sort coming waste regularly. The project would be delayed if the construction activities were not well organized. Because management just considers the project length, onsite waste sorting has a lower influencing score than offsite waste sorting. If the project duration is longer, they get to choose the offsite waste sorting option.

II. Environmental Impact

Environment has an impact on how and when city highways may be used, how strength waste collection and sorting is, how much dust there is, and how much water can flow. This factor's influencing scores for the three sorting options do not differ significantly. This means that the factor is not considered important when choosing sorting options.

III. Interference with site normal activities

Since on-site waste sorting needs a large amount of the site's space, skilled workers, and additional transportation to transfer the sorted material, normal site operations must be suspended. The results of the poll show that Option I is the least practical because it significantly worsens daily tasks. However, until the collected garbage is transferred, storage facility space is needed, which will interfere with routine activities.

In conclusion, Option III outperforms the others, particularly in major construction projects with limited site space, and Option I should be the last option unless an outside facility for waste sorting cannot be obtained.

4.5 Discussion of management practices for effective waste sorting & management

Furthermore, the most influencing factor for waste sorting was revealed as management effort, hence the best management practices for effective waste sorting must be determined. As a result of the literature review, the following elements were identified, and respondents' opinions on their selection were obtained based on their experience from the questionnaire carried out along with waste sorting method selection.

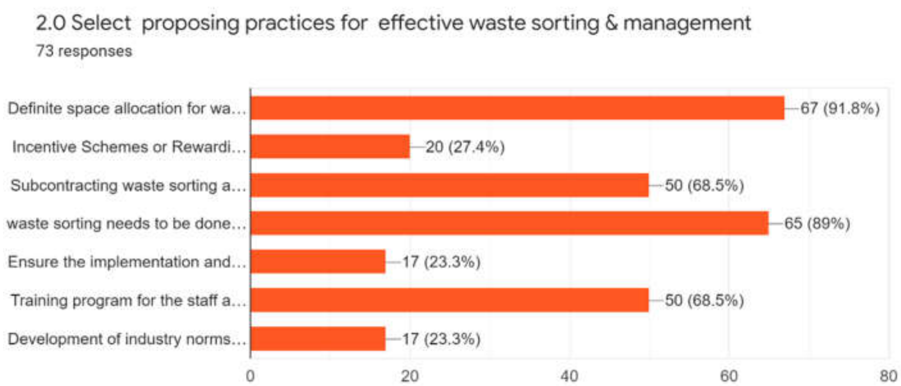

Figure 15: Best management practices for waste sorting & management

As per figure 15, in terms of waste sorting management effort, 67 out of 73 respondents voted for 'definite space allocation for waste sorting' as the best management approach, with 'arrangement of waste sorting to be done at the time of generation' and equality recommended, as well as 'subcontracting waste sorting' and 'Training program for the staff and works for waste sorting.

4.5.1 Obstacles to waste management at sites

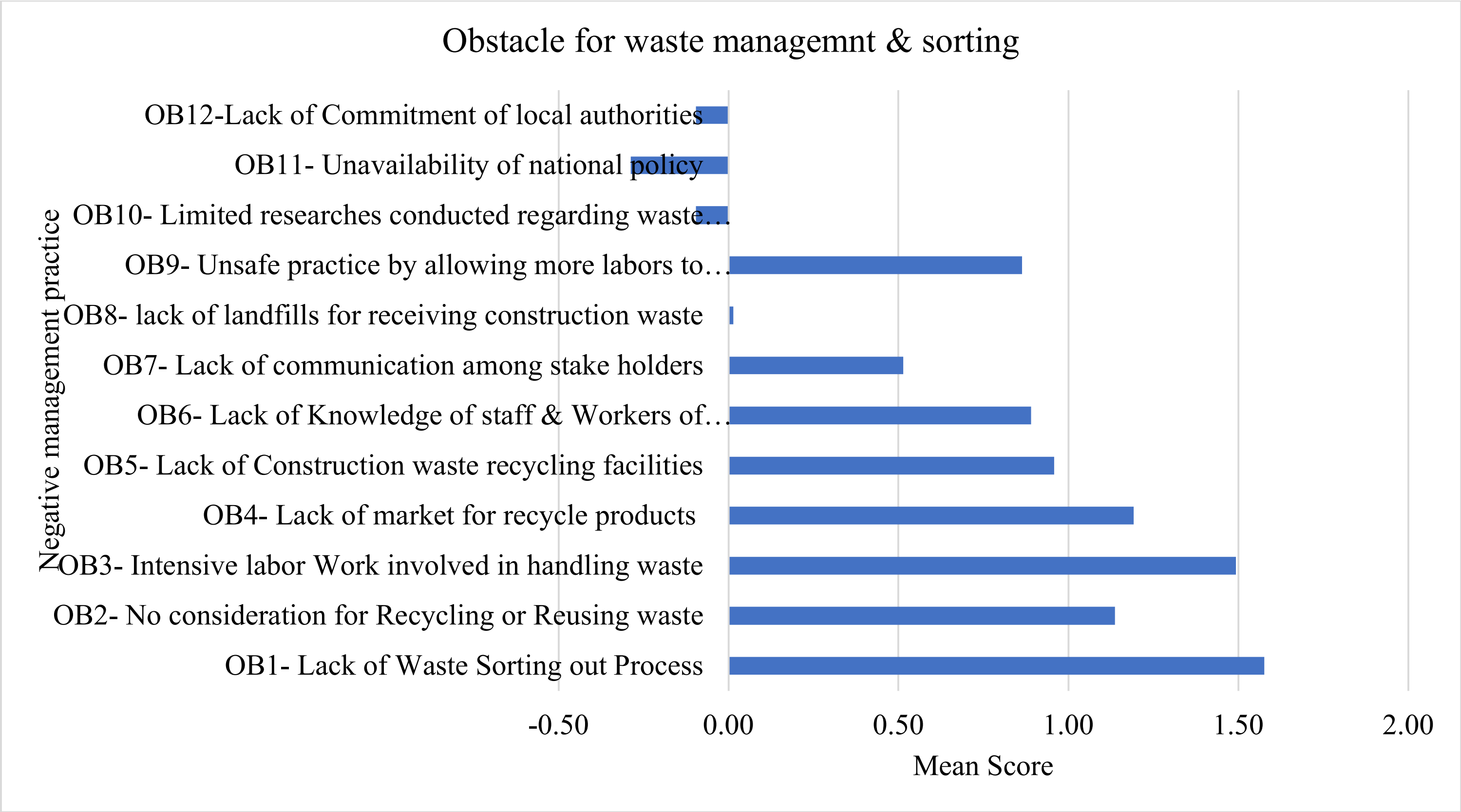

Figure 16: Obstacles to effective waste sorting & management

In Hong Kong, (Shen LY, 2004) identified several major obstacles, for instance, there is no waste sorting procedure, recycling waste is not a priority, processing waste requires a lot of effort, and collecting waste from the collection point takes a long time. It also said that to increase the effectiveness of on-site waste management, these problems needed to be addressed. Finding from this study demonstrates as per figure 14, the said all obstacles which were identified by (Shen LY, 2004) are also still valid in the Sri Lankan context. Accordingly, the lack of waste sorting out processes at any project greatly contributes to improper construction waste sorting out. Consequently, the lack of consideration for recycling or reusing the construction waste affects the waste management plan. Also, in the growing market there exists recycle markets for 'concrete and mortar waste,' 'timber and template waste,' and' steel bar waste.' Accordingly, these wastes are the most common on-site wastes. Now, most recycling is done by private companies; their capital is limited, facilities are less, and these companies only collect one or two types of waste.

