< Reducing Landfill Waste in Sierra Leone with Construction Industry Material Waste Management >

Master Thesis

International Master of Science in Construction and Real Estate Management

<Joint Study Program of Metropolia Helsinki and HTW Berlin>

Faculty 2

from

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Date:

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[Copy of proposed conceptual formulation]

Metropolia

htw. Hochschule für Technik und Wirtschaft Berlin University of Applied Sciences

International Master of Science in Construction and Real Estate Management - Joint Study Programme of Metropolia Helsinki and HTW Berlin
Date: 21.05.2021

Conceptual Formulation

Master Thesis for: Ms. Miriam Mosiatta Sesay

Metropolia Student ID number: 2018815

Topic: Reducing Landfill Waste in Sierra Leone with Construction Industry Material Waste Management

Source: Russillo, J., 2018. The Kingtom dumpsite in Freetown, Sierra Leone.

Ari Koistinen

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Name and Signature of Second Supervisor

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Name and Signature of Second Supervisor

Background

Sierra Leone is grappling with the issue of construction site sustainability. Another of the main challenges would be the increasing amount of material waste produced by construction and disposed of in landfills. The World Bank (WB), 2004, reported over three million kilograms of trash are generated daily in Sierra Leone's capital city, with no safe way of disposing of it. The WB stated that the country's waste collection in the town had about 40 per cent of the overall waste produced in the town. Surrounding areas around the city's landfill sites present environmental and health risks.

Municipal material waste management poses several health and safety hazards from the environmental pollution in Sierra Leone. Risks result from haphazard waste generation, collection deficiencies, and disposal. Russillo, 2018 quoted the environmental and social officer of the Freetown City Council (FCC), "Both landfills in Freetown have exhausted their capacities. Additionally, these initiatives require significant resources, and we have struggled to enforce legal and economic standards effectively." Gogra et al., 2010, stated that Freetown's limited industry contributes approximately 20 tons of waste per day. As the population increases, so do the need for construction, generating more waste as there are no waste management practices adopted for the construction industry in the country.

Research Questions

- How could the Sierra Leone construction industry contribute to reducing wastes deposited in landfill sites?
- What are the benefits of waste management in the construction industry to the country?
- What challenges would practising waste management in the country's construction industry bring?

Research Methodology

This paper examined earlier research on the causes of waste and suggested measures to lessen it. The report investigated the root sources of waste in Sierra Leone's construction industry, including the advantages of regularly implementing efficient waste management practices. The study will use a survey methodology incorporating current scales from peer-reviewed, high-quality academic journals. The research investigates material waste management and obtained information from project managers

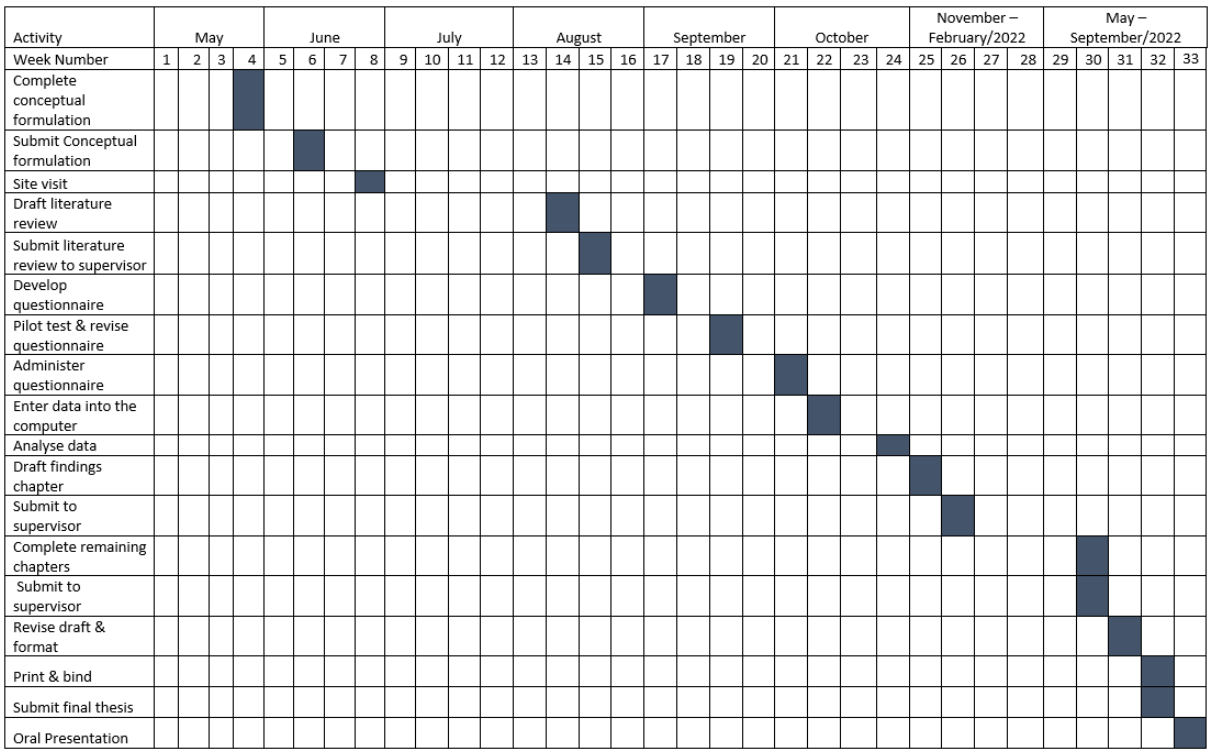
regarding the methods used to cut down waste on construction sites. Four project sites undergoing construction and demolition were visited in different locations and of varying dimensions. The data from this chapter is merged with the literature findings to develop and analyse the questionnaire survey.

The study examined the difficulties and causes of production waste and waste source reduction strategies and their benefits on construction projects in Sierra Leone from the viewpoints of construction professionals and operators. The intended participant would be project managers and contractors in different construction companies, not less than ten companies, with a target of at least five participants per company.

Resources

- A literature review of different sources highlighted in the reference section
- Questionnaires are created online through google forms or word documents to be completed by respondents.

Timescale



Abstract

Rapid material waste generation is linked to rising populations and expanding trade and industry in urban locations worldwide. The problem of material waste is particularly concerning in developing countries. Sierra Leone's ability to provide vital sanitation services, such as material waste collection, recycling, and treatment, has been overwhelmed by population increase. The waste generated by the construction sector is a big challenge to be addressed. One of the biggest hurdles to attaining sustainability on construction sites has been the high volumes of waste created from construction works and placed in landfills. Defects in waste collection, transportation, disposal, and indiscriminate waste generation and dumping have resulted in episodic risks affecting the capital's overall population. The increase in population increases construction demand, generating tremendous waste as there are no waste management practices developed for the construction industry in the country. This study investigates construction waste sources or causes in project locations. It evaluates the existing measures for material waste minimization implemented by contractors in Sierra Leone. This study also investigates previous studies on construction waste sources and proposed waste minimization measures. The researcher visited four construction sites in Freetown. The waste types produced on the project sites, at various construction or demolition phases, were investigated to understand whether there were any waste management processes and how they were implemented and managed on these sites. The research includes interviews with site supervisors about waste reduction strategies and their benefits. The main reason for material waste, according to this study, was unskilled labour leading to rework. Two case studies consolidate the finding from the analysis. This research provides a solution for this waste source through the Last Planner System (LPS). There is a difference between "planning," which means creating strategies to accomplish goals, and "control," which means bringing strategy into practice to achieve goals. The LPS is to control project output. It directs the process toward the goals, takes action to advance along the intended course; and, if necessary, find alternate means of achieving the plans when the original path is impractical.

Keywords: Landfill, Construction Industry, Material Waste, Waste Management, Waste Minimization, Last Planner System.

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List of Abbreviations

BRE	Building Research Establishment
CCC	Clark County Code
C&D	Construction and Demolition
C&DW	Construction and Demolition Waste
CPM	Critical Path Method
EU	European Union
FCC	Freetown City Council
LC	Lean Construction
LPS	Last Planner System
MW	Mega Watts
NGO	Non-Governmental Organization
PPC	Planned Percentage Complete
PVC	Polyvinyl chloride
SDGs	Sustainable Development Goals
SWMP	Site Waste Management Plan
WB	World Bank
WFD	Waste Framework Directive

1. Introduction

1.1 General Introduction of the Research Study

Freetown, Sierra Leone's capital and largest city, was severely impacted by a ten-year rebel conflict in 1991. The conflict affected the city's economic development and infrastructure, destroying all existing equipment for waste management. The capital, Freetown's population, climbed from 708,000 in 2001 to a projected peak of 1,236,000 in 2021 after the conflict ended in 2001[1]. Figure 1 shows that the current metro area population of Freetown in 2022 is 1,272,000, a 2.91 per cent increase from 2021.

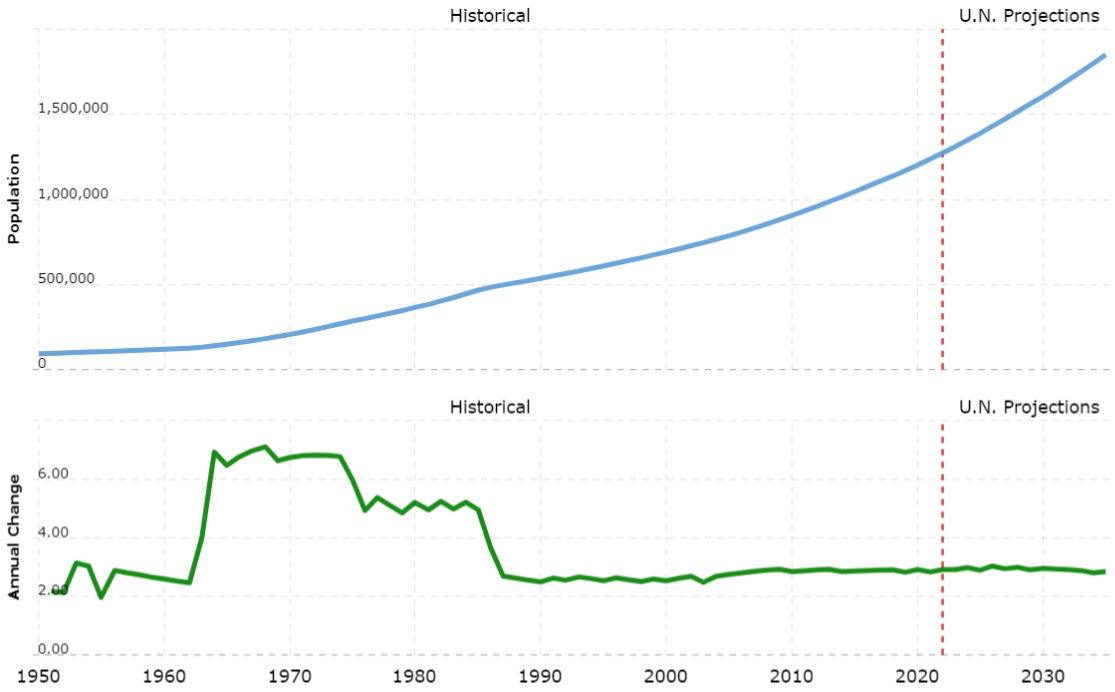

Figure 1: UN Projection of Freetown, Sierra Leone

(Source: Source)

Population growth increases the demand for living space and, consequently, increases construction activities. Because construction waste is bulky and heavy, it is more challenging to transport than other types of waste.

[1]www.macrotrends.net

Another of the biggest problems with the municipality's environmental and public health in Freetown, Sierra Leone, is the handling of waste produced. The United Nations (UN) and the WB recently anticipated a 4 per cent yearly population increase in Freetown[2], directly increasing the material waste produced in Freetown. Construction operations lead to the accumulation of material waste in the city. The World Bank, 2004 reported that more than three million kilograms of trash are generated each day in the capital city, Freetown, with no safe way of disposing of it. The WB report continued that the country's waste collection was about forty per cent of the total waste generated, and areas around the city's landfill sites present environmental and health risks. This estimate excludes construction and demolition waste because these items are hugely unpredictable and might bias quantity calculations. According to Sood, 2004, the industries in Freetown produce about twenty tons of material waste daily.

1.2 Research Problem and Research Questions

Sankoh et al., 2014 surveyed Freetown and estimated that the primary waste materials, represented in figure 2, on a typical mean weight basis, were: 69 per cent organic garbage that is compostable, 7.7 per cent plastic, 2.9 per cent metal, 3 per cent glass, 29 per cent paper and cardboard, 3.1 per cent ash and 5.4 per cent others. Also determined by Sankoh et al., 2014, plastic, metal, glass, paper, and cardboard were other types of waste that result from construction activities. The material wastes generated from the construction activities end in landfills. Studies show that about 42.6 per cent of waste is generated in Freetown. Waste management in Freetown is a costly and annoying problem. There is an average of 40 per cent low service coverage, insufficient budgets to manage waste, highly inadequate equipment, inefficiencies in the society such as poor public perceptions, and extensive illegal rubbish disposal throughout the city. Compared to the amount of waste produced, Freetown's capacity for collection and transportation is far lower.

[2]World Factbook, 2008

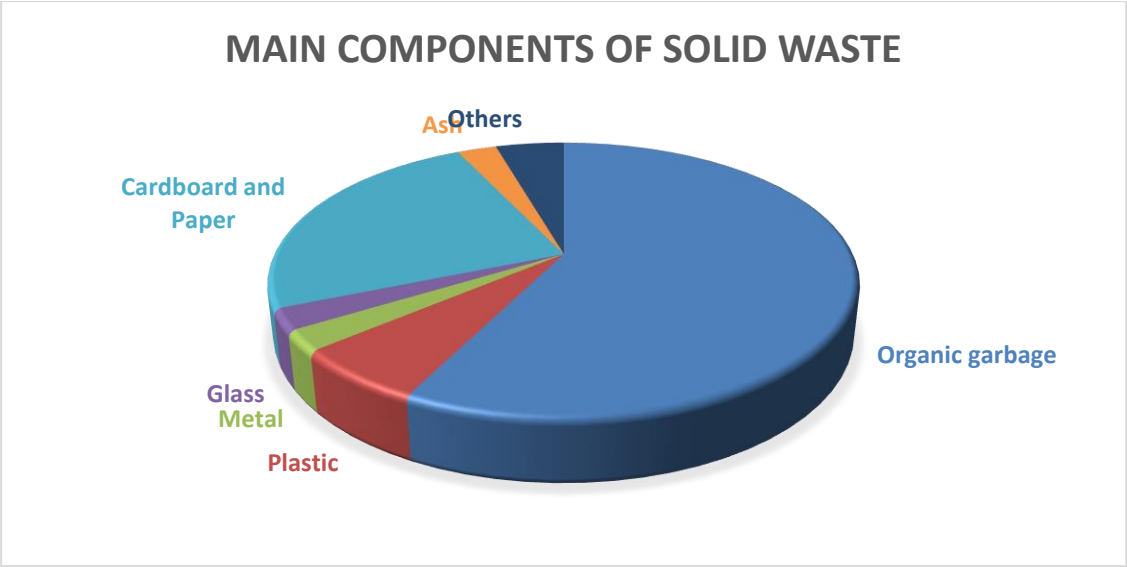

Figure 2: Main components of material waste

Landfill sites are not just an eye sore or a problem of increasing waste piles; they are a significant source of pollution. Garbage buried in landfills decomposes slowly and poses a long-term hazard for future generations. Toxins, leachate, and greenhouse gases are dump sites' main issues. Weak acidic chemicals in the decomposing material interact with waste liquids to generate leachate and landfill gas. Organic trash produces bacteria that break down organic waste. Some consequences include foul odours, unappealing sights, and rat and seagull infestations, which cause waste concerns. Toxic chemicals are in many waste materials. One example is electronic garbage. Electronic garbage, such as televisions, computers, and other electronic items, can contain harmful elements like leads, chemicals, acids, heavy metals, mercury, arsenic, and Polyvinyl chloride. These pollutants permeate our soil and groundwater over time, posing long-term environmental risks.