The magnitude of the recyclable markets is also influenced contractors' interest in on-site waste sorting. In the preliminary study, contractors also provided influence as per their experience with the recyclable construction waste market, as illustrated in Figure 16.

4.5.3 Relation between waste sorting practices and management practices

A theoretical foundation is essential during project planning for construction waste management. As a result, the framework has adjustable pillars, such as the ones listed below.

I. Waste management monitoring, analysis, and reporting

- introduction of a statistical information system for the quantity of waste production
- Analyze the site's waste management procedures
- Monitoring of the organizational process for waste collecting

II. Awareness of the client, design team, contractor, and subcontractors of waste management

- introduction of waste-efficient designs
- Programs to enhance knowledge of innovative waste reduction strategies

III. Regulatory and institutional structure

- Create new guidelines and rules
- Create a centralized organization

IV. Allocation of funds

- Training programs
- Research
- Recycling facilities

V.Project waste management plan

- Facility development for on site for sorting waste
- Use construction techniques and materials that generate less waste.
- Training program for workers

VI.Adaptation of waste management hierarchy

- Waste reduction, reuse, and recycling innovations
- Avoid improper disposal

VII.Supportive workplace

- government cooperation in the waste management process
- encouraging the private sector to manage waste

To improve waste sorting methods and make them more effective, these theoretical procedures must be applied.

5. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

This study assessed critical waste management practices that can aid construction waste minimization. The purpose of this study was to determine the best waste sorting alternative based on the current influencing factors that affect its applicability. Three waste sorting options were considered. These options were studied based on eleven influencing factors through a questionnaire survey at 30 construction sites across Sri Lanka. Option (ii) was found as the most appropriate. Furthermore, the findings of the study suggests that on-site waste sorting options might result in significant waste reduction because the sorted waste can be reused for subsequent operations.

The top limiting factors, according to the data obtained, were ‘management effort’, ‘market for recyclables’, ‘waste sortability’, ‘availability of site area’ and ‘manpower and expense’. Furthermore, the obstacles to ‘management effort’, the most critical factor, were identified as 'lack of waste sorting out process', 'high labor involvement in sorting process', and 'lack of market for recyclable products. Accordingly, it implies the importance of management involvement in this waste sorting and the influence of government policies to empower the market to sort and recycle products.

Finding the best management strategies for minimizing the waste produced by building activities was another goal of this study. Development of alternatives for the waste sorting process that it generates, as well as measures within the job activities of building site managers, have been investigated as the primary and underlying management approaches for minimizing waste generation. Although current construction methods have been shown to reduce construction waste, the decision to adopt construction methods and modular construction techniques might have been made before the appointment of a construction site manager. This research does not collect information from other industry sectors that do not directly deal with waste, such as designers, architects, employers, and government officials. Other factors that may impact the process of on-site wastes, such as design coordination and procurement procedures, were not included in this study and the correlation of the factors, as well as the variances between the samples, are not considered.

Construction waste management is a challenging task, and this issue must be brought to the attention of not only management personnel but also regulatory authorities. Due to the relatively limited landfill capacity for waste disposal and the need to conserve this limited capacity for the future, landfilling of solid waste has been designated as the least desirable disposal technique in Sri Lanka. However, as compared to European and American construction industry, the use of legal, economic, and administrative strategies to regulate and reduce waste growth is negligible. To summarize even if the important to set clear supports recycling and waste reduction, the country's waste management institutions and policy frameworks are insufficient to ensure long-term waste management sustainability.

5.2 Recommendations

On-site waste sorting methods are in place for all building waste. Different categories of waste, including domestic waste, inert and non-inert construction waste, and chemical waste, are collected, and disposed of in various designated areas/facilities on the construction sites, reducing waste collection time and preventing double-handling. Furthermore, rather than appointing a single person to be responsible for each operation, all workers should be expected to sort and place generated construction waste following the waste management plan. Rather than being a burden to the construction process, waste sorting must be an essential element of normal construction activities.

On-site sorting, on the other hand, is significantly reliant on the cooperation of contractors, employers, and engineers, among others. It includes educating employees and subcontractors about waste management. For the most part, becoming familiar with and comfortable with waste separation is a continuous learning process. Furthermore, environmental, and economic considerations have elevated the need of controlling waste generation. The Contractor of a project plays a critical role in making sure that the construction activity is as clean and efficient as possible. The advantages of such a strategy are obvious.

This study highlights the importance of management efforts for effective waste management through identified critical factors. Even though the other factors influence waste management at the site, these management practices play a major role in the success of construction projects.

5.3.1 Waste Reduction through Precast Products

When the historical data is considered, the prefabricated concrete construction system has equivalent production values to ready-mixed concrete manufacturing after 150 years of application. When these qualities are examined within the context of our nation, it becomes clear that precast concrete is far behind traditional construction techniques. However, prefabricated concrete production methods have benefits over conventional methods that might be favored in many areas due to both the good qualities it possesses and the potential of the production system structure.

Construction waste discharges from prefabricated concrete applications are 50% lower than those from conventional methods. The major causes of this predicament are that prefabrication is an industrial construction process, which means that waste management applications are being used, less building materials are needed during manufacture, and these resources are used in a relatively regulated environment. Due to the long history of prefabricated concrete production, the industry may focus its efforts on designs, waste management, and sustainable practices. According to the thesis's content, this kind of research and design studies can make it possible to integrate a variety of environmentally conscious applications into every process, from the project stage to the application stage. The construction industry does not require temporary formwork, scaffolding, etc. for its prefabricated concrete buildings. As a result, concerns with safety, time waste, and environmental pollution caused by the usage of these tools are all avoided. (Bayraktar, 2020)

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DEVELOPING AN EFFECTIVE WASTE MANAGEMENT PLAN FOR BUILDING CONSTRUCTION SITES

Dear Participants,
I B J P Edirisinghe is currently work with the National Water Supply and Drainage Board as a Project Engineer. I have enrolled as a postgraduate student in the Faculty of Engineering at the University of Moratuwa's MSc in Construction Project Management program and am currently reading for my research project on "Developing an effective waste management plan for building construction sites In Sri Lanka.". The main objective of my research are as follows.
1.0 Assess the waste generation of main construction materials and type of work activities which are made high waste
2.0 Assess the waste sorting techniques which are currently practicing on sites
3.0 Opinions for waste sorting techniques
4.0 Identify and assess the influencing factors for effective waste sorting practices at site
This questionnaire is part of my research, and the information contained inside it will be considered confidential and used solely for academic purposes. I would appreciate it if you could take a few moments out of your hectic schedule to complete this questionnaire.
Thanking You

B.J.P Edirisinghe (BSc Eng (Hons), C Eng, MIESL ,PMP)
Project Engineer
National Water Supply & Drainage Board

* Required

Section A-General Information

Please provide your details

1. 1.1 Designation of the Respondent *

Mark only one oval.