Leachate is a liquid that forms when garbage decomposes in a landfill and water filters through it. This highly poisonous liquid has the potential to damage land, groundwater, and waterways. Plastics like PVC and other materials break down and release toxic compounds into the environment. Therefore the landfill contains a lot of harmful elements. Heavy metals, solvents, and acids are in electronic waste. Leachate, a vile-smelling liquid comprising ammonia and several hazardous ions, is produced when rainwater soaking through the waste breaks and discharges 5-7 per cent of the toxins. Based on the quantity of rain that falls each year, a particular dump site may produce enough leachate to fill several Olympic-sized swimming pools annually.

The generation of greenhouse gases is landfills' most prominent environmental concern. Organic waste, such as food and green waste, compacts and fills landfills. An anaerobic process removes oxygen and causes it to break down. Eventually, methane is emitted, which has a 25-fold more significant global warming potential than carbon dioxide. Methane and carbon dioxide are found in landfill gas in amounts between 35 and 55 per cent. Global warming and climate change have far-reaching implications. Methane's greenhouse effect is significantly harsher than carbon dioxide's within the first 20 years of emission—between 84 and 100 times more potent. A typical garbage dump generates a sizable amount of gas, enough to power a power plant. Landfill gas power is typically called renewable energy generated by plant operators and governments. Even so, it is neither a long-term nor environmentally beneficial energy source. Methane, like oil and coal, produces carbon dioxide when burned.[3]

As seen in figure 3, there are two landfills in Freetown: the Kingtom Landfill in the west and the Granville Brooke Landfill in the east. These locations are close to informal settlements, urban farming operations, and open water bodies in highly populated residential areas. Waste is carelessly thrown into landfills. It is harmful to the adjacent households since the waste is not deposited according to type. Thousands of people live near Freetown's two main dump sites. Officials from the government and law enforcement have attempted to evacuate the area and prevent individuals from scavenging in the dumps. Other international organizations have issued analyses and recommendations for the Sierra Leonean government to resolve the country's waste management problems. However, the country is still incapable of implementing most international assistance, advice, and solutions.

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[3]https://www.unisanuk.com/what-is-a-landfill-why-are-landfills-bad-for-the-environment/

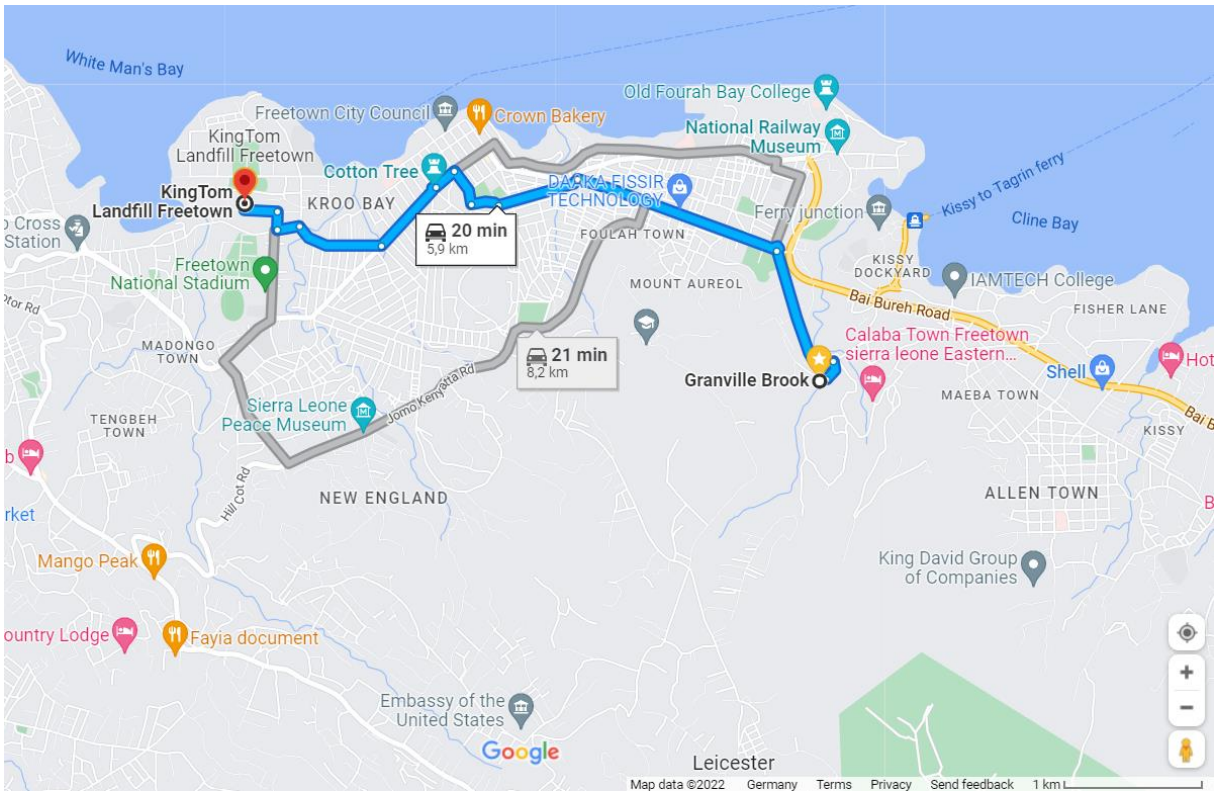

Figure 3: Location of Freetown's main landfill sites.

(Source: Google maps)

Recent news has been that these landfills have reached their capacity. However, there are no new sites for disposal, so waste deposition is in the two existing landfill sites. Due to the poor waste management practice in the country, drains along the streets of Freetown for surface water discharge clog up with waste. When there are heavy rain-storms, flooding occurs in the city. Thousands of residents have become scavengers as they make their living from selling collected waste items. Despite the waste management rules and penalties for non-compliance, there are still constraints due to lack of awareness and low education levels.

There is very minimal awareness of responsible waste management. On construction sites, material waste is deemed usual. Material waste generated on construction sites is either dumped in landfills or piled up and burnt, often producing unpleasant and hazardous smoke for the environment.

Figure 4: Granville Brook dumpsite overlapping residential houses

(Source: uploaded by Tran Quang Yen)

Figure 5: The Kingtom landfill

(Source: uploaded by Jack Russillo)

1.3 Reasons or Needs for the Research Study

A detailed elaboration of the research questions is as follows:

How could the Sierra Leone construction industry contribute to reducing wastes deposited in landfill sites? – This is the primary and most important question of this study. The construction industry needs to start implementing practices to reduce the waste their activities generate as the Sustainable Development Goals (SDGs) talk, and climate change is rising. Sustainability is no longer an option; it is a way of life we must embrace to preserve our survival and humanity's long-term viability. The construction industry contributes about 36 per cent of global energy consumption and 40 per cent of energy and process-related emissions worldwide.[4] Climate change, pollution, and depleting fossil fuel supply affect many aspects of human activity. As a result, it is critical to implement the most up-to-date sustainable technology and construction processes and boost the energy effectiveness of existing structures. The construction industry must take the lead to ensure a long-term future.

What advantages does waste management in the construction industry provide for the nation? – For the workers to effectively implement waste management practices on their sites, they will need to have an end goal. The benefits of managing waste need to be clarified and simplified so that every worker understands and sees the value of doing it. A nation's system for managing its waste can result in the availability of valuable materials to reuse in different ways. It saves money while potentially creating new jobs and business opportunities.

What challenges would practising waste management in the country’s construction industry bring? – To achieve the aim of this study in a developing country such as Sierra Leone, there will be challenges. These challenges will range from the construction workers to government officials and the existing policies in the country. This research seeks to understand those challenges from the Sierra Leone construction workers, which could open more ample research opportunities for future studies.

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[4]https://www.iea.org/topics/energy-efficiency

1.4 Research Limitation and Scope

Unfortunately, population growth isn't Freetown's only issue with material waste management. Government policies are also significant contributors as they are sometimes inadequately formulated. There are financial and operational constraints. Most importantly, there is an issue in the attitude of the residents towards waste management. Due to a lack of proper education, Sierra Leone construction sites produce more waste. There could be plenty of onsite discharge of slurry, polluted water and various other forms of waste in construction projects that cannot be quantified. However, this research will not look into all of these. This kind of research is the first in Sierra Leone. There is still limited information on the internet that is publicly available to provide details on the topic. This research will be a foundation for future research projects concerning waste management in the Sierra Leone construction industry. Waste management in this research considers reducing material waste throughout all phases of a construction project and not from the Lean Construction Management approach. This research will understand the current perspectives of the construction field workers or project managers and their challenges in implementing waste management on site.

1.5 Definition and Explanation of Key Terminologies

Landfill – Modern landfills are well-engineered and managed facilities for material waste disposal. Landfills are located, designed, organised, and monitored in compliance with federal rules. They protect the environment from toxins found in the waste stream. Landfills should not be in environmentally sensitive locations and should have environmental monitoring devices.[5]

Material Waste - Material waste is a significant issue in the construction industry, with far-reaching consequences. Reports indicate that the construction sector generates intolerable levels of material waste.

[5]The United States Environmental Protection Agency

Construction Industry - Construction is a large sector that includes many different constructions and civil engineering employment. Carpentry, road construction, bridge development, and home design jobs are part of the construction business. Because it builds the infrastructure for cities, communities, and countries, this is among the most prominent industries worldwide. There are numerous speciality trade associations in the construction sector. Bricklayers, floor installers, and carpenters are just a few examples. The general contractor directs and guides the majority of speciality trade groups.[6]

Waste Minimization - Implementing creative or alternative methods that aid in reducing dangerous pollutants in the environment.[7] Waste reduction frequently leads to cost reduction. However, it's relatively uncommon to devise cost-cutting strategies that don't reduce waste volume.

Waste Management - The management and control of waste products and the gathering, delivery, treatment, and disposal of material waste are all components of waste management. Waste management involves treating solid, liquid, and radioactive waste differently. It utilizes several waste management techniques to lessen the adverse effects of waste on the environment. In industrialized and developing countries, there are communities (urban or rural) and producers who work in the industrial and residential sectors. Non-hazardous waste collection for residents and institutions is usually the responsibility of municipal governments in metropolitan areas. However, it is typically the generator's responsibility to manage non-hazardous commercial and industrial waste.[8]

[6]Troy Holmes, 2022. What is Construction Industry?
[7]https://ehs.ucsc.edu/programs/waste-management/waste-minimization.html
[8]UKEssays. November 2018. Material Wastage On Construction Sites Work.

2. Literature Review

2.1 The Existing Situation of Freetown’s Waste Management

"...Freetown lacks a suitable waste collection and management system," said Joseph Rahall, the executive director of Green Scenery which is an environmental Non-Governmental Organization (NGO) in Sierra Leone. He continued that the landfills in Freetown are a disaster waiting to happen.

Sierra Leone's economic and financial capital and the country's economic hub is Freetown. Freetown is home to the headquarters of most foreign companies and the country's most giant corporations. The city's economy revolves around its port. The main commercial port in Sierra Leone is the Port of Freetown, and it serves as the country's main entry point for trade and business. Suppose there are no measures to curb demographic increase and waste output; reports state that waste generation will exceed 1000tonnes/day in 2030 and 2000tonnes/day in 2050. On the other hand, Sierra Leone lacks environmental legislation, and industrial pollution control is through Environmental Impact Assessment (EIA) licenses.

In 2004, WB reported that garbage had clogged most of Freetown’s drains, and many skips (large containers) for waste transfer needed repairs. According to the research, the unmanaged waste management system "is a significant factor to the city's large increase in vector-propagated diseases." The Freetown Waste Management Company (FWMC), 2013 cited some of Freetown’s waste management shortcomings. It included the city's lack of equipment, inaccessibility of low-income areas, funds availability, and employees' availability. According to the FWMC, the town has 45 waste transit sites. These transit points were unevenly positioned mainly across Freetown's western outskirts, resulting in increased pollution in the city's more populated eastern areas. EuropeAid designated the city's two significant landfills as high-risk zones in 2014. EuropeAid suggested closing the two landfills due to the appalling past circumstances at the dumping sites. They endanger human health and degrade the environment's beauty. The EuropeAid report recommended that it is essential to prioritize, plan, and initiate relocation to other locations due to the dump sites' severe health and environmental hazards. Waste pickers, scavengers, animals, and flies have unfettered access to open dumps, often emitting unpleasant and toxic smoke from slow-burning fires. As

a trash disposal alternative, the garbage that has been strewn or accumulated in tiny or significant quantities is frequently set on fire. In Freetown, waste generation significantly outnumbers waste collection capacity and transportation.

Material waste management in Freetown is now carried out at a rudimentary level or not at all. There are no rules and regulations for industries to follow. The management of Freetown's major landfills is insufficient. The Clean Oceans Project Identification and Preparation (COPIP) cited in a publication in 2022 that there are a lot of illegal dumpsites in the city, with 68 of them being labelled significant. Susan Bay, Kroo Bay, and Rokuper are three main slum settlements on the Freetown beaches. The COPIP continued that these towns, with about 50,000 inhabitants, are on ground reclaimed by backfilling the sea with material waste. Several minor watercourses run through Freetown, each transporting destruction to the ocean daily. For many kilometres, the beaches of Freetown are littered with debris. There is no central sewage and wastewater treatment system in Freetown. According to estimates, only 6 per cent of liquid waste is managed. Sierra Leone generates more than 96.000 tonnes of plastic garbage each year, with 84 per cent mishandled. Institutional capacities in material waste management, control, and law enforcement are lacking.

2.2 Material Waste in the Construction Industry

2.2.1 What is Waste?

There are several different definitions of waste. Al-Hajj and Hamani, 2011 elaborated on the history of the meanings of waste. Building Research Establishment (BRE), 1978 identified differences between ordered materials and materials utilized in the construction project. BRE, 1981 defined waste as any material carried away from the construction site or used on-site for reasons other than those planned. The Environmental Act enacted in the 1990s defined waste as scrap material, wastewater, or any surplus substance resulting from any process. According to the Polytechnic in Hong Kong (HK), construction project waste can be defined as by-products produced during the development, maintenance, and destruction of civil engineering structures sites. Other sorts of material waste in construction were researched by Koskela and Alarcon in 1992 and 1993, respectively. Waste related to time and process results from actions that

consume time, commodities, or space which do not produce value. Non-adding valuation models and strategies for reducing waste have formed the basis of the lean construction concept.

According to the BRE,1978, waste is the material remainder when the construction project has utilized materials from the ordered materials. For this research, we will take the meaning of waste from the standard report of waste by the Waste Framework Directive (WFD) of the European Union (EU):

"an object or a substance that the owner discards or intends to discard".

Thomas, 2020 described a waste facility as any designated area used for accumulating or depositing extractive waste in solid or liquid form, solution or suspension. The period waste is stored on-site determines the definition of the waste facility. The only exception is a category A waste facility deemed high risk with no period associated.[9]

[9]Directive of the European Parliament and of the Council of 15 March 2006 on managing waste from extractive industries and amended Directive 2004- Statement by the European Parliament, the Council, and the Council Commission.