- ◯ Construction Project Manager
- ◯ Construction Planning Engineer
- ◯ Quantity Surveyer
- ◯ Site Engineer

2. 1.2 Working Experience in the current Industry *

Mark only one oval.

- More than 10 Years
- 5-10 Years
- Up to 5 Years

3. 1.3 What is the sector of your Company *

Mark only one oval.

- Government Owned Construction Company
- Private Owned Construction Company
- Consultancy Firm

4. 1.4 What type of project you are involving? *

Mark only one oval.

- Institutional or Social Beneficial Construction Project
- Housing and Apartment Construction Project
- Commercial Building Construction Project

5. 1.5 State the Type of the Client of your Project *

Mark only one oval.

- Public
- Private

Section B-Waste Generation

6. 1.0 State the quantity of waste generation in the activities as per your experience *

Mark only one oval per row.

	1-None	2-Less Quantity	3-Moderate Quantity	4-High Quantity	5-Very High Quantity
1.0 Concreting Works	⬭	⬭	⬭	⬭	⬭
2.0 Reinforcement Works	⬭	⬭	⬭	⬭	⬭
3.0 Form Works	⬭	⬭	⬭	⬭	⬭
4.0 Block & Brick Works	⬭	⬭	⬭	⬭	⬭
5.0 Rubble Works	⬭	⬭	⬭	⬭	⬭
6.0 Electrical Wirings	⬭	⬭	⬭	⬭	⬭
7.0 Aluminum Works	⬭	⬭	⬭	⬭	⬭
8.0 Plastering Works	⬭	⬭	⬭	⬭	⬭
9.0 Painting Works	⬭	⬭	⬭	⬭	⬭
10.0 Tiling Works	⬭	⬭	⬭	⬭	⬭

7. 2.0 State the relative tendency of raw materials are wasting in your site till dispose *

Mark only one oval per row.

	1-None	2-Less Quantity	3-Moderate Quantity	4-High Quantity	5-Very High Quantity
1.0 Cement					
2.0 Sand					
3.0 Aggregate					
4.0 Rubble					
5.0 Steel Reinforcement					
6.0 Engineering Bricks					
7.0 Cement Blocks					
8.0 Timber					
9.0 Ply Wood					
11.0 Electrical Wires					
12.0 Earth (Soil)					
13.0 Tiles					
14.0 Paint					

8. 3.0 State up to what extent following reasons have caused waste generation at your site *

Mark only one oval per row.

	1-None	2-Less Quantity	3-Moderate Quantity	4-High Quantity	5-Very High Quantity
1.0 Design Changes	⬭	⬭	⬭	⬭	⬭
2.0 During Transporting	⬭	⬭	⬭	⬭	⬭
3.0 Mistakes of officers or Workers	⬭	⬭	⬭	⬭	⬭
4.0 Quality of work activity	⬭	⬭	⬭	⬭	⬭
5.0 Mismatches in required materials	⬭	⬭	⬭	⬭	⬭
6.0 Poor Skills of workers	⬭	⬭	⬭	⬭	⬭
7.0 Weather Condition	⬭	⬭	⬭	⬭	⬭
8.0 Negligence	⬭	⬭	⬭	⬭	⬭
9.0 Material handling	⬭	⬭	⬭	⬭	⬭
10. Poor Supervision	⬭	⬭	⬭	⬭	⬭
11. Changes by Architect or Engineer	⬭	⬭	⬭	⬭	⬭
12. End of product life	⬭	⬭	⬭	⬭	⬭

9. 4.0 Practicing measure in site to manage and minimize waste at your site *

Check all that apply.

- [ ] 1.0 Identify construction activities that may result in the release of reusable materials from the construction site
- [ ] 2.0 Waste reduction target for sub Contractors
- [ ] 3.0 Use of secure storage facilities for materials
- [ ] 4.0 Prevent over- ordering
- [ ] 5.0 Prevention of double handling of materials
- [ ] 6.0 Reuse of off cut materials (Reinforcement, tiles etc...)
- [ ] 7.0 Landscaping with demolished or excavated materials
- [ ] 8.0 Prefabrication space on the site for proper construction waste sorting/Management
- [ ] 9.0 Stick to the Project drawings & specifications
- [ ] 10. Checks on the use of construction waste containers on regular basis
- [ ] 11.Avoiding generated waste mixing with soil
- [ ] 12.Providing each subcontractor with waste collection bins
- [ ] 13.Reduce the number of changes during construction
- [ ] 14.Erecting temporary bins at each construction zone
- [ ] 15.Ensure sufficient access to the site for material supply and movement
- [ ] 16.On site waste auditing to track records
- [ ] 17.Dedicated area for cutting & Storages
- [ ] 18.Waste skipping technique for pre-defined activities
- [ ] 19.Reuse of scrap materials from cutting stocks
- [ ] 20.Waste sorting for reuse and recycling
- [ ] 21.Dedication the responsibility to subcontractor for waste disposal
- [ ] 22.Maximizing the reuse of raw materials
- [ ] 23.Procurement waste minimization strategies
- [ ] 24.Improvement attitude towards construction waste minimization
- [ ] 25.delopment of waste data collection model(Mapping flow of waste)

Section C-Waste Sorting Practices

10. 1.0 State how you deal with generated waste *

Check all that apply.

- [ ] 1.0 On Site Waste Sorting
- [ ] 2.0 Off Site waste Sorting
- [ ] 3.0 Directly Dump into Land fills
- [ ] 4.0 Selling

11. 2..0 Select activities from the list where waste sorting methods are practiced *

Check all that apply.

- [ ] 1.0 Concreting (Manual Mixing)
- [ ] 2.0 Steel Reinforcement (Cutting, Bending and Fixing)
- [ ] 3.0 Form Work erection and dismantling
- [ ] 4.0 Cement blocks/Bricks works
- [ ] 5.0 Rubble works
- [ ] 6.0 Plastering Works
- [ ] 7.0 Tiling Works
- [ ] 8.0 Painting Works
- [ ] 9.0 Aluminum Works
- [ ] 10.0 Electrical Wiring Works

Section D-Opinion for Waste Sorting

State the constraint for the Options (I ,II III) for waste sorting when adapting it.