2.2.2 Waste Management Hierarchy and Classification

Ghazvinei, P.T. et al., 2017 mentioned the waste hierarchy and classification, as shown in figure 6 below:

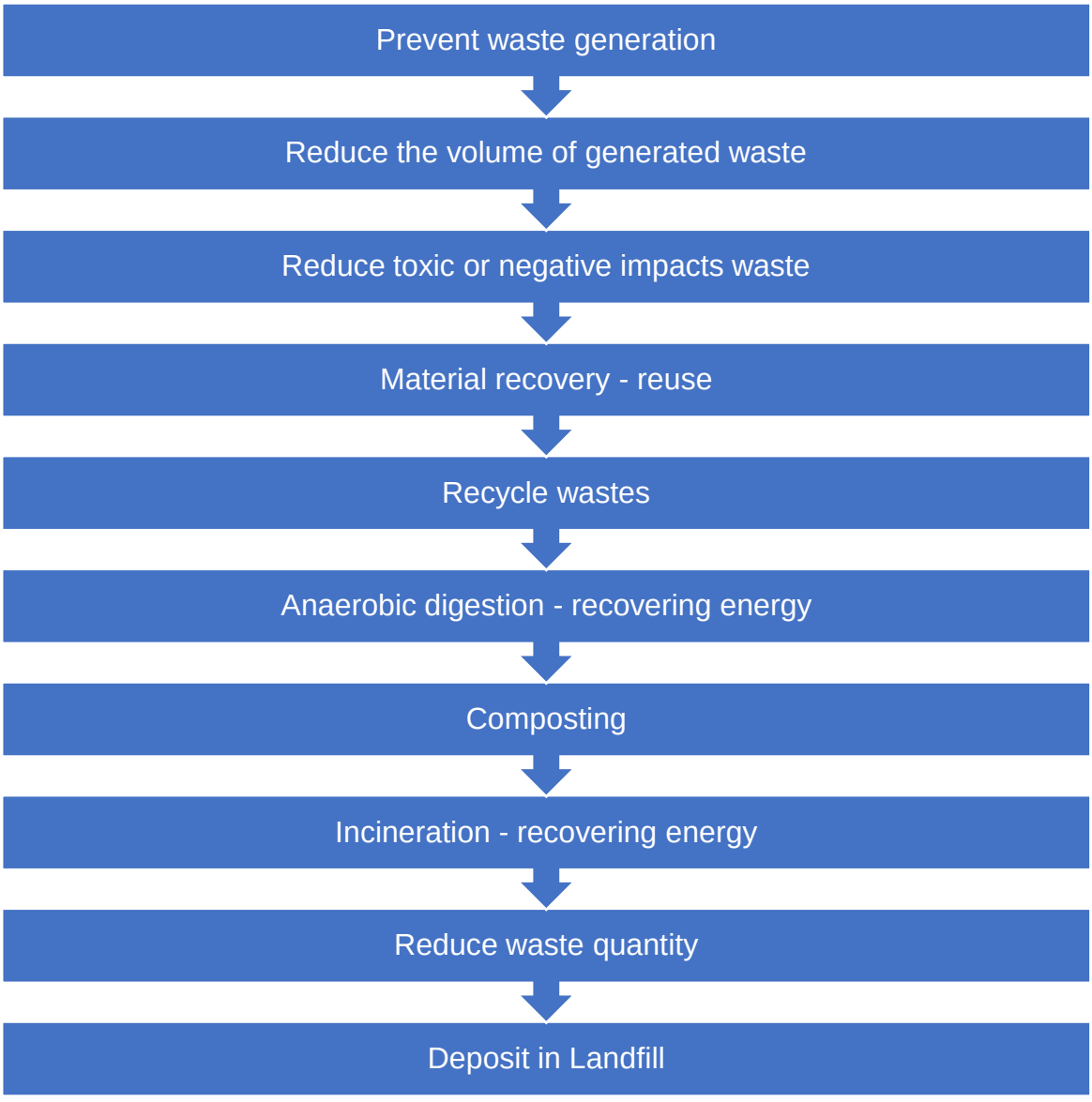

Figure 6: Waste hierarchy and classification

(Source: Al-Salem, 2009)

Thomas, B. 2020 reported that the overarching EU WFD[10] endorses a hierarchical approach, as shown in figure 7.

[10]Directive 2008/98/EC of the European Parliament and the Council. URL: http://data.europa.eu/eli/dir/2008/98/oj.

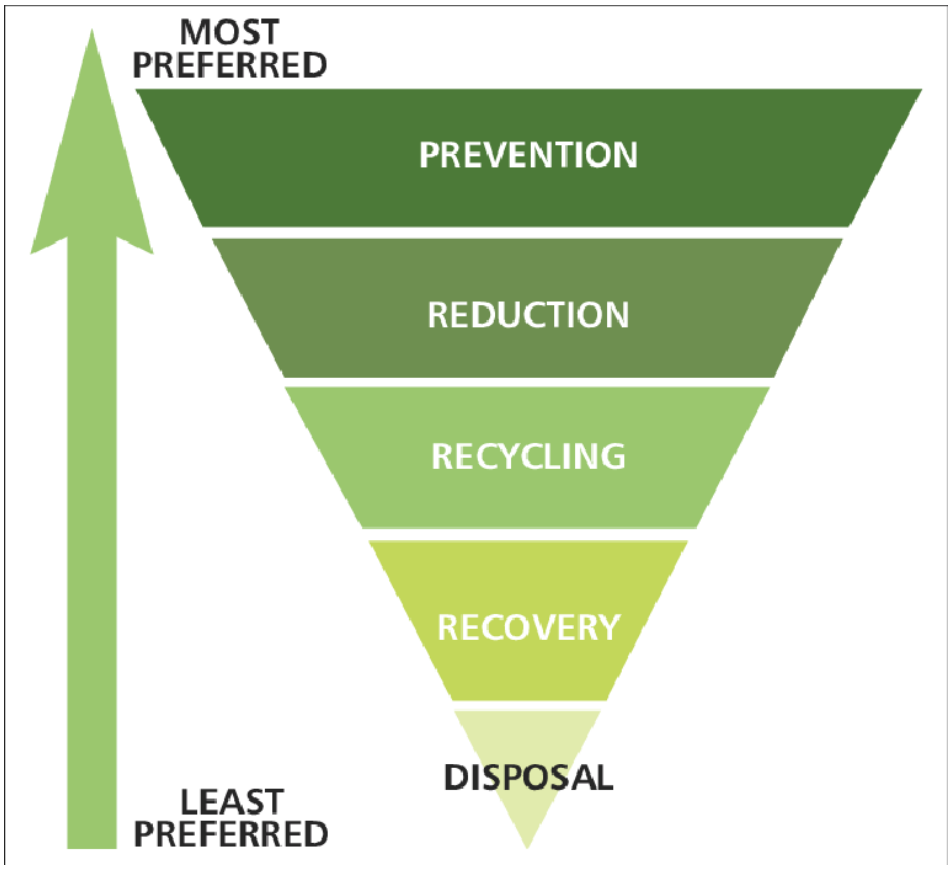

Figure 7: The waste hierarchy in the EU Waste Framework Directive 14.

(Source: https://www.researchgate.net/figure/The-waste-hierarchy-as-described-in-the-EU-Waste-Framework-Directive-14_fig3_339796148)

2.2.3 Sources of Construction Waste

Numerous factors influence the growth of wastage of materials in the construction business, according to Al-Hajj and Hamani (2011). Ekanayake and Ofori, 2000 classified them into design procurement, handling and management of materials, and operation. Lingard et al., 2000 summarized the primary sources of waste materials falling within each group, as illustrated in figure 8 below:

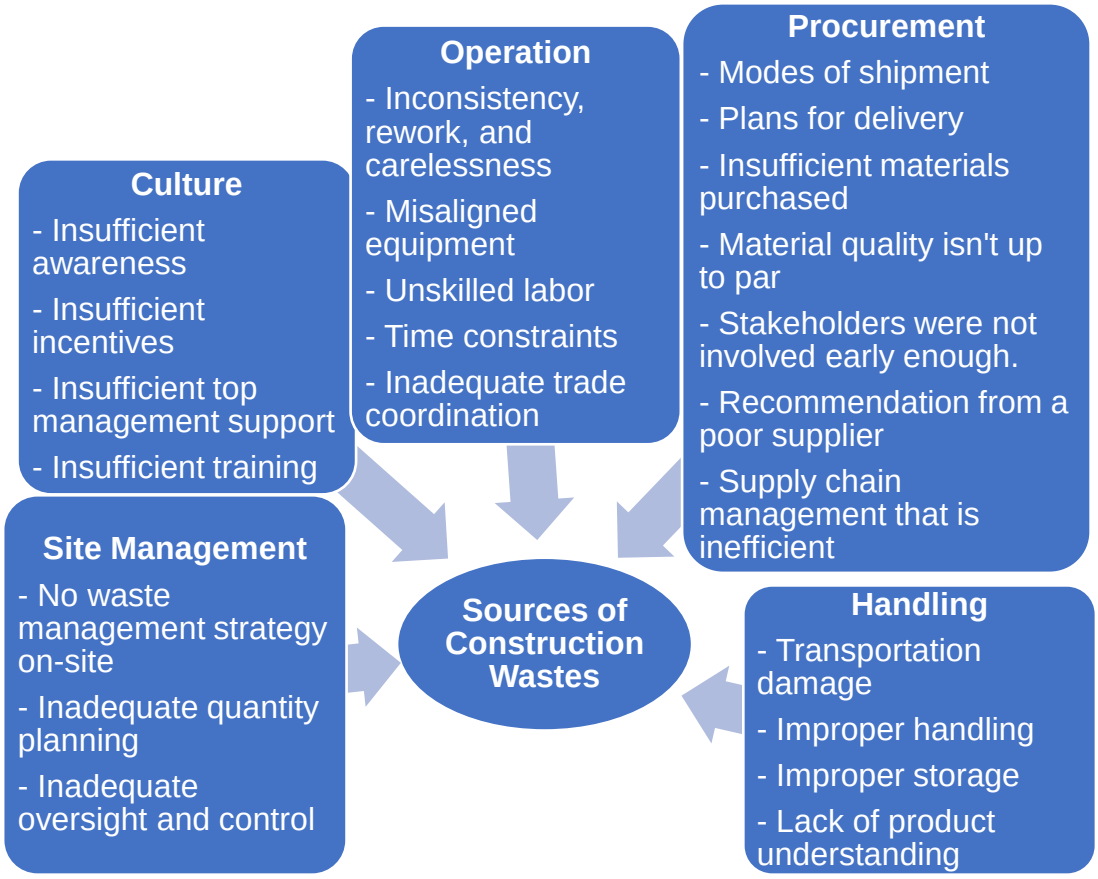

Figure 8: Primary sources of construction waste

Figure 9 below shows the results of a data analysis carried out by Fadiya et al., 2014 on how various waste sources contribute to the construction sector.

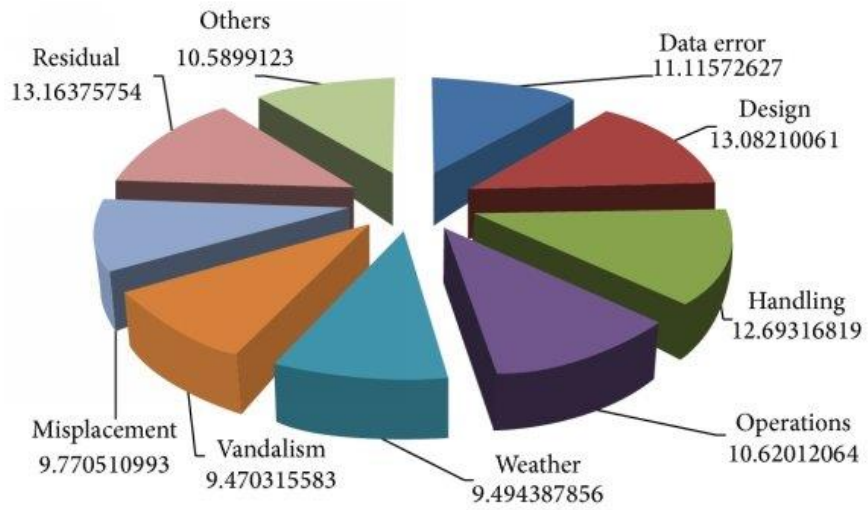

Figure 9: Contribution rates of the origins of construction waste.

(Source: https://www.researchgate.net/figure/Contribution-rates-of-the-sources-of-construction-waste_fig1_287397122)

2.2.4 Causes of Waste

The pre-construction stage has its own set of challenges. Construction waste generation occurs throughout the project lifecycle, from initiation to demolition, according to Letcher and Vallero (2019). As shown in table 1, they classified construction waste into 11 clusters and calculated its causes.

Table 1: Sources of construction waste

Waste Sources	**The Causes of Waste**
Contractual	Is it client-driven or government-mandated?
	Mistakes in contract documents
	Before beginning construction, the contract documents are incomplete.
Procurement	Late stakeholder involvement
	Poor communication between parties as well as poor co-ordination
	No responsibility allocated for appropriate decision making
	Insufficient documentation
Design	Late design changes
	The complexity of the design detail
	Errors in design and construction
	Specification that is insufficient, unclear, or inaccurate
	Late information, customer requests at the last minute, and slow revision of drawings
Planning and carrying out on-site management	No waste management plan on-site
	Inadequate forecasting of quantities

	Data on materials elements not received promptly
	Poor material control on-site
	Lack of monitoring
Site operation	Inadvertent Accidents
	Materials and Products that haven't been utilised
	Failures of the Equipment
	Craftsmanship is lacking
	Material Misuse and Disposal
	Time Constraints
	Workplace etiquette that isn't up to par
Transportation	Transportation damage
	Difficulty in approaching delivery vehicle to the construction site
	During the unloading process, there is insufficient protection.
	Method of unloading
Material ordering	Ordering items that do not meet specifications
	Difficulty in small orders
	Shipping and supplier error
Material storage	Improper storage on site.
	Improper storage methods lead to damage or deterioration
	Keeping materials far from the point of processing
Material handling	Material delivered in large quantities
	Construction site conveyance strategy from the storage location

	Improper material handling
Residual	From the processing process
	Cutting off-cuts up to the length of the material
	Cutting inefficient shapes results in waste
	Packaging

2.2.5 Types of Waste

Waste can be categorized based on solid, liquid, or gaseous conditions. The classification can also be according to their nature. According to El Haggar, 2007, demolition waste is a complex blend of construction materials, such as granite stones, cement, timber, plastic, metal, and glass. It involves frequent pollution created by the continuous or intermittent reduction or ruination of a building, including artificial or natural phenomena. Figure 10 below illustrates building demolition and the kinds of waste generated.

Figure 10: Construction demolition waste

(Source: Junk king, 2016)

El-Haggar, S., 2007, claimed that wastes primarily contain industrial construction and demolition (C&D) wastes. The materials generated directly from construction activity

include concrete, rubble, fibreglass, brickwork, mortar, timber, metal, cardboard, debris from the roofing process, tar paper, and many other products. Construction and demolition waste can also comprise packaging materials and land clearance debris, according to El-Haggar, 2007. Disposing of such scraps can have the following environmental consequences:

- unattractive and can result in financial loss;
- the tiniest amounts of harmful substances into aquifers due to improper demolition waste disposal or the use of construction material;
- non-hazardous substances like chlorine, sodium, sulfates, and ammonia contaminate aquifers due to the leaching of construction and demolition primary waste.

2.2.6 Waste Reduction/Minimization

Letcher and Vallero, 2019 define waste minimization as decreasing waste at the source by identifying the leading cause and rethinking current processes and practices to reduce waste generation.

Minimizing construction waste

The best way to manage construction waste, according to Haggar, 2007, is to reduce it at the source before it becomes an issue. Reducing waste at the source can be done at any time during the project's life cycle, as shown below:

- Planning Phase - In the early planning phase, the client team needs to define the project objectives and consider waste minimization as one of the project objectives. The project management entity, which functions as a designer, construction supervisor, contract manager etc., must include these objectives in the client’s contract.
- Design Stage - Designers optimize the materials used by specifying appropriate quantities of high-quality and durable materials to reduce scrap and waste.
- Tendering and Bidding Phase - The key to successful project management is choosing reliable suppliers, contractors, subcontractors, and outsourced services. The businesses and individuals you collaborate with will impact how well

the project turns out. This process offers companies an efficient approach to evaluating potential contractors.