12. 1.0 Option I-Separation of materials as per the type (Ex- Domestic waste, Inert waste, Non Inert waste and chemical waste *

Mark only one oval per row.

	1 Least Influence	2 Less Influence	3 Moderately Influence	4 Highly influence	5 Very Highly influence
1.0 Site Space	⬭	⬭	⬭	⬭	⬭
2.0 Management effort	⬭	⬭	⬭	⬭	⬭
3.0 Man Power & Cost	⬭	⬭	⬭	⬭	⬭
4.0 Interference with site normal activities	⬭	⬭	⬭	⬭	⬭
5.0 Waste storability	⬭	⬭	⬭	⬭	⬭
6.0 Market for recyclables materials	⬭	⬭	⬭	⬭	⬭
7.0 Project stakeholder's attitude towards implementing on site waste sorting	⬭	⬭	⬭	⬭	⬭
8.0 Attitude of the site Contractors	⬭	⬭	⬭	⬭	⬭
9.0 Project duration	⬭	⬭	⬭	⬭	⬭
10. Equipment for sorting waste	⬭	⬭	⬭	⬭	⬭

11. Environmental benefits	⬭	⬭	⬭	⬭	⬭

13. 2.0 Option II-Separation of materials as per the economic value (Separate steel or Reinforcement and the rest collect to sell) *

Mark only one oval per row.

	1 Least Influence	2 Less Influence	3 Moderately Influence	4 Highly influence	5 Very Highly influence
1.0 Site Space	◯	◯	◯	◯	◯
2.0 Management effort	◯	◯	◯	◯	◯
3.0 Man Power & Cost	◯	◯	◯	◯	◯
4.0 Interference with site normal activities	◯	◯	◯	◯	◯
5.0 Waste storability	◯	◯	◯	◯	◯
6.0 Market for recyclables materials	◯	◯	◯	◯	◯
7.0 Project stakeholder's attitude towards implementing on site waste sorting	◯	◯	◯	◯	◯
8.0 Attitude of the site Contractors	◯	◯	◯	◯	◯
9.0 Construction duration	◯	◯	◯	◯	◯
10. Equipment for sorting	◯	◯	◯	◯	◯

waste					
11. Environmental benefits	⬭	⬭	⬭	⬭	⬭

14. 3..0 Option III-Off site waste sorting-with combination of option I and II- The waste generated on-site is collected once a week or even more frequently to a rented location, where workers will sort the waste according to option I & II. *

Mark only one oval per row.

	1 Least Influence	2 Less Influence	3 Moderately Influence	4 Highly influence	5 Very Highly influence
1.0 Site Space	◯	◯	◯	◯	◯
2.0 Management effort	◯	◯	◯	◯	◯
3.0 Man Power & Cost	◯	◯	◯	◯	◯
4.0 Interference with site normal activities	◯	◯	◯	◯	◯
5.0 Waste storability	◯	◯	◯	◯	◯
6.0 Market for recyclables materials	◯	◯	◯	◯	◯
7.0 Project stakeholder's attitude towards implementing on site waste sorting	◯	◯	◯	◯	◯
8.0 Attitude of the site Contractors	◯	◯	◯	◯	◯
9.0 Construction duration	◯	◯	◯	◯	◯
10. Equipment	◯	◯	◯	◯	◯

for sorting waste					
11. Environmental benefits	◯	◯	◯	◯	◯

Section E-Obstacles Waste Sorting and Opinion for effectiveness

15. 1.0 State your opinion why waste sorting practices are negatively influence for on site waste minimization

Mark only one oval per row.

	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1.0 Lack of Waste Sorting out Process					
2.0 No consideration for Recycling or Reusing waste					
3.0 Intensive labor Work involved in handling waste					
4.0 Lack of market for recycle products					
5.0 Lack of Construction waste recycling facilities					
6.0 Lack of Knowledge of staff & Workers of waste sorting					
7.0 Lack of communication among stake holders					
8.0 lack of landfills for receiving construction waste					
9.0 Limited researches conducted					

regarding waste sorting or management					
10.0 Unavailability of national policy					
11.Lack of Commitment of local authorities					

16. 2.0 Select proposing practices for effective waste sorting & management

Check all that apply.

- [ ] Definite space allocation for waste sorting
- [ ] Incentive Schemes or Rewarding for waste sorting workers /sub -contractors
- [ ] Subcontracting waste sorting activities
- [ ] waste sorting needs to be done at the time of generation
- [ ] Ensure the implementation and compliance of waste management plan
- [ ] Training program for the staff and works for waste sorting practices
- [ ] Development of industry norms for waste management

DEVELOPING AN EFFECTIVE WASTE MANAGEMENT PLAN FOR BUILDING CONSTRUCTION SITES

73 responses

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Section A-General Information

1.1 Designation of the Respondent

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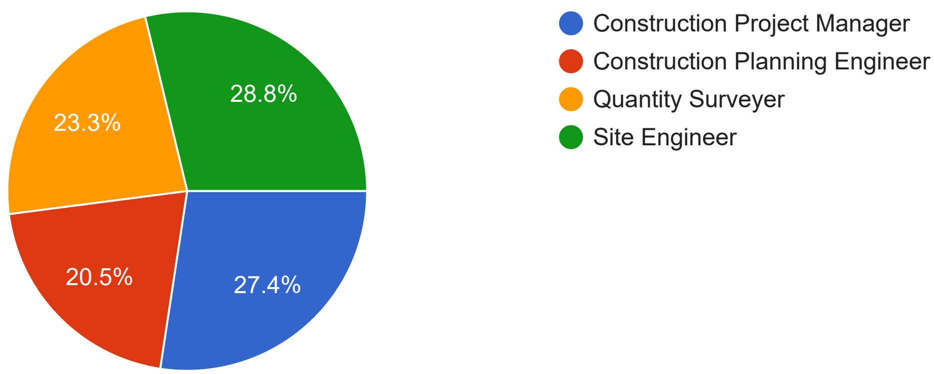

1.2 Working Experience in the current Industry

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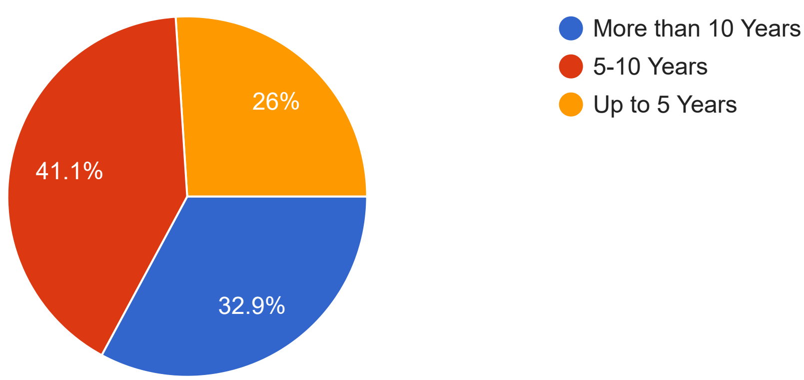