- Construction phase - To effectively implement waste management practices in construction, the project manager must evaluate the contractor's fieldwork. This process eliminates/reduces material waste, stops defective work, and establishes management standards. The project manager may use a visual inspection checklist to measure the contractor's performance. Contractors need to maintain communication and coordination with project managers. After receiving the award notice, the contractor must provide a detailed waste management plan with a maximum time limit.

A group of researchers in Taiwan, Lai et al., 2016, suggested in a study the following flow chart for construction waste processing, as shown in figure 11.

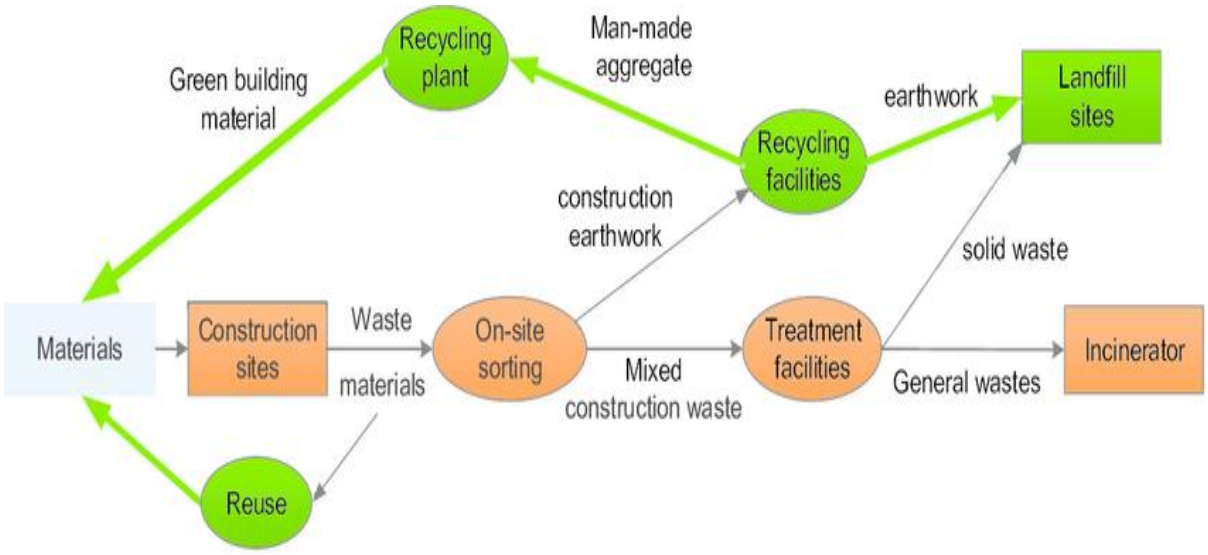

Figure 11: Flow chart of waste disposal tracking and management.

(Source: https://www.researchgate.net/figure/Flow-chart-of-waste-disposal-tracking-and-management_fig1_305889188)

Figure 12: Offsite Manufacturing

(Source: MMC News - Offsite construction can become the “new normal”, 2020.)

An example of a waste minimization practice is offsite manufacturing. Figure 12 illustrates an example of an off-site manufactured roof. Smith, 2016, explained that off-site construction is the organizing, designing, creating, transferring, and putting together of construction components for quick site fabrication with a greater level of finish than conventional disjointed on-site construction works. In addition to a range of materials, scales, and systems, computerized software, production, construction techniques, and social and technical integration improvements are included in the off-site construction. Integrating these technologies with the supply chain through investigation, design, experimentation, and experimentation is an off-site optimization technique.

On-site development and conventional contract methods clearly define roles and responsibilities, with much detail on the ramifications of failure. This environment encourages risk-averse behaviour, resulting in project teams refusing to collaborate and presenting a negative mindset which is harmful to all parties. Project clients experience financial losses on projects, architects and engineers see a slight improvement in design quality, and contractors incur a high economic and risk cost. The fragmentation measurement is in terms of waste and production. In comparison to manufacturing, 57

per cent of construction activities are inefficient and non-value-adding, according to the US Bureau of Labor Statistics. Manufacturing is the polar opposite, with 62 per cent of all actions adding value. Using modular techniques can reduce waste and boost project value. For large-scale projects, off-site and lasting prefabricated components are not always the best choice. The price, duration, workforce, scope, quality and risk considerations offer a tiered structure of possibilities and tradeoffs rather than predetermined answers. Modular construction can assist strike an equilibrium between such occasionally incompatible performance goals of construction when done purposefully and with preparation. Proactive preparation and off-site delivery are related ideas. The advantages of off-site construction have been the subject of much research, which is still ongoing. Reduced project timelines, more predictable financial projections, less material waste, and lower carbon emissions from worksite transportation are all established advantages of off-site construction over conventional on-site construction. Last, there will be less disruption to the site and more trade machinery, and labourers will be safe and secure.

Off-site initiatives have a 30 per cent higher labour effectiveness than on-site initiatives. Off-site development directly benefits risk mitigation.[11] The most significant environmental advantage of off-site manufacturing is the decrease in transportation fuels and carbon caused by employees travelling to a facility instead of the construction site and supply warehouses throughout the day.[12]

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[11]http://construction.com/market_research/freereport/prefabsmr/ - McGraw Hill 2009; http://www.fmi-net.com/media/pdf/report/PrefabricationSurvey2013.pdf - FMI 2013; Mortenson Construction 2014; Quale et al. 2012

[12]Construction Matters by Quale, J., et al., 2012. Journal of Industrial Ecology.

2.2.7 Construction Waste Minimization Challenges

According to Letcher and Vallero, 2019, while the concept of construction waste reduction is well-known and well-accepted, putting it into practice has proven difficult. They continued by stating that the construction industry seems slow to adopt new practices despite evidence showing waste minimisation's financial and commercial advantages. They discovered in their research that considerable waste minimization limits are linked to waste management views and attitudes. The construction industry has traditionally produced waste as an inescapable consequence. As a result, the belief that waste is inherent in construction activities prevents project-level strategic considerations, participation, and implementation efforts to reduce construction waste. As a result, on-site waste management is addressed in the regulatory and health and safety context. Project stakeholders encounter the following problems, according to Letcher and Vallero, when implementing successful waste reduction techniques in their projects:

- Insufficient managerial commitment
- No construction waste minimization standards
- Difficulties in modifying current processes
- Lack of waste management knowledge among employees
- The notion that waste management systems are inefficient
- Construction waste is seen as an unavoidable by-product.
- Aversion to reusing or recycling products with low economic worth
- Additional expenditures for implementing waste-related strategies and initiatives in the construction industry
- Any savings are allocated unequally, leaving workers with little motivation to assist in trash management
- Individual duties for waste management are poorly defined
- There is a lack of waste minimization recommendations.
- Dedicated time to sorting and managing on-site waste, causing the work plan schedule to be extended
- More paperwork for completing out control forms and inspection reports has resulted in increased red tape, etc.

Waste creation is a behavioural issue as much as a technical one. The labour-intensive character of infrastructure projects indicates that behavioural barriers are likely to profoundly impact waste amounts, according to Teo et al., 2000. Lingard et al., 2000 backed up this claim by stating that effective waste minimization hinged on how construction process participants adjusted their attitudes toward waste issues. P. Wynn and J. Sanders, 2004 conducted an attitudinal survey and found that construction workers:

- believed that waste reduction initiatives are only effective if cost, quality, and time are prioritized;
- unaware of what happens to the waste they produce, the repercussions, and the importance of decreasing it;
- regarded waste as an unavoidable by-product of construction and had negative attitudes toward waste recycling and reuse;
- thought that any possible waste reduction benefits were irrelevant to them.

Lee, K. and Vachon S., 2016 added that besides the cost of the waste material itself, there were:

- The cost of transferring the waste off-site, frequently to a dump, a reclamation centre, or a third party company, and the tipping fee charged by the operator, is included in the disposal costs.
- Storage costs – waste requires storage from the moment it is generated until it exits the plant. Even if there is strict control on waste, it may require significant operating and capital costs (flammable, toxic, biomedical). The price could simply be the amount of space taken up by the debris.
- Handling expenses - moving garbage across the facility adds to the organization's handling costs, including labour, equipment, and possibly logistical expenditures.
- Administrative costs - it is common for companies to have a waste manager responsible for ensuring that waste is collected, stored, and disposed of in a timely and efficient manner.

2.2.8 What is Waste Management?

Letcher and Vallero, 2019 defined waste management as the process of managing waste after it was already amassed. It includes site planning, transportation, warehousing, materials handling, on-site activities, segmentation, reuse, recycling, and disposal practices. According to Hagger, 2007, the suggested waste management recommendations are divided into five components, as shown in figure 7. This section will focus on the Reuse, Recycling, Recovery, and Disposal techniques, with reduction described in detail in section 2.2.6.

Reuse Techniques – according to Haggar, 2007, most items on a construction site can generate profit through reuse. The contractor bears substantial responsibility for implementing the reuse strategy in the projects.

Recycle techniques – Recycling is described by Haggar, 2007 as using waste as a natural resource in various services. In the construction phase, recycling efforts are advantageous. The following are the obligations assigned to the contractor:

- For waste materials, the contractor should recycle on-site and off-site.
- The contractor shall ensure that all recycled products pass national quality control testing when using recycled materials.

Recovery Techniques – This technology was defined by Haggar, 2007 as creating energy from waste materials that could not be reduced, repurposed, or recycled. It is a waste-to-energy recovery process that is universally endorsed. This method is used throughout the construction phase. The contractor is in charge of implementing various waste recovery procedures.

Disposal - The responsibility for dumping unavoidable waste in controlled dumping sites falls on the client's department, the architect's team, and the municipal government. The owner's staff should closely monitor all disposal procedures. An effective monitoring system, such as a manifesto system with five carbon copy certificates, is recommended for the waste's legal disposal.

It is everyone's responsibility to go up the waste management ladder. Engaging staff members and including them in projects is crucial. Employee involvement in the waste minimization target can be boosted by implementing effective communication strategies, such as publications and videos. In addition to engaging employees, construction

waste management accountability and ownership are essential. Waste management is perceived as the responsibility of facility management, which is a significant barrier to long-term progress. The leaders and managers of companies strongly support waste management for this reason. According to Haggar, 2007, a waste management team should be tasked with carrying out the duties required for recycling programs. A supervisor of construction debris and many skilled workers should make up the team. The construction waste manager's objectives ought to be:

- To launch the waste management initiative.
- Keep an eye on the waste sorting and separating processes.
- Watch over waste reuse per the contractor's waste management plan.
- Oversee the preparation of waste for delivery to recyclers.
- Watch after the proper waste disposal.
- Teach and direct the work of skilled labourers.
- Keep an eye on the wastes occasionally to avoid any contamination from mixing.

Contractors should be proactive and consider the following to minimise waste:-

- Employ reliable and confidential storage
- When moving materials, take into account mechanical components and equipment to reduce wastage
- Monitoring construction activity
- Off-site construction
- Effective packaging

People must learn about and practice waste reduction. The client and the waste contractor are equally responsible for the wastage of materials, as are the other relevant stakeholders. All parties concerned must cooperate to manage waste.

Clients - By defining guidelines for appropriate material use and disseminating these guidelines to the project team, clients should make the first move and take a leadership role. The clients must make sure that the problems surrounding material waste are discussed. Working to ensure that everybody engaged is trying to decrease waste is very much in the client's best interest.

Main Contractors - The client provided facts regarding the wastage of materials that the general contractor must practice. The contractor will keep track of waste data by acquiring data from the job site and comparing it to data from the job site. The main contractor develops a site waste management plan with a waste budget. A waste reduction plan requires integration into the program.

Sub-Contractors - To guarantee the fulfilment of the client's needs, the subcontractor must help the principal contractors. Reliable waste predictions for each subcontractor's speciality are required. They should devise waste-reduction strategies and present them to the main contractors. Control materials' effective and proper usage to reduce waste. After completing a project, the subcontractor must submit precise information on the amount of waste produced, the creation process, and the amount reduced.

2.2.9 Managing Key Construction Materials on Site

Some construction materials and components, such as timber, sand, and crushed stone, rely heavily on nonrenewable energy sources and resources that are rapidly depleting. Some contend that unskilled labour should be the main priority in avoiding waste. The time it takes to work on a material significantly impacts its value.

Table 2: Reducing key construction material waste

Key Materials	**Reduce**
Timber	• Use alternative materials in place of wood. • Use prefabricated construction materials, gypsum walls, and standard timber frames.
Bricks	• Establish a method for cutting blocks to use both halves with no breakage.
Concrete	• Utilizing alternative construction techniques, • Prefabricated components, and • Order and calculate the appropriate quantity with accuracy.

Material packaging	Consider the various packing purposes: • Labels should describe the product and all pertinent health and safety information. • Containment protects materials from corrosion, excessive moisture, and condensation by using plastic and cardboard as enclosures. • Protection - Shrinkwrap and cardboard help to reduce movement during transport. It shields goods from collisions and rubbing against one another. • Protect the products: Merchandise that isn't secured is more likely to be forgotten or lost. • Handling simplicity - Managing a single set of loose materials is more uncomplicated than managing many.
Steel	• Manufacturing companies show bend steel beforehand to reduce waste from on-site cutting.

Table 3: Reusing key construction material waste

Key Materials	**Reuse**
Timber	• Always examine the wood before using it again. Check for quality and appropriateness for the planned usage. • Various types of wood, such as floors, rafters, doors, windows, and fences, can be recycled on-site. • Before being discarded, use temporary formworks numerous times.
Bricks	• Offer the customer leftover (whole) blocks; • Remove any leftover blocks used as aggregate or as a landscape cover.
Concrete	• It can be temporary work

Material packaging	• Multipurpose pallets can be restored and utilized locally to stack additional materials or serve as masonry curing tables. • Offer single-use pallets for sale to distributors or businesses that use them as raw materials. • To protect from weathering, use plastic bags. • Store the debris from demolition in used polypropylene bags. • To simplify classification, keep cut-offs or garbage in product cartons.
Steel	• Making a table out of scrap rebar is one of the most popular uses. Bending the legs of the bar will create the table.