1.3 What is the sector of your Company

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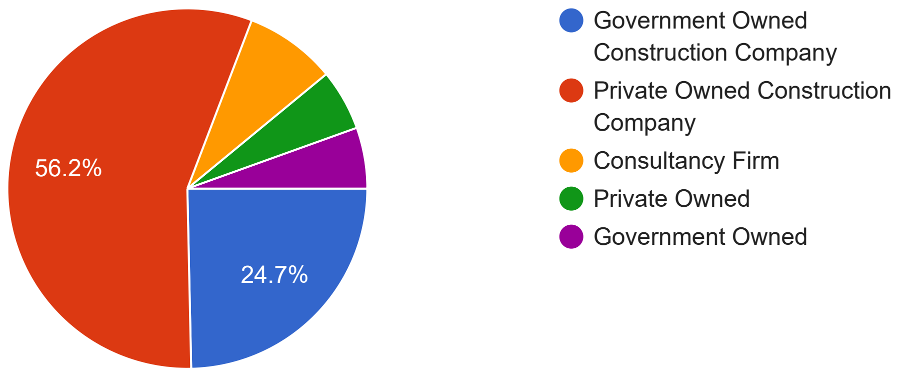

1.4 What type of project you are involving?

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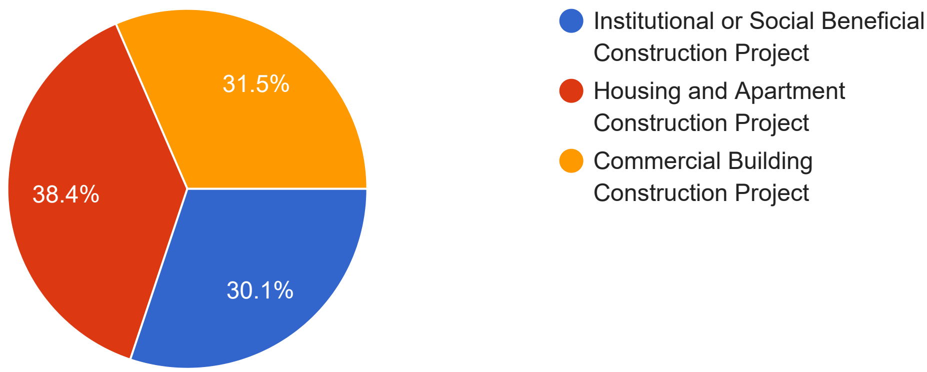

1.5 State the Type of the Client of your Project

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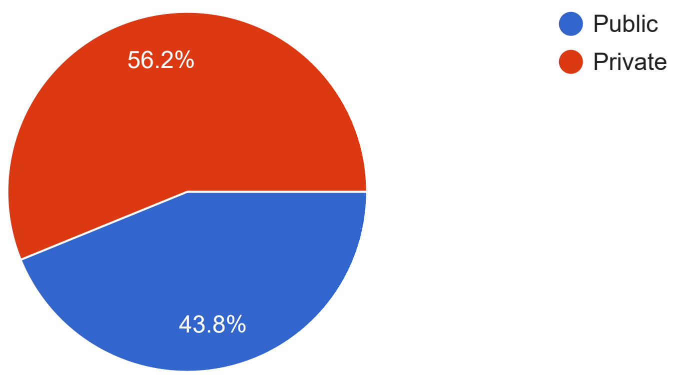

Section B-Waste Generation

1.0 State the quantity of waste generation in the activities as per your experience

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2.0 State the relative tendency of raw materials are wasting in your site till dispose

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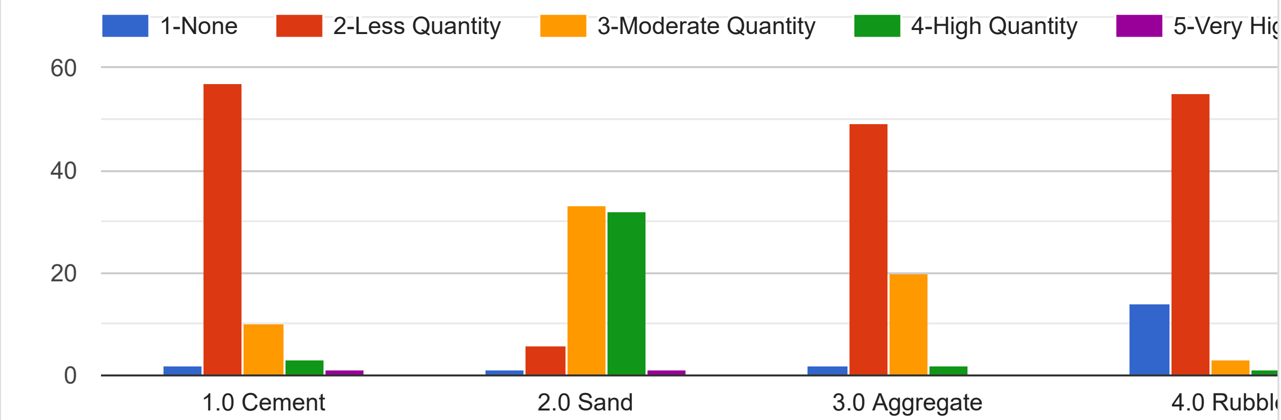

3.0 State up to what extent following reasons have caused waste generation at your site

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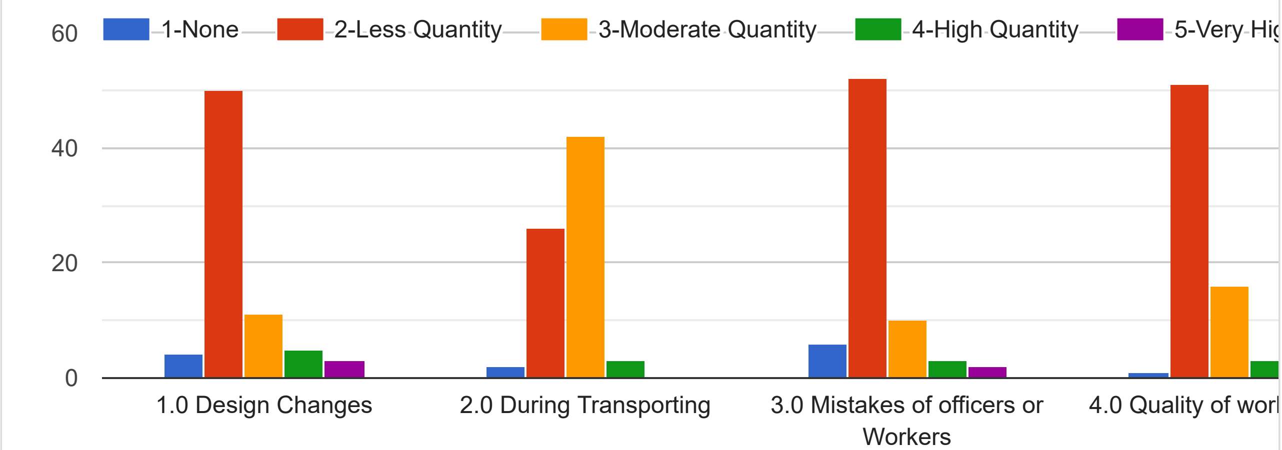