Table 4: Recycling key construction material waste

Key Materials	**Recycle**
Timber	• Clean unused wood on-site, de-nail, and resize it before transporting it to a recycling station. • Recycle into landscaping pellets, mulching and chipboard to create new kitchen units.
Bricks	• To promote recycling and deter wasteful worksite activities, provide a clean-up incentive in the block layer's subcontract scope.
Concrete	• Concrete can be an aggregate for concrete production

Material packaging	• Designate garbage containers using colour-coding techniques. • Mark the waste types on skips using signage. • To learn about pickup costs, speak with nearby recycling groups. • Take into account composting cardboard and paper. • To cut costs and increase recycling, learn about pooled collection programs. • Speak with a registered waste manager contractor to find the optimum site for non-recyclable goods.
Steel	• Without losing any physical characteristics, 98 per cent of all reinforced steel can be a new steel product. • The reinforced steel bars can sell as ferrous scrap

2.2.10 Advantages of Managing Waste

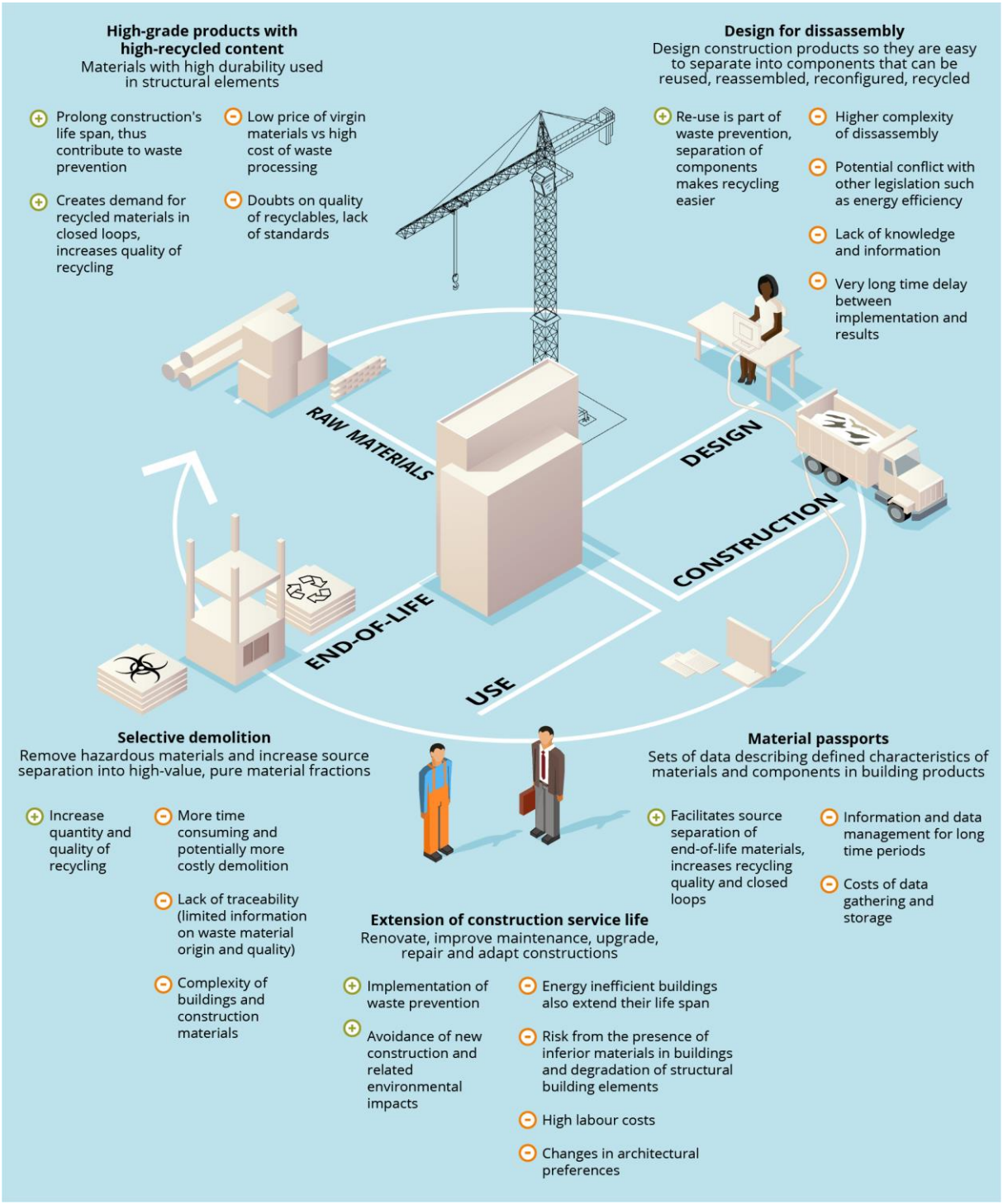

Figure 13: Examples of circular actions that improve the management of C&DW

(Source: https://www.eea.europa.eu/publications/construction-and-demolition-waste-challenges)

The activities shown in Figure 13 could help manage construction and demolition waste (C&DW). Haggar, 2007 outlined the various benefits, especially of working with multiple waste kinds, including construction and demolition trash.

Construction Waste – developing suitable strategies for construction waste management will modify the construction industry's actions toward achieving sustainable goals. The various environmental benefits of waste management include reducing non-renewable waste, protecting natural resources, extending the life of landfills, reducing project costs, social benefits from creating employment opportunities, and avoiding visual pollution.

Demolition Wastes – it reduces air pollutants from waste handling operations. It reduces the potential for hazardous heavy metals and materials in waste streams contaminating soil and groundwater. It improves health and safety conditions and reduces visual pollution that hurts a community's socio-economic growth.

2.3 Conclusion

Currently, recycling in Freetown is minimal and unstructured. Few private recycling industries operate for profit in Freetown. These private companies use recyclable materials to make items such as shoes, wheelbarrows, cookware, watering cans, and cutlass. However, a formal waste recycling and recovery program do not exist despite the shortage of new materials and high electricity costs. A competent material waste management system is necessary for long-term economic growth since it aids in generating more money and resources for waste management.[13] The Freetown City Council's (FCC) capacity to develop and implement a material waste management program is challenged. It is incumbent on project managers to take a step toward this challenging situation. Every year Freetown experiences flooding during the rainy season, and there have been reports of the landfills reaching their capacity. Freetown desperately needs a solid independent organization and the help of investors and donors to put in place a proper waste management system. The contractors and project managers could make a big difference in a feasible solution for their construction projects.

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[13]World Bank, 1999

3. Research Methodology

3.1 Introduction

Chapter 2, the literature review, described the meaning of waste and the waste types generated in the Sierra Leone construction industry. It made precise how crucial waste management is to the sector. It also emphasized the waste sources, which formed the cornerstone of this thesis's chapter on research method. It assessed the current material waste minimization practices implemented on construction sites. The researcher investigated the causes of construction material wastes that are encountered on projects during construction. Four construction sites in different areas and at various stages of construction were studied. The material waste management on these sites were investigated along with the measures to minimize construction waste. The data analysis from the site visit, combined with the literature review in the previous chapter, enabled the design of the questions in the survey questionnaire. The questionnaire followed a random sampling approach, shared with construction companies in Freetown, Sierra Leone. This chapter describes the type of data and the methods used in collecting the data for this research. It also gives an insight into other related issues or limitations observed during the data collection process.

This chapter of the research comprises six main sections describing the methodology used in the study. The data collected is primary, and the first four sections represent the data collection sources. The three sections each contain details on the data collection and study techniques. The fifth section describes how the data collected was analyzed. It explains the analytical approach of interviews and questionnaires briefly. The sixth section briefly discusses some of the challenges of the field research methodologies. The last section, section six, provides the conclusion of the chapter. This methodology flow is illustrated in figure 14.

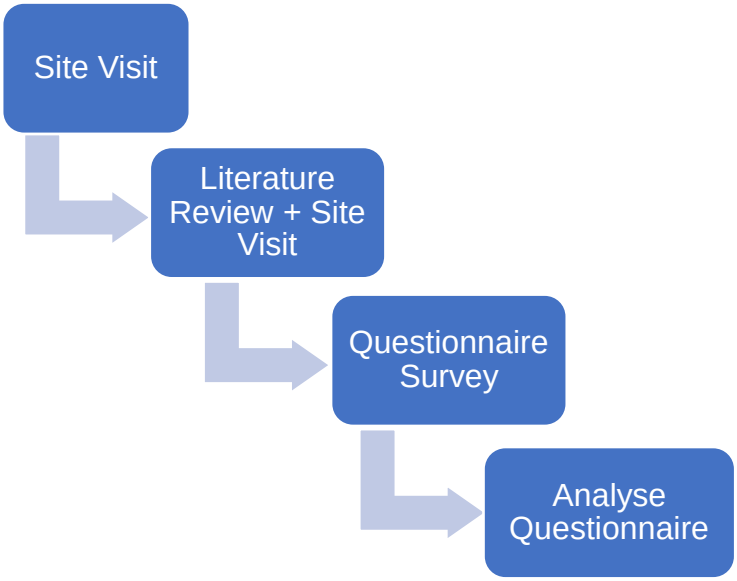

Figure 14: Research methodology approach

3.2 The Research Nature

This research investigates the experiences of construction workers in managing waste on their construction sites. The primary source of information for the research is a survey questionnaire. The survey is both qualitative and quantitative. This study is not only limited to questions of What? How? and Who? Qualitative inquiry research aims to describe the research going on. The nature is open-ended rather than a survey with measurable data. The data in this research is observable, having narrow and specific questions (Creswell, 2005). Comparing samples or looking for links among various factors are examples of qualitative survey questions instead of the quantitative method (Creswell, 1998).

3.3 Interviewing Methods

The researcher conducted each interview in person, with a non-standardized or unstructured interview technique. The questionnaire included indirect questions about the different types of waste generated from each site, the attitude toward waste minimization and other general observations. The following subsections provide more details on the interview approaches used:

3.3.1 Non-standardized or Unstructured interviews

An unstructured interview means collecting data with little control over the conversation between the researcher and interview participants. Compared to the structured interview, with fixed questions in selected sequences, the unstructured interview is flexible. It requires a lot of communication between the researchers and the subjects (Kerlinger & Lee, 2000). However, there were fixed questions asked during the interview. The targeted specific questions were related to waste minimization methods used on-site and in the company. Hittleman and Simon, 2002 stated that these questions encourage subjects to discuss their perceptions, beliefs about events, and feelings about the situation under review. Foddy, 1993 described a "sense-making activity" used during the interview sessions. The sense-making activity is where interview participants actively participate in the interview process. This interaction allows the interview to be a discussion and increases the information gathered (Bogdan & Biklen, 1992; Gorman & Clayton, 2005). Moving the interview in this direction increases the researcher's breadth and depth of understanding of the issues investigated (Gorman & Clayton, 2005).

3.3.2 Interview Questions – Open Ended

Interviews with site managers focused on their perceptions, attitudes and how the interviewer observed the area around the site. Open-ended questions have the value that they are not yes or no questions. Understanding the context and connecting crucial qualitative research components could be beneficial (Gorman and Clayton, 2005, p. 45). Respondents occasionally make unexpected responses, which could reveal the presence of previously unbelievable linkages. Kerlinger and Lee, 2000; Creswell, 2005) limit the solutions to the open question as much as possible. According to Creswell (2005), open-ended inquiries do not alter the content or structure of the respondents' responses. This technique enabled the researcher to assess better the participants' beliefs, attitudes, and perspectives.

3.3.3 Site Selection

The interviewer chose four different sites at different levels of construction in different geographical location to get a fair representation of construction sites in Freetown. The selection focused on getting various locations supervised by different contractors. The requirement stipulated that the site regions must vary.

3.3.4 The procedure of the Interviews

Initial contacts with construction supervisors from all selected companies were via telephone. The researcher shared requests with participants from the different companies. The proposals issued to construction supervisors sought their companies' permission to the conduct interviews on their project sites. The researcher contacted the various supervisors to confirm consent and booked appointments afterwards. After each interview, the researcher had a site visit that lasted two hours per site. The researcher noted the interview responses and observations on a notepad.

3.4 The Questionnaire

The questionnaires promoted additional validity and reliability to the theory in chapter 2, the literature review, with the information from the site supervisors and the site visits. According to Creswell, 2005, surveys can determine individual perspectives on policy topics. The focus of the questionnaires was to collate the worker's understanding of waste in the construction industry in Sierra Leone. The researcher also wanted to know how construction workers and companies minimize the generated waste. The answers given by site workers in the interviews were detailed and descriptive. During the preparation of the questionnaires, there were concerns about the respondent's interpretation of the interview and questionnaire questions. The survey's easy-to-understand questions were those the respondents did not want to be repeated and correctly answered. Before an effective communication exchange occurs, the responder must comprehend the inquiry as the investigator anticipated, according to Foddy's explanation in 1993. The investigator must also understand the response in what the responder planned.

The questionnaire design measures current attitudes and practices in implementing waste minimization on construction sites. Creswell, 2005 proved that ideas and perceptions are essential factors in understanding people's thoughts and behaviours. The questionnaire consisted of twenty questions under different research categories. The order of the questions ensured that the participants gave clear answers. The questionnaires put the most general questions first and the most specific questions last. The first section of the questionnaire inquired about the type of project. The kind of construction, where it was located, how far in progress it was at the beginning of the survey, and who was qualified to offer the answers. The researcher recorded details about the types of waste that were generated as well as potential causes and steps that may be taken to less material waste.

The survey collected data regarding existing systems on the construction sites that recorded and measured the waste generated on each site. Additionally, the researcher observed waste origins and source reduction techniques used in each development during site inspections and held meetings with members of staff of the primary companies. Finally, the researcher noted any general comments from the respondents for each project.

3.5 Formular for Analyzing the Questionnaire

The questionnaire analysis was based primarily on calculating weighted average values and standard deviation using the following formulas by Begum et al., 2006. Begum et al., 2006 used these formulas to assess Malaysia's significance and levels of waste minimization practice factors. Shen and Tam, 2002 studied the benefits of and barriers to implementing Hong Kong's Environmental Management System using the same procedure. The standard deviation reveals the degree to which a population deviates from the average. It aids in comparing several datasets of values with the comparable average value. With a weighted standard deviation, you can give each result in a sequence of items more weight or greater relative importance.

$$\text{(A):}\quad AS_i = \frac{\sum_{j-1}^{n} X_j N_{ij}}{N}$$

$$\text{(B):}\quad \delta_i = \sqrt{\frac{\sum_{j=1}^{N} (X_j - AS_i)^2}{N}}$$

$$\text{(C):}\quad IV_i = AS_i + \frac{AS_i}{\delta_i}$$

Figure 15: Formulars for analyzing the questionnaire

(Source: Begum et al., 2006)

ASi: the attribute's (i) average rating

Xj: the rank assigned to the attribute (i)

Nij: the proportion of respondents who assigned the attribute (i) to the rank Xj

n: the number of available ranks

δi: the attribute's (i) standard deviation

IVi: the attribute's (i) index value

Samples with higher weighted values are considered more significant than those with lesser values.[14]

3.6 Limitation of the Methodology

Knowledge and individual perspective were the two types of data from the interviews required for this study. The interviewer kept the discussion focused. The interviewer had to think about wording the questions to avoid harming or making the interviewee feel uncomfortable. The interviewer also had to ensure that the responses received were as expected by guiding the respondents in areas where they had doubts as to what the meaning of the question was. Respondents were skeptical or afraid to answer some questions. Some respondents were worried about their company's reputation.

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[14]Microstrategy analytics and mobility - Functions Reference

3.7 Conclusion

This chapter introduces the research methodology applied to collect and analyse data. The study used two data sources for information accuracy and consistency; relevant publications were the first information gathering. Respondents contributed the other ones, while some were publicly disclosed. Interviews with professionals in the field made up the second batch of data. Data and information directly from those who operate in the construction industry are necessary for the study to be thorough. The information obtained from the interviews helped the researcher understand the nature of waste minimization in the construction industry and other underlying beliefs in the literature review. Face-to-face, non-standardized, and open questions were used as the interviewing technique. The open-ended survey questionnaire included veiled inquiries to learn more about workers' opinions and convictions regarding waste minimization. The questionnaire response provides different views on the topic.

4. Analysis of Findings

4.1 Introduction

This research provides answers to the following questions as outlined in the research proposal:

- How could the Sierra Leone construction industry contribute to reducing wastes deposited in landfill sites?
- How would practising material waste management in the industry benefit the country?
- What issues would practising waste management in the country's construction industry bring?

A qualitative survey was utilized to collect the information from participants working in construction. It looked into the research subject and offered solutions to the inquiries. The researcher investigated the waste management procedures for material waste on Sierra Leone construction sites by visiting four construction projects in distinct locations and at varying construction stages. This understanding from the site supervisors and project managers developed the knowledge of measures utilized by various companies to minimize construction waste in the country: the site visit and literature review analysis designed the questions in the survey questionnaire. The questionnaire was sent out to construction companies and contractors in Freetown, Sierra Leone, using a random sampling approach. The researcher personally administered the questionnaires to participants. The survey results were frequency counts that changed to percentages and pie diagrams. This chapter presents an analysis of the data from the research survey.

This research seeks to enhance the awareness of construction workers of the importance of minimizing material waste and reducing the level of material waste generated by the industry. It also aims to highlight the different sources of waste in the construction industry and suggest various waste minimization measures to help reduce the waste generated and deposited in the already filled landfills. The researcher was also interested in understanding workers' perceptions and understanding regarding waste management workers in the industry.

4.2 Findings from the Site Visit

It became evident after the site visit that waste was generated a lot from material off-cuts. In construction projects, timber, ceramic tiles, and bricks/blocks generate waste when cut. Timber is the primary material used in Sierra Leone for formwork. The timber wastage can be because of continuous or wrong usage and overcutting. The respondents agreed that the timber used for formwork might end us in the trash as it is no longer helpful. The timber used for roofing could also become waste in the long term as it cannot resist termites and could easily break. The respondents mentioned that many off-cuts are because the standard length of materials supplied is never the exact length required for the particular task. Often, lengths of timber, steel, pipe, and electrical cables will be leftover when the contractors cut the needed sizes. Ofori, 2000 reported a similar finding that the waste generated is directly related to issues the site workers do not control. When contractors estimate materials to carry out a particular task in construction projects, they always make allowance for excess to avoid material shortage on-site and face blame from the clients. These points concluded that having off-cuts is inevitable in construction projects. It is not a problem for just the industry. Therefore the way forward is to think of ways to utilize these off-cuts to attain sustainability in construction projects rather than dumping them in landfills and bringing more harm to the environment. Contractors need to know the standard supplier material sizes to estimate materials correctly.

Table 5 presents the general information on four project sites visited. The data collected included the type of project, project location, project stage at the time of the investigation, and the experience level of the site worker interviewed. The table also showed the waste generated on the site, the possible sources of waste generation, and measures to reduce the waste. Items that seemed relatively small but wasted on site were screws and nails. These are connection materials. They are used in large quantities and are easily damaged or discarded as the workers may think it is a waste of time to straighten a bent nail for reuse. This material waste on-site poses health and safety concerns. There have been many accidents caused by nails being stepped on or exposed in a risky way.

Table 5: Analysis of site visit

				
Site 1			Site 2	
				
Site 3			Site 4	
Type	Commercial	Site 1	Site 2	
	Retail	Site 2	Site 3	
	Residential	Site 3	Site 4	
	Special (Hospital)	Site 4		

Waste Types	Staff interviewed	Stage	Location
Off-cuts from wood Wood after repetitive use Steel off-cuts Concrete (during pouring and from temporary work)	Title: Construction Manager, Civil engineer Years of Experience: 9	Foundation	Freetown, Sierra Leone
Bricks Steel Glass Metal bars Wood	Title: Project manager Years of experience: 35	Demolishing	Freetown, Sierra Leone
Tile leftovers Fragments of wood Steel by-products Concrete leftovers after pouring Package made of plastics	Title: Contractor, Years of experience: 6	Structure	Freetown, Sierra Leone
Scraps of wood Steel by-products Timber used repeatedly Material packaging	Title: Project engineer, civil engineers Years of experience: 6	Foundation	Kailahun, Sierra Leone

General observations	Waste Minimization Measures
The site observed some waste minimisation measures despite no contractual terms for managing waste. Three waste streams, steel, wood and concrete waste, were separated. Waste segregation was by traditional means, with the waste gathered at different locations on the site. No skips were present for waste collection. No formal waste management plan was implemented on-site.	Recycling wood. Reduce on-site warehousing by using just-in-time delivery. The site and storage area was well protected and organised
Waste management was part of the Project Director's duties. The main waste streams were bricks and metal bars at this project stage. Lack of awareness, poor quality work, and cheap method of demolition. Waste management, in this case, was inevitable as the road condition in this area is poor, and the brick material from the destruction is considered valuable and beneficial in backfilling the road.	Bricks reused as road construction material. Separation mainly for steel and wood Due to landfill recycling and waste remixing, there is no waste segmentation.
No measures are present for packaging waste. Storage was as per the type of materials: uncovered, shuttled, and air-conditioned. Reused some waste materials such as off-cuts from bricks to backfill and level ground areas in the compound	There was a waste separation area at this location. It processed wood for reuse. Recycling steel off-site Reusing broken tiles
There is a waste management plan submitted with the tender documents. No measures for packaging waste. Three storage types were available per the material type: uncovered, shuttled, and air-conditioned. The corporation sought the advantages of waste minimization to enhance its corporate image and save transportation and waste disposal expenses.	Enough storage space Waste segregation on-site Use of bar bending schedules to minimise steel off-cuts, and

Specific problems faced in Sierra Leone regarding waste minimization
The poor quality of products is a primary cause of damage, particularly for wood; The inconsistency in market conditions forces material over-ordering to avoid shortage or material price increase.
Lack of awareness of unskilled labour. Lack of waste minimization and management culture. Lack of understanding of the importance and risks of poor waste management.
Lack of policies and incentives for minimizing waste. Price escalations make it impossible to use a just-in-time delivery method for some materials.
Lack of guidelines or incentives for waste minimization. Price escalations make just-in-time delivery impossible for some materials.

Another problem observed during the site walks was storage and handling, which could lead to material waste. However, some of the sites did try to practise waste segregation. The segregation done by the site workers was not for the sustainability of their work but rather to save money on the project. Changing workers' attitudes in the construction industry concerning material waste generation in construction is necessary. From observations, site workers only separated the material waste they believed valuable, like wood and steel. The respondents justified that these two types of material were expensive in the market so could not be wasted. All respondents' primary benefit of on-site waste management is its financial benefits.

The interviewees agreed that waste is mainly generated on-site in all four sites visited due to off-cuts. Table 6 summarizes the responses from the four project sites. Most interviewees mentioned that another issue that creates construction waste is the materials' poor quality. There are always inconsistencies between the market's material sizes and the design drawings' material sizes. Other sources of waste included design flaws, variances, and employees' and clients' ignorance of waste management practices.

Table 6: Respondent's perspective on material waste in construction

Projects	**1**	**2**	**3**	**4**
Sources/Causes of waste				
Contractual				✓
Procurement				✓
Design	✓		✓	
Managing and organizing on-site	✓	✓	✓	
Site operation	✓	✓	✓	
Transportation		✓		✓
Material ordering	✓		✓	✓
Material handling	✓	✓	✓	✓
Material storage	✓		✓	
Residual	✓		✓	
Waste minimisation measures				
On-site waste segregation	✓	✓		
Reusing material off-cuts	✓	✓	✓	✓
Adopting a just-in-time delivery approach				
Have enough storage facilities on-site	✓		✓	✓
Adopting a take-back/return scheme				✓

Has and implement a waste management plan				✓
Has a demarcated area on-site for waste segregation	✓		✓	✓
Reuse formwork material	✓		✓	✓
Waste minimisation benefits				
Saves project cost	✓	✓	✓	✓
Protect the environment and enhance sustainable development				✓
Makes improvements to the employees' health & welfare				✓
Enhances the corporate image and reputation of the company				✓

4.3 Result of the Questionnaire

The survey had many closed questions and a few open questions to motivate the respondents. The survey lasted only for a maximum of 3 minutes. The questionnaire was limited to only construction workers of different job titles, with 41 responses. The questionnaire collected data on the systems project sites had to record and measure the waste generated in the Sierra Leone construction sites. It also gives a figure for the amount of garbage generated by the most prevalent waste streams in the construction sector. Three (3) components made up the survey. The participants' identity and prior employment in the projects were collected in the first part. The second part of the survey asked respondents to select the sources and factors contributing to material waste on construction sites from a list developed from the literature. This information was used to understand the waste of materials in the construction industry. Information and suggestions from respondents were gathered in the third section on the advantages and difficulties of eliminating waste in the construction business in Sierra Leone.

4.3.1 Section 1 of the Questionnaire

This section focused on the personal details of each respondent. In the survey, individual names were asked but were not a requirement. Some respondents' provided their names on the questionnaire forms, and some were anonymous. The result of the data was not affected in any way because respondents' names were not of significance to the data we aimed to collect. This section gives an overview of the types of construction projects the respondents have experienced. It also shows different construction companies in Sierra Leone and the respondents' roles in the construction industry. Figure 16 shows that out of the 41 responses received, 100 per cent of the respondents targeted in this survey had or are still working in the construction industry in Sierra Leone. This survey relies on actual experiences of the current and previous situations in the industry.

Figure 16: Respondent construction site/project experience

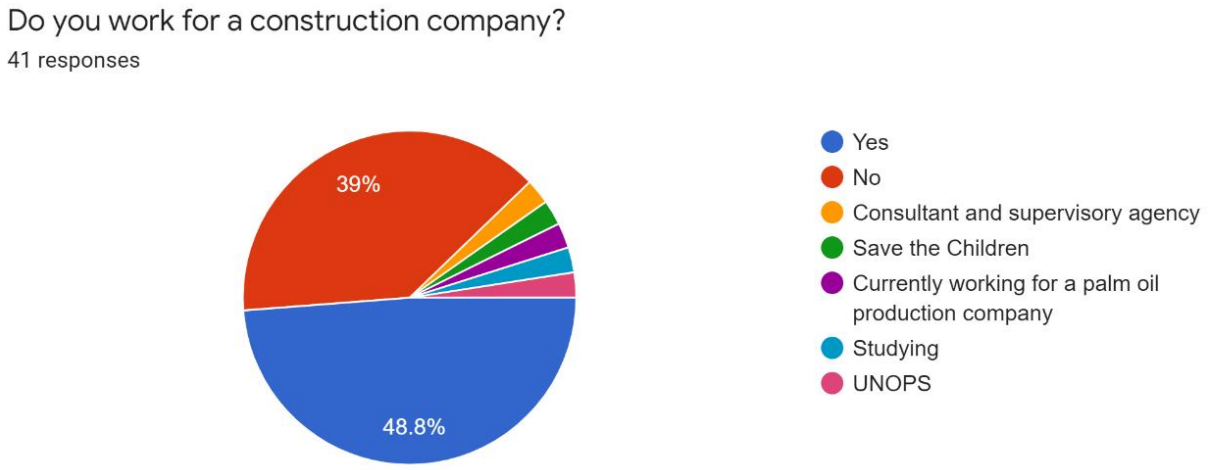


Figure 17: Respondent's current workplace

Out of the 41 responses received, 100 per cent of the respondents had experience working on construction sites. Figure 17 shows that 48.8 per cent currently work in construction companies, and others work in organizations such as the United Nations, NGOs and consultancy companies in Sierra Leone.

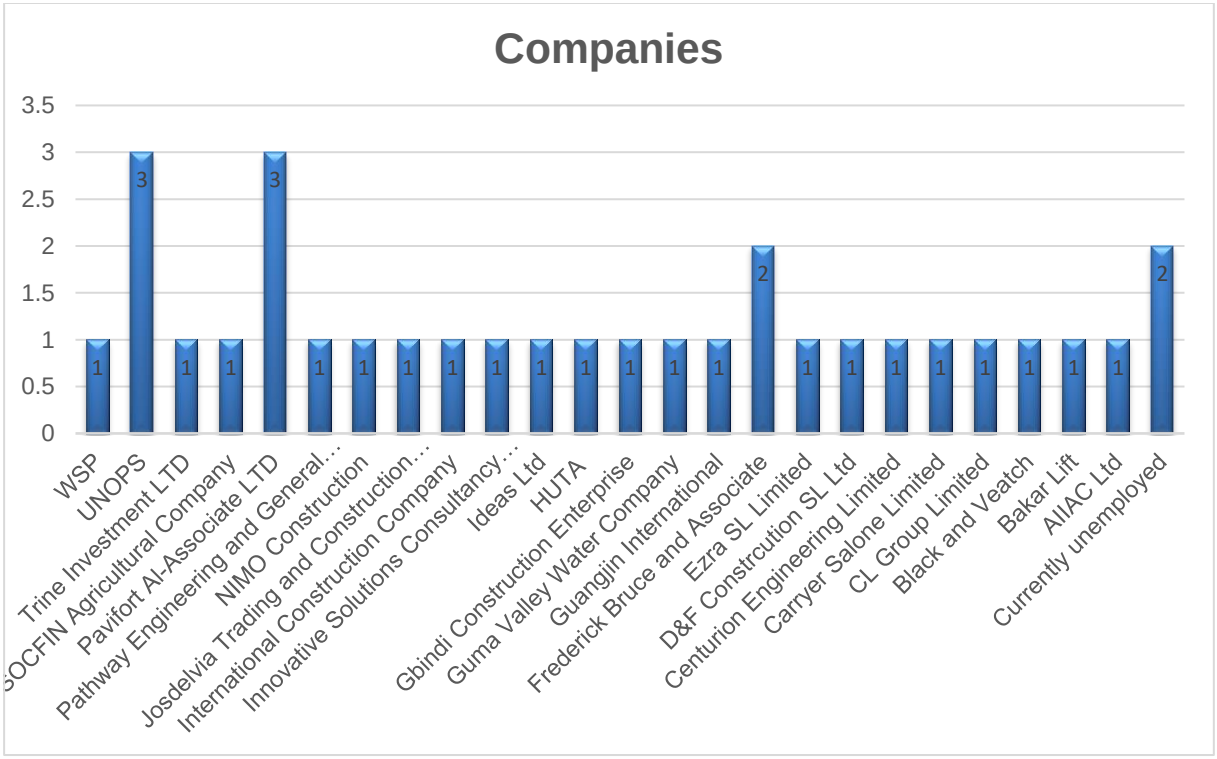


Figure 18: Names of construction companies in Sierra Leone

Out of 41 respondents, 31 recorded their current employment status and the names of their present companies. The remaining ten respondents did not register their company

names, which might be to save the reputation of their company. Figure 18 illustrates the number of respondents from some of the companies in Sierra Leone. The companies recorded by the respondents include The United Nations Office for Project Services (UNOPS), Trine investment Ltd, SOCFIN Agricultural company, Pavifort Al-Associate LTD, Pathway Engineering and General Services, NIMO Construction, Josdelvia Trading and Construction Company, International Construction Company, Innovative Solutions Consultancy SL Ltd, Ideas Ltd, HUTA, Gbindi Construction Enterprise, Guma Valley Water Company, Guangjin International, Frederick Bruce and Associate, Ezra SL Limited, D&F Construction SL Ltd, Centurion Engineering Limited, Carrier Salone Limited, CL Group Limited, Black and Veatch, Bakar Lift, and AIIAC Ltd.

The survey also collected information on the types of construction projects the respondents had or have experience with, as shown in figure 19. Twenty-two respondents confirmed that they had experience working in construction, which gives 53.7 per cent of the total. Three respondents recorded that they had experience in road construction, which is 7.3 per cent of the whole. Fifteen respondents recorded that they had experience working on construction projects which is 36.6 per cent of the total. One respondent registered that he had experience in other construction projects such as bridges and tunnels with 2.4 per cent of the whole.