4.0 Practicing measure in site to manage and minimize waste at your site

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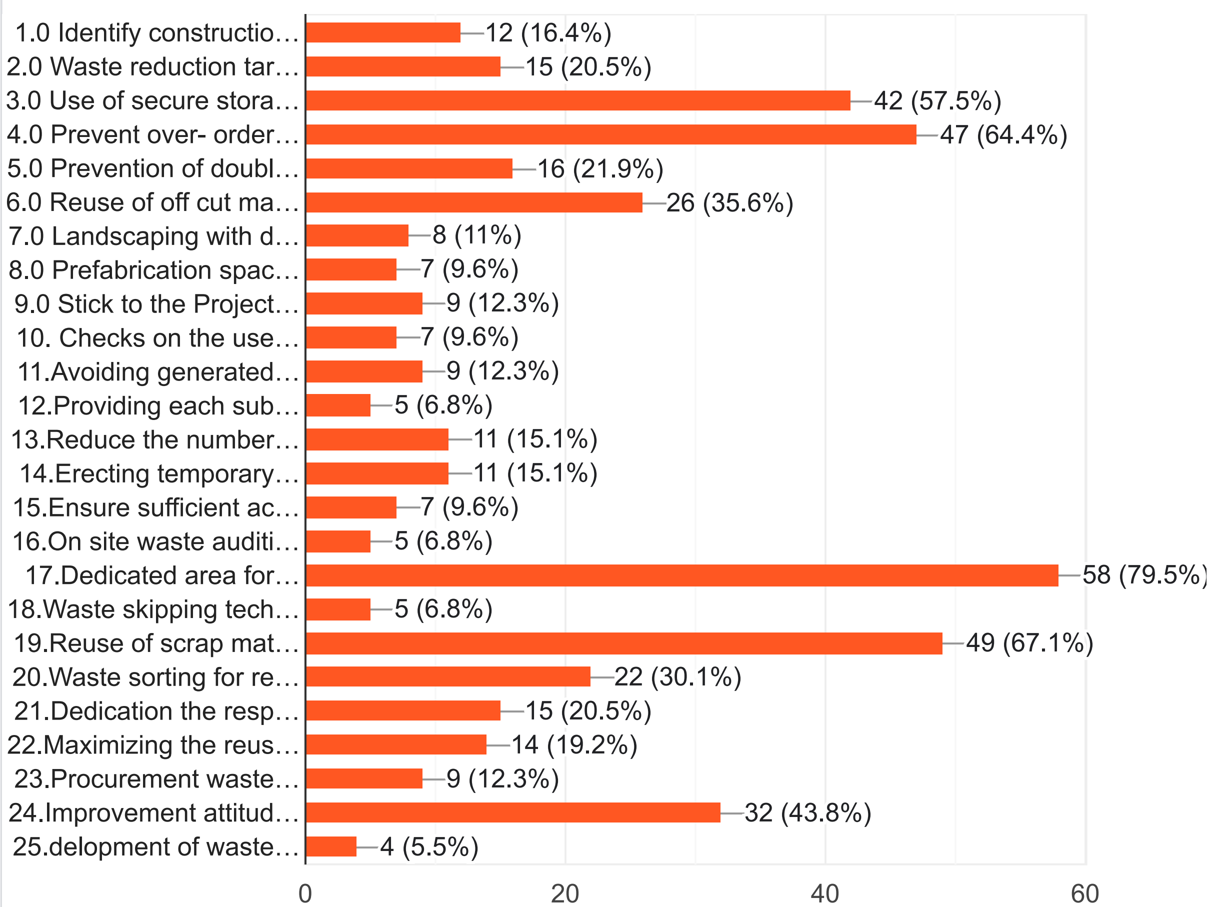

Section C-Waste Sorting Practices

1.0 State how you deal with generated waste

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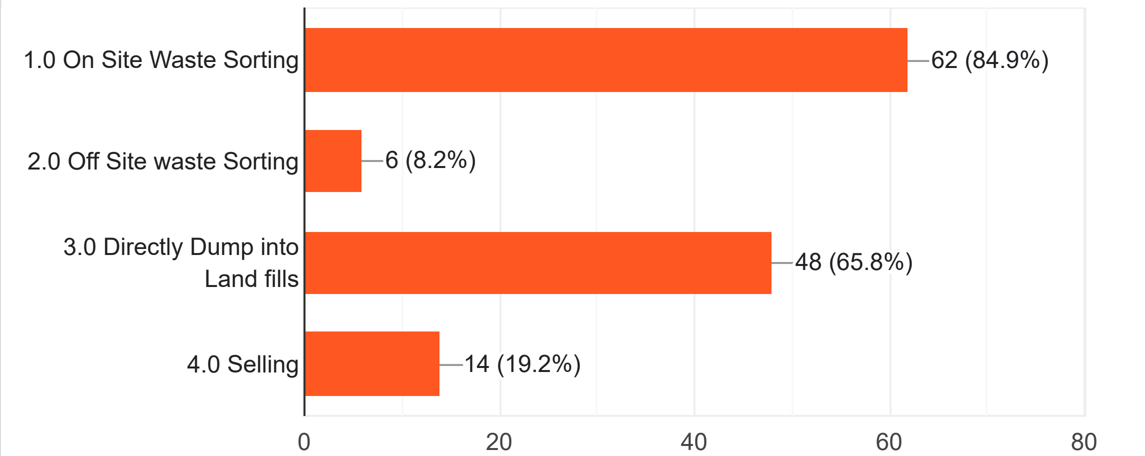