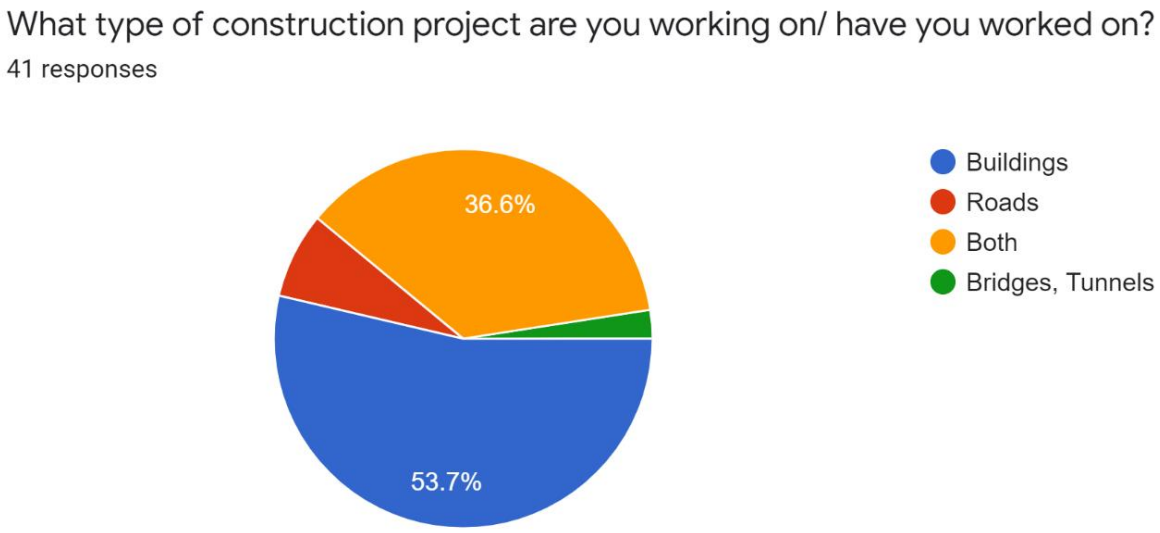


Figure 19: Types of construction projects

Some respondents' roles included Project Engineer, Site Engineer, Project Manager, Civil Engineer, Construction Coordinator, Civil Highway engineer (intern), Storage

keeper, Site Foreman, Site supervisor, and Construction Engineer. Out of the 41 responses recorded, five (5) respondents are Project Engineers, five (5) respondents are Site Engineers, three (3) respondents are Project Managers, two (2) respondents are Civil Engineers, one (1) respondent is a Construction Coordinator, one (1) respondent is a Civil Highway engineer (intern), one (1) respondent is a Storage Keeper, one (1) respondent is a Site Foreman, five (5) respondents are Site supervisors, and three (3) respondents are Construction Engineers.

4.3.2 Section 2 of the Questionnaire

This section aims to understand the necessary waste materials generated in the Sierra Leone construction industry and the current measures to minimize this waste.

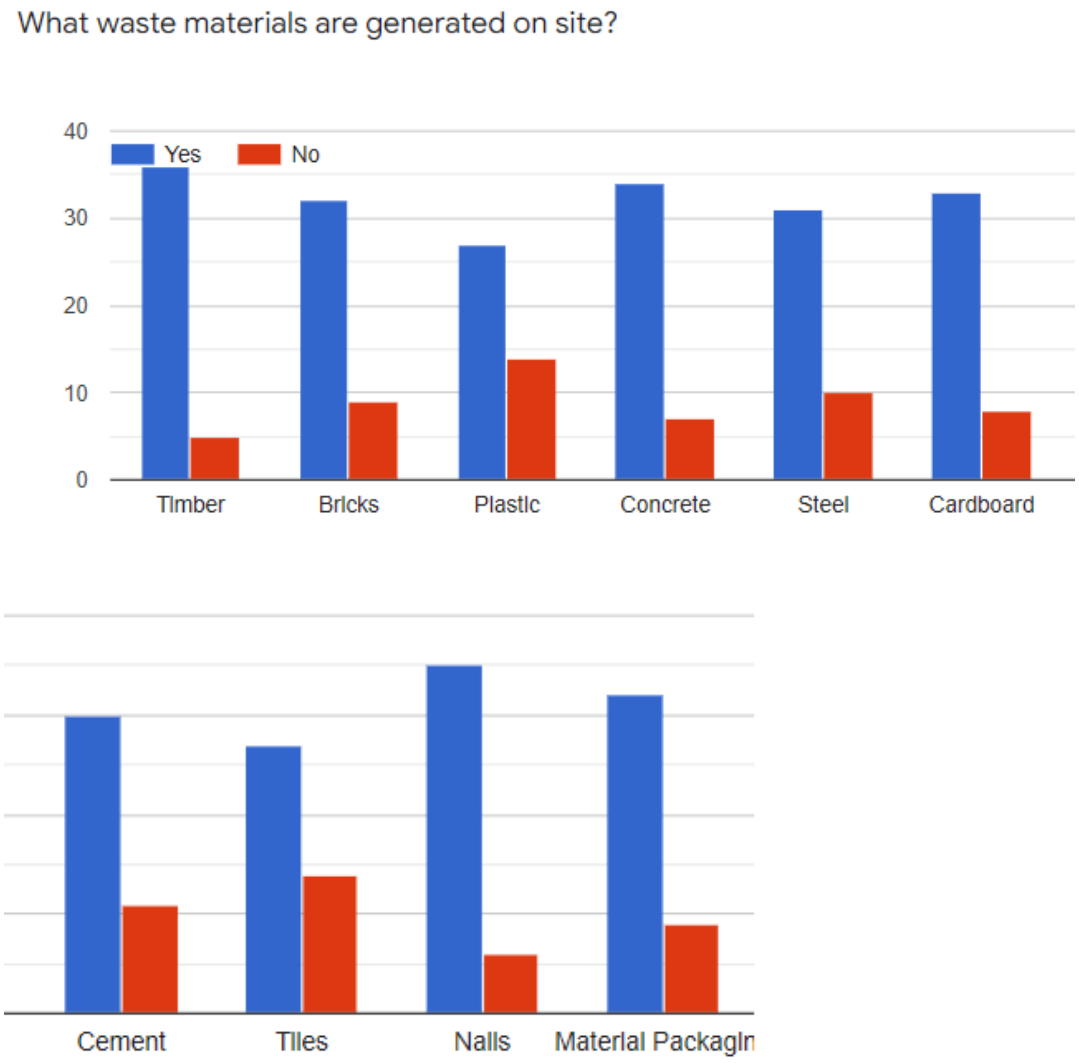


Figure 20: Kinds of material waste generated onsite

Figure 20 illustrates the kinds of material waste on a construction site, and the number of responses for each waste is in table 7 below:

Table 7: Number of responses on the kinds of waste generated

Waste material	No of YES	No of NO
Timber	36	5
Bricks	32	9
Plastic	27	14
Concrete	34	7
Steel	31	10
Cardboard	33	8
Cement	30	11
Tiles	27	14
Nails/Screws	35	6
Material packaging	32	9

This conclusion backs up studies in the literature, which show that concrete, cement/tar, lumber, bricks, and steel are the most commonly discarded items on construction sites (Wang et al., 2008; Shen et al., 2002; Formoso et al., 2002).

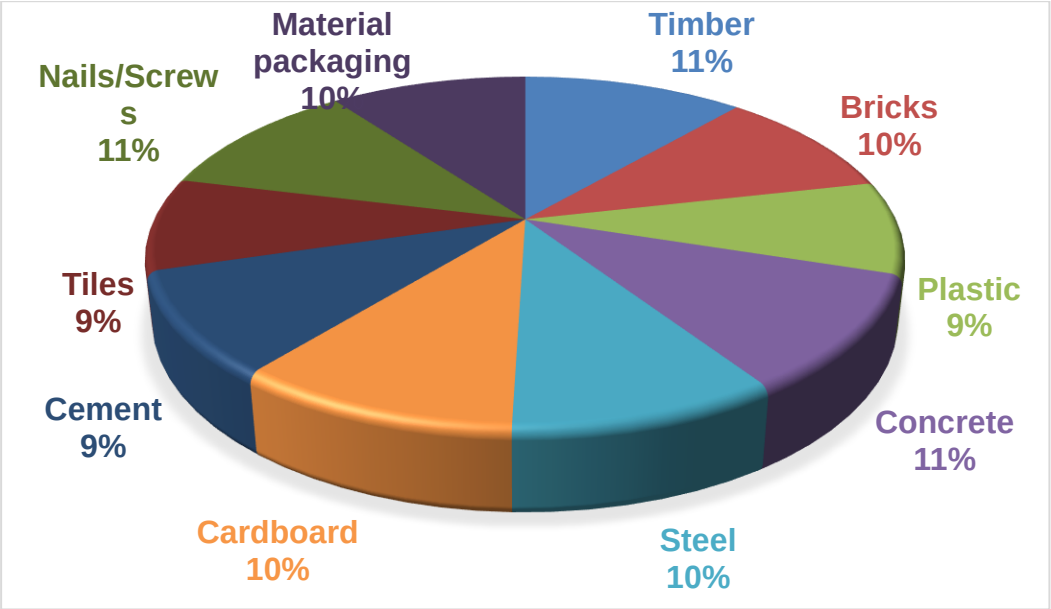


Figure 21: Percentages of waste material

The acquired results appeared reasonable, as most fall within or close to the ranges reported. From figure 21, it was interesting to see that plastic and tiles were the least

waste generated on-site compared to the others. Plastics and tiles have usage only at particular stages of the construction project. Tiles come into use during finishing works in construction and are hardly wasted. Even if broken, tiles create a unique, stunning work of art that beautifies the home or yard. Plastic in construction emerges from jobs such as plumbing, electrical conduit, rainwater collection, sewage pipes, and gas distribution. Cutting during piping work and improper storage, where employees recklessly toss it onsite without considering its vulnerability and longevity, are two common causes of plastic waste. When plastic comes into direct touch with heat, it melts and cannot withstand oxidation processes. The amount of plastic deposited in landfills hinders the sustainability of the environment and construction practices. According to the assessment, timber is one of the most wasted resources on-site. At the same time, wood is one of the most commonly used materials for formwork—it wastage due to improper or continuous use and overcutting. After the formwork completion, the timber is usually useless. Wood is susceptible to termites and easily breaks, making it unsuitable for long-term use.

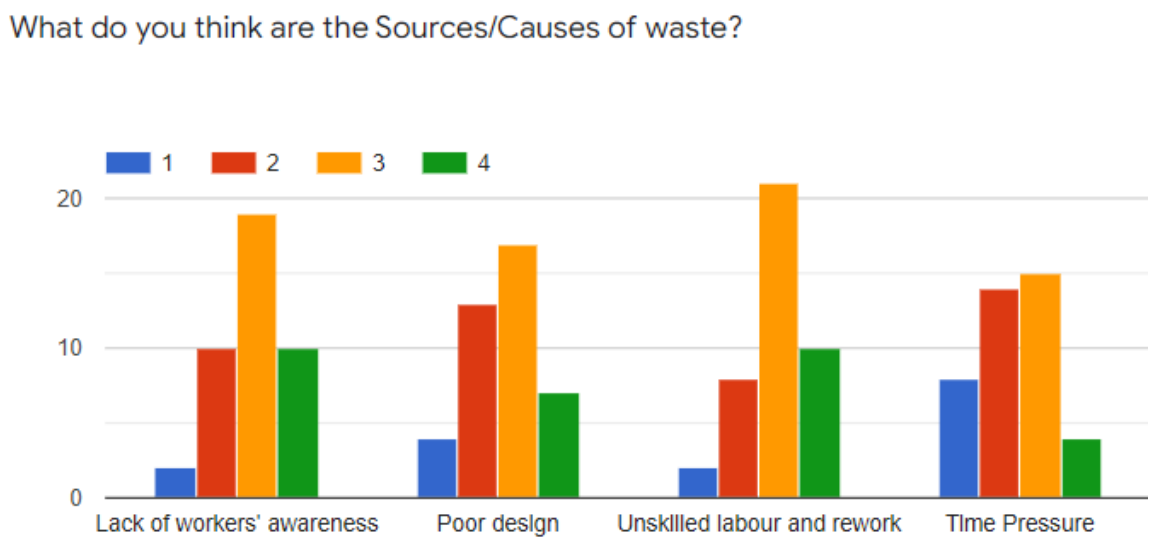
Other items that may seem relatively small but are highly wasted on-site materials are screws and nails. Because of their small sizes, these connection materials are easily lost, damaged, or discarded. Discarding screws or nails by workers has led to an increase in wastage. Most workers may think it is a waste of time to straighten a bent nail for reuse or find a screw that goes missing. There have been many accidents caused by nails being stepped on or exposed in a risky way. These construction materials are relatively cheap compared to other construction materials. Their on-site waste poses health and safety concerns that may lead to costly damages and delays. Concrete comes next. Concrete is for construction substructures and superstructures.

Regarding the delivery of ready-mixed concrete, there is a discrepancy between the amount of concrete needed and the quantity ordered. Due to poor management planning, the service provider may not know the precise amount, resulting in over-ordering. Delays in concrete pouring and inadequate material handling can also lead to waste. Improper cutting and irresponsible material handling are the most common causes of waste. Brick is a fragile material, and careless handling could lead to brick and block debris. Within a structure, bricks are used as walling and dividing materials. Bricks sitting about the job site unutilized will eventually end up in the trash bin. Construction projects have a more negligible negative environmental impact when waste is

managed correctly. In many construction sites, packaging makes up one-third of the total waste. One can find recyclable materials on construction sites, including metals, untreated wood, paper, cardboard, and plastics. Understanding how to use packaging might assist you in negotiating with suppliers and reducing packing on their products. You'll need to deal with your suppliers to reduce packaging on your site. Before the things you order arrive at your location, suppliers may remove various layers of packing. Both parties will save money as a result of this.

In construction projects, steel reinforcement is a necessary component. Reinforced steel is wasted due to over-design, corrosion, design modifications, and cut and bend errors. During handling, transportation, and installation, damages contribute significantly to the project expense (Formoso et al. 2002; Poon et al. 2004; Tam et al. 2006). Cutting patterns supplied to steel suppliers during the structural design of reinforced concrete elements can significantly impact the amount of steel waste created during the cutting process. Cement mix can also lead to waste during construction activity. Due to design changes or poor craftsmanship, excess cement mix is leftover after a job. It's worth remembering that un-used or un-set cement is always hazardous, especially for on-site workers.

4.3.2.1 Waste Generation – Sources of Waste



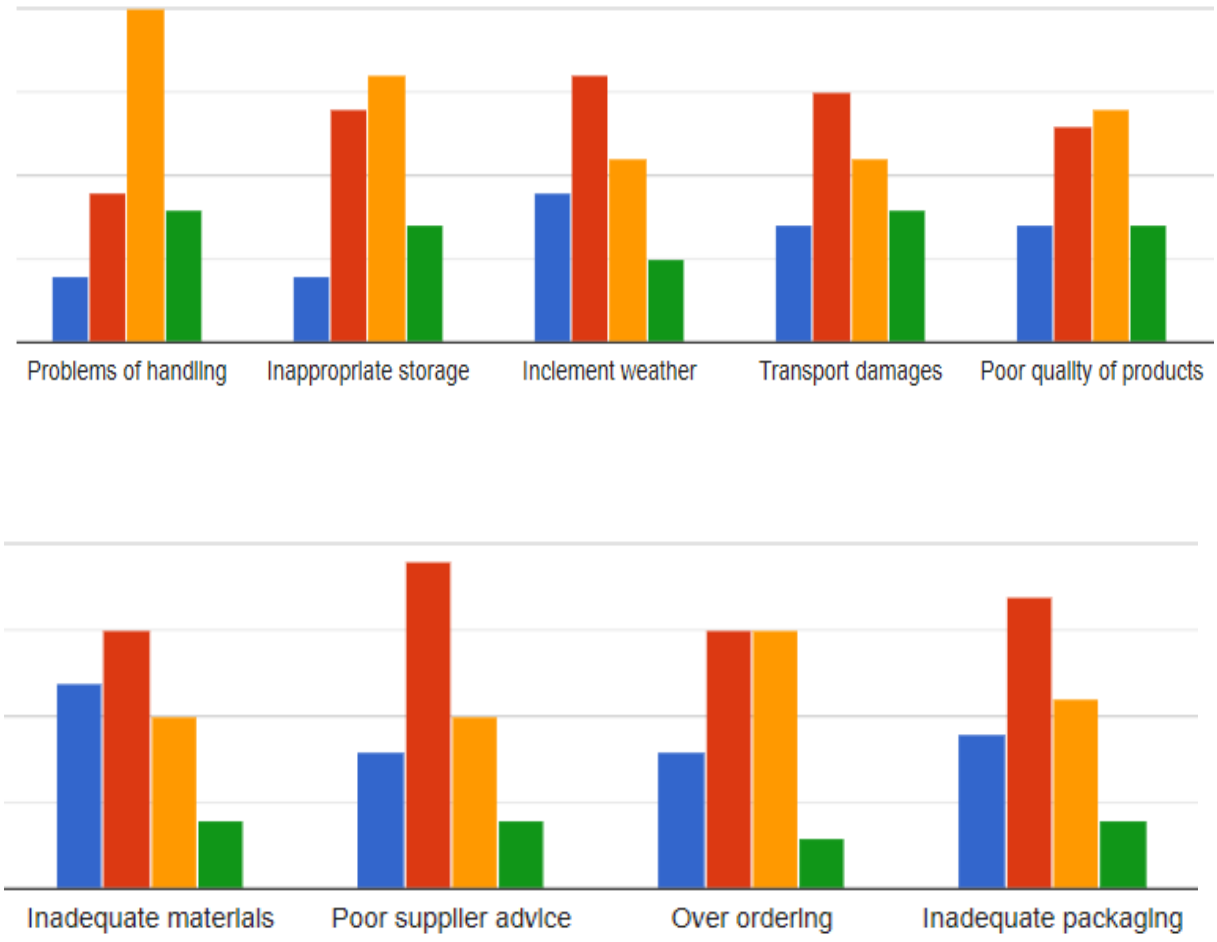


Figure 22: Sources of construction waste

On a Likert scale of 1 to 4, the responses from the respondents illustrated in figure 22 were rated. This rating was regarding waste sources that contribute the most to the generation of waste on-site (where 4= Always, 3= Occasionally, 2= Rarely, and 1= Never). The analysis is in table 8.