2..0 Select activities from the list where waste sorting methods are practiced

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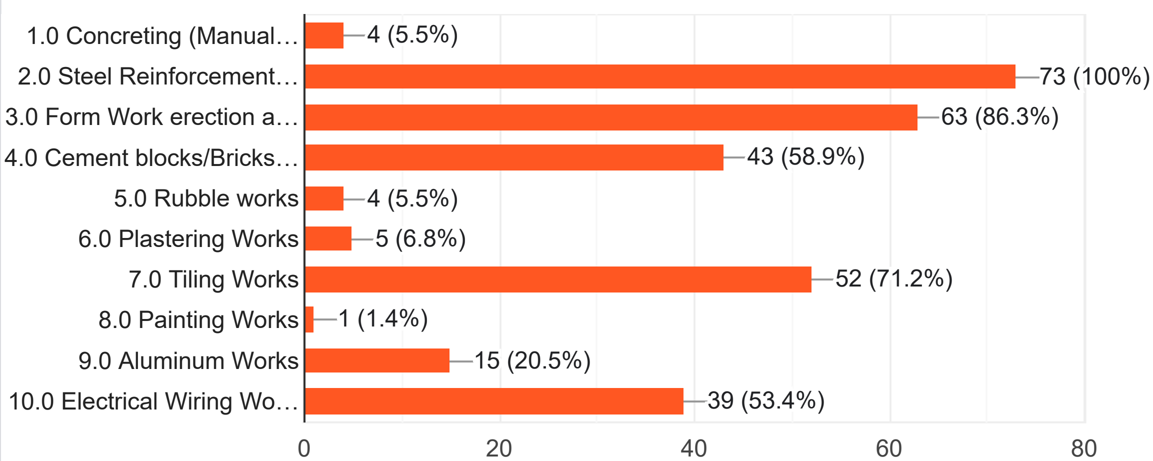

Section D-Opinion for Waste Sorting

1.0 Option I-Separation of materials as per the type (Ex- Domestic waste, Inert waste, Non Inert waste and chemical waste

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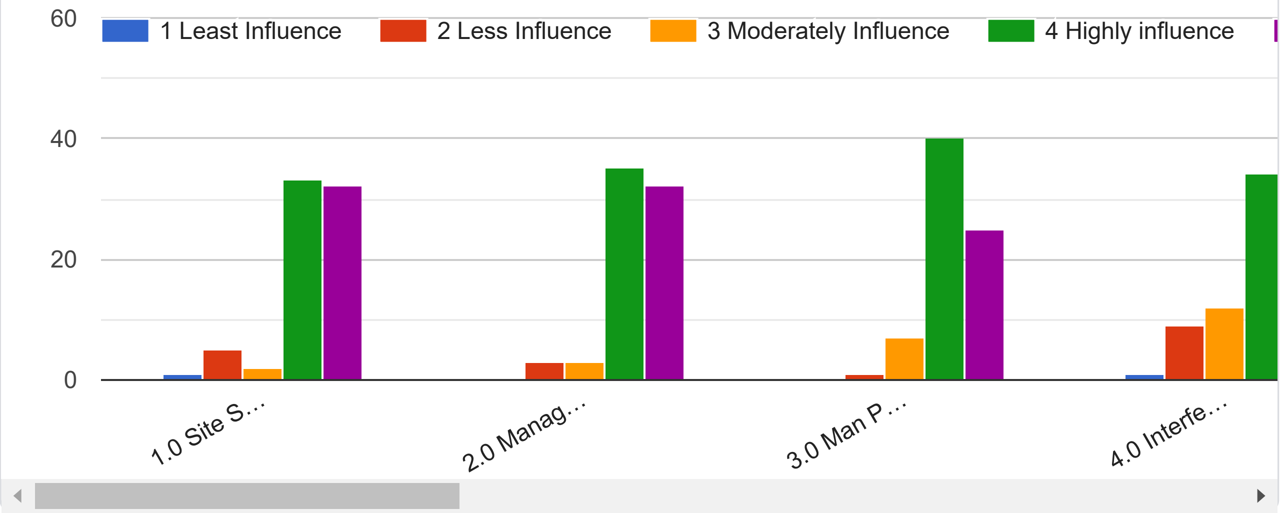

2.0 Option II-Separation of materials as per the economic value (Separate steel or Reinforcement and the rest collect to sell)

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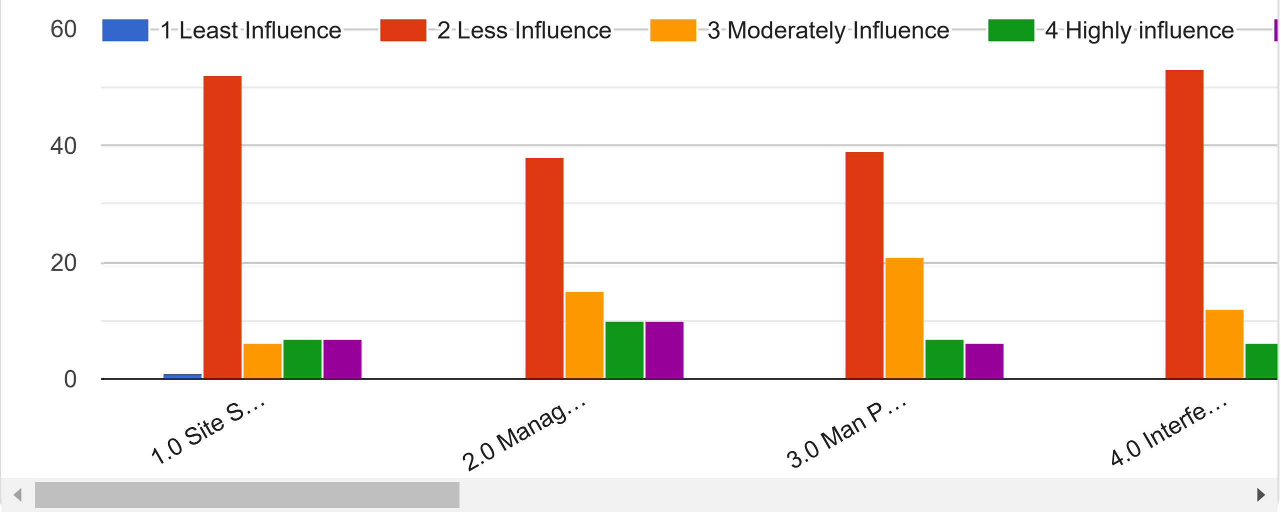

3..0 Option III-Off site waste sorting-with combination of option I and II-The waste generated on-site is collected once a week or even more frequently to a rented location, where workers will sort the waste according to option I & II.

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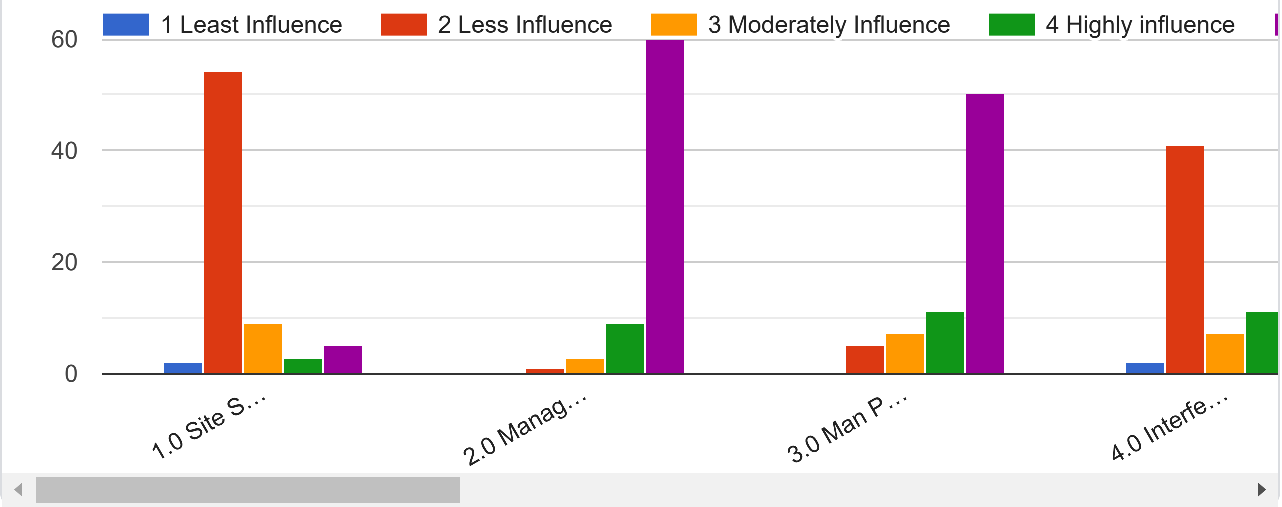

Section E-Obstacles Waste Sorting and Opinion for effectiveness

1.0 State your opinion why waste sorting practices are negatively influence for on site waste minimization

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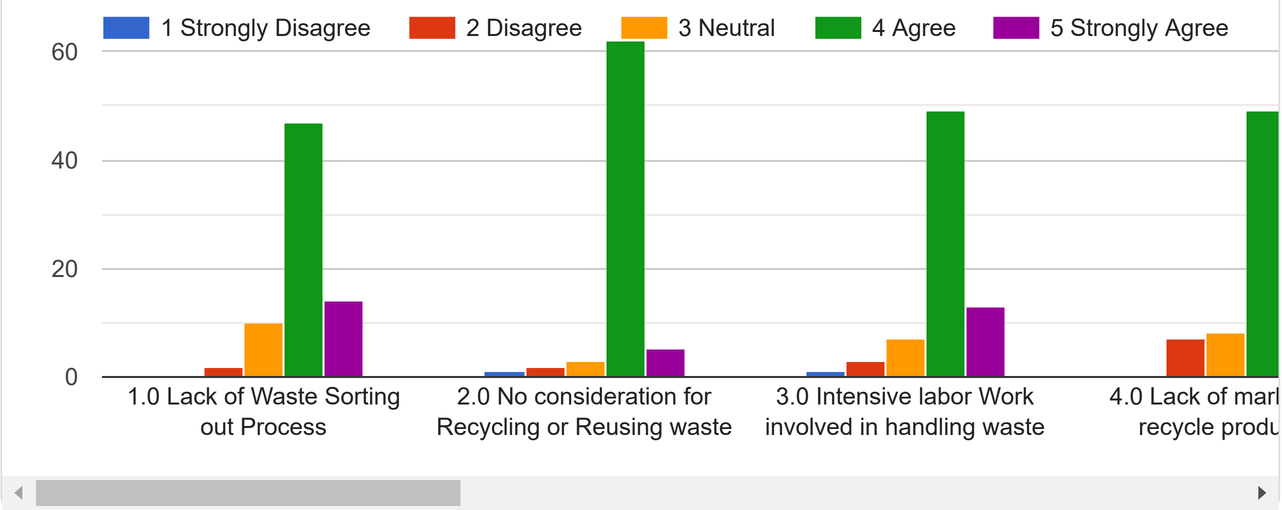

2.0 Select proposing practices for effective waste sorting & management

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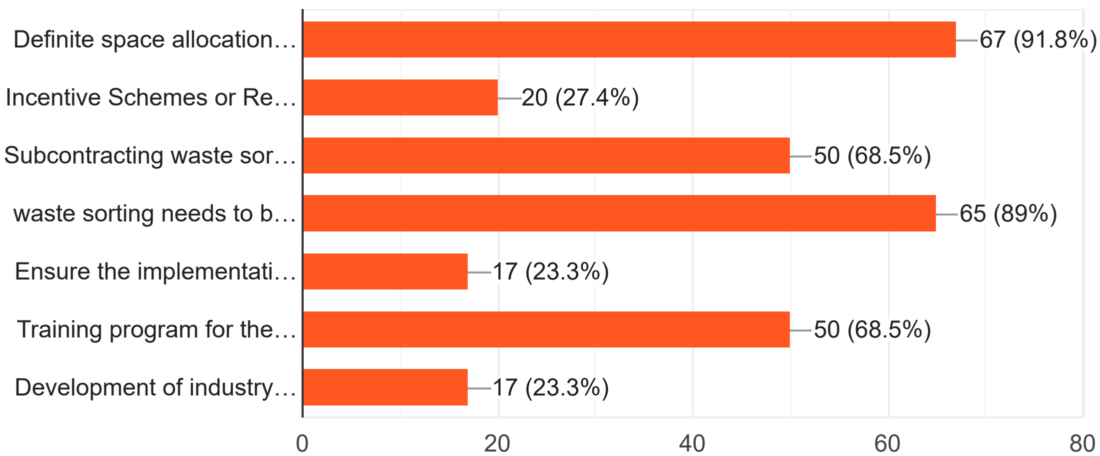

Appendix III

Project List

No	Organization	Project Name
1	**State Engineering Corporation**	Lunawa Housing Scheme
		soizapura Housing Project
		Angoda Housing Project
2	**Centracl Engineering Consultancy Bureau**	Construction of Courts Complex - Homagama
		Proposed Building for OPD, Laboratory, Radiology Unit and Ward, base Hospital
		Kothalawala - Defense University,Teaching Hospital
		E-City
3	**Access Engineering PLC**	Urban Regeneration Project, City of Colombo
		Construction of the phase 1B of the nano technology center of excellence
		Water Front-Slave Island
4	**CML MTD Construction Limited**	Salamulla Housing Project
		Alith Mawatha Housing Project
		Ragama Housing Project
5	**Home Lands Private Limited**	Canterbury Golf Resort Apartment-Kahathuduwa
		Elexia 3C's Apartments Malabe
		Santorini Resort Apartments Negambo
6	**Thudawe Brothers Pvt Ltd**	UDA - 672 Housing Units, Aluth Mawatha Road, Colombo 15
		People's Leasing Havelock Property Ltd, Head office – Colombo 07
		Lee Hedges Development - Colombo 03
7	**Sanken Construction Pvt Ltd**	Twinpeak Apartments at Colombo 04
		Capital Casa Apartment at Thalapathpitiya
		Medical Faculty Building Project at Borella
		Administrative building office at Gampaha
8	**Maga Engineering**	Prime Grand, Colombo 07
		Fairway Urban Homes, Koswatta
		Urban Regeneration: Colombage Mawatha