Table 8: Analysis of waste sources

	Rating Scale				Overall		Index	Rank
	1	2	3	4	Weighted Average	Standard Deviation		
Lack of workers' awareness	2	10	19	10	2.90	1.19	5.35	2
Poor design	4	13	17	7	2.66	1.13	5.01	4
Unskilled labour and rework	2	8	21	10	2.95	1.21	5.40	1
Time Pressure	8	14	15	4	2.37	1.13	4.47	8
Problems of handling	4	9	20	8	2.78	1.15	5.19	3

Inappropriate storage	4	14	16	7	2.63	1.13	4.97	5
Inclement weather	9	16	11	5	2.29	1.14	4.31	10
Transport damages	7	15	11	8	2.49	1.12	4.71	7
Poor quality of products	7	13	14	7	2.51	1.12	4.76	6
Inadequate materials	12	15	10	4	2.15	1.17	3.98	12
Poor supplier advice	8	19	10	4	2.24	1.15	4.20	11.5
Over ordering	8	15	15	3	2.32	1.13	4.36	9
Inadequate packaging	9	17	11	4	2.24	1.15	4.20	11.5

Rating scale:

(Highest range – Lowest range)/ highest range = 0.75

Descriptive Equivalent:

1 = NEVER 1 – 1.75

2 = RARELY 1.76 – 2.50

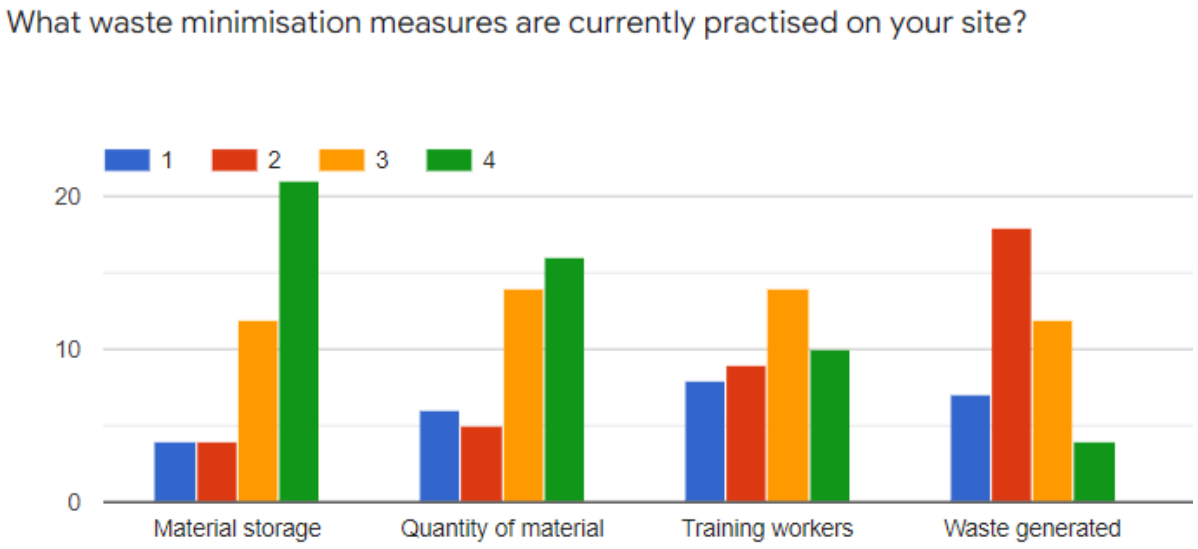
3 = SOMETIMES 2.52 – 3.25

4 = ALWAYS 3.28 – 4.00

Using the formula by Begum et al. (2006), the table showed the respondents' opinion that all factors contribute significantly to materials waste generation on Sierra Leonean construction sites. Two factors had a very high weighted mean. These factors were the use of unskilled labour, which often leads to rework and the workers' lack of awareness of the importance of waste management. There were seven factors in the table above, with an average of less than 2.5. These factors contribute minimally to waste production. From the site visit and the questionnaires, it is evident that a general issue is an awareness lacking among the construction industry site workers. The cause, poor design leading to off-cuts, is one example of a problem that falls outside the contractors' control as designers do the design. The worker's culture and mentality in the construction industry do not consider the sustainability and environmental impact of the activities carried out as a priority, which is therefore out of the contractors' control. However, the contractor must raise awareness on his site about the environmental impacts of the construction activities to minimize the material waste generated on the site. Unskilled labour, which also leads to rework, was also mentioned by Smith (2008) as another cause leading to off-cuts.

The seven factors in the procurement process include transport damages, time pressure, inclement weather, inadequate materials, poor supplier advice, over-ordering, and inadequate packaging. These were the direct responsibility of the contractor. This analysis supports the findings that Ekanayake and Ofori, 2000 made, which stated that contractors do not usually consider factors related to procurement as the primary contributors to site waste generation. Ekanayake and Ofori, 2000 revealed that office consultants/engineers identified risks associated with design and documentation as the primary sources of material waste on Sierra Leone construction sites. Project managers, site forepersons, and site supervisors who work directly on implementing the construction work identified materials storage and handling as the significant source of material waste. The original classification of material waste was into five categories in a literature review: site management, procurement, material handling, operation, culture, and others (Lingard et al., 2000). Waste in the construction sector might come from any of the sources above or a combination.

4.3.2.2 Waste Minimization Analysis



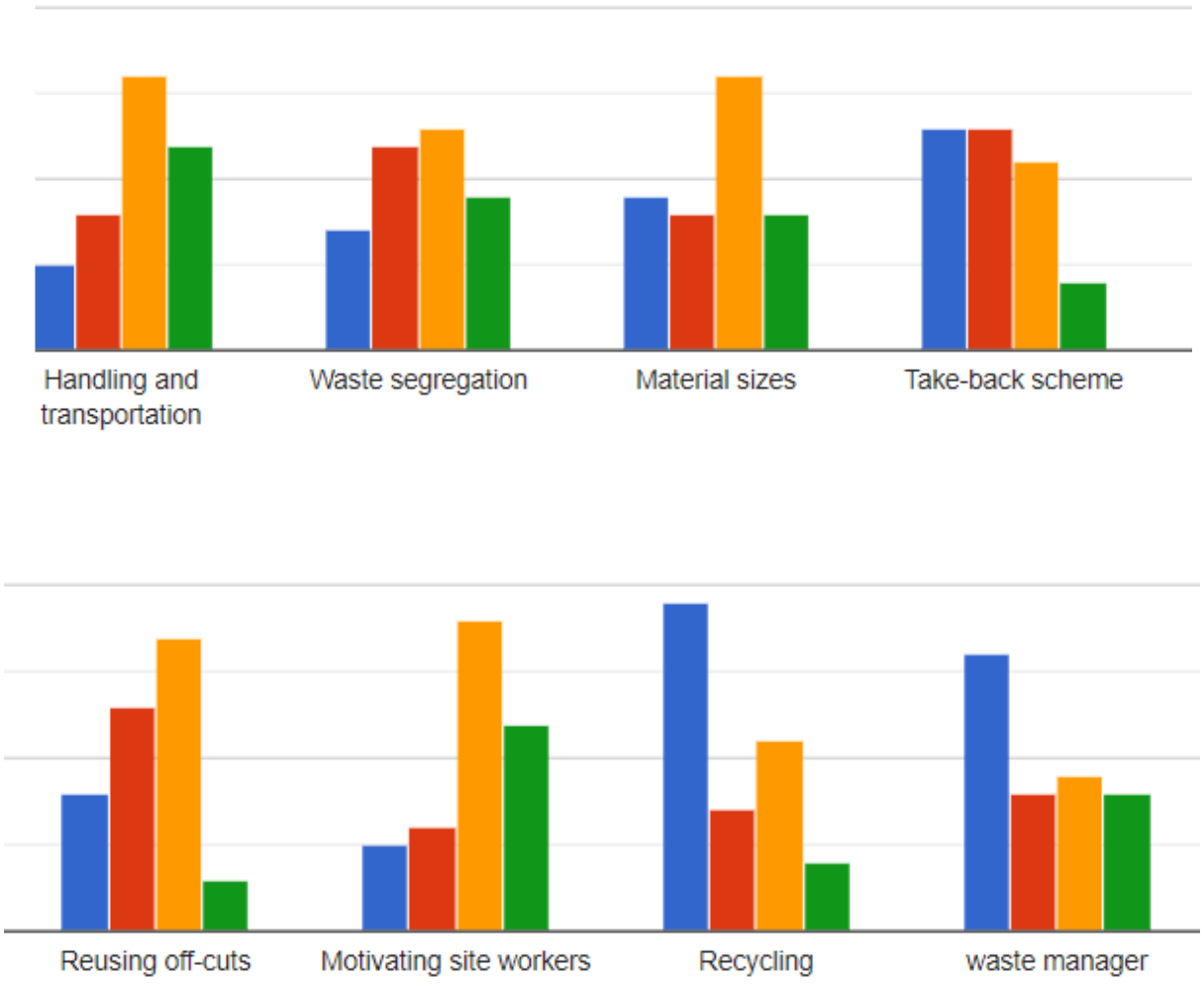


Figure 23: Waste minimization measures

Material waste minimization implemented on-site, illustrated in figure 23, is related to the Site Waste Management Plan (SWMP) frequency rate. The frequency ranged from 1-Never, 2-Rarely, 3-Sometimes, to 4-Always. Since they all work with companies, all respondents confirmed that they have and implement an SWMP.

Table 9: Analysis of waste minimization measures implemented on-site

	Rating Scale				Overall		Index	Rank
	1	2	3	4	Weighted Average	Standard Deviation		
Adequate material storage facility	4	4	12	21	3.22	1.33	5.64	1

Accurate quantity of material ordered	6	5	14	16	2.98	1.21	5.42	2
Training workers to enhance awareness	8	9	14	10	2.63	1.13	4.97	5
Measuring and recording waste generated	7	18	12	4	2.32	1.13	4.36	9
Proper handling and transportation of materials	5	8	16	12	2.85	1.17	5.29	4
Waste segregation on site	7	12	13	9	2.59	1.12	4.89	6
Ordering exact material sizes	9	8	16	8	2.56	1.12	4.85	7
Take-back scheme with suppliers	13	13	11	4	2.15	1.17	3.98	11
Reusing off-cuts	8	13	17	3	2.37	1.13	4.47	8
Motivating site workers	5	6	18	12	2.90	1.19	5.35	3
Recycling on and off site	19	7	11	4	2.00	1.22	3.63	12
Appointing a waste manager on site	16	8	9	8	2.22	1.15	4.15	10

Rating scale:

(Highest range – Lowest range)/ highest range = 0.75

Descriptive Equivalent:

1 = NEVER 1 – 1.75

2 = RARELY 1.76 – 2.50

3 = SOMETIMES 2.52 – 3.25

4 = ALWAYS 3.28 – 4.00

Shen and Tam, 2002; Poon et al., 2004; McDonald and Smithers, 1998 studied different countries and proved that the Site Waste Management Plan (SWMP) is effective. They concluded that having a Site Waste Management Plan is an important measure

to reduce the waste generated on construction sites. Table 9 shows that Sierra Leone rarely implements this technique on construction sites. A majority of the sites do not have the SWMP at all. The respondents confirmed that they rarely practice all waste minimization measures or sometimes. Still, no company had not practised any at all, even if they did not know that what they were doing was reducing waste.

The analysis showed the top three measures of waste minimization to be (i) storing materials adequately, (ii) ordering the exact amount of materials, and (iii) motivating site workers. These measures are the obvious preferred options for most, if not all, companies to adopt. These measures can prevent waste from the source rather than dealing with the problem after. Also, two other measures showed to be implemented less frequently in the industry by the contractors. These are the (i) recycling on and off-site, (ii) take-back scheme with suppliers, and (iii) appointment of a waste manager on-site to supervise waste minimization activities. These measures are not the best measures selected by contractors because there is a lack of recycling facilities to carry out offsite, and recycling on-site will be very costly. Take-back schemes are frowned upon by suppliers. Most construction materials are imported into Sierra Leone and not manufactured. It is a challenge for the supplier to collect used products or materials from consumers and reintroduce them to the initial processing and manufacturing cycle. The least desired alternative for construction companies would be to employ a waste manager because it would require hiring more staff, which would be expensive.

4.3.3 Section 3 of the Questionnaire

4.3.3.1 Benefits of Waste Management

Analysis of the responses on the benefits of material waste minimization shows that the current motivation for such practices is immediate cash rewards, not regulation or environmental concerns. The four initiatives covered in this analysis, as well as the literature, came to similar results. Some benefits of waste minimization from the opinion of the respondents included:

- Reduces the carbon footprint and CO2 emissions caused by the production, transportation, and use of materials, as well as the recycling or disposal of waste materials

- Significantly reduces waste disposal cost, which increases the possibility of generating revenue from waste (resources) and opportunities for the business
- Waste could be a source of fuel, e.g. Methane gas, obtained from proper material waste management
- Protect the ecosystem and wildlife
- Employment opportunities for waste management workers
- Enhances the site's security as intruders mostly invade the area to take and use some of the waste.
- Diminishes the demand for landfill space.
- Enhance quality work environment
- Reduces pest infestation that impacts the spread of diseases
- Less use of natural resources and the reduces the need for deforestation
- Promote quality control and quality assurance
- Enhance the quality of the air and water while cutting emissions of greenhouse gases
- Enhance productivity and reduce delays in project delivery

In summary, the benefits are increased profit, clean and safe site conditions, saving the cost of disposal and transport, enhancing the company's image as a green contractor, and protecting the environment. This research demonstrates the global construction industry's growing interest and understanding of health and safety issues. The remarks indicate that health and safety concerns are more than merely necessary to the industry. They are increasingly becoming the industry's top priority. The second financial benefit is related to reduced disposal and transportation costs. Sierra Leone's landfill prices are not exceptionally high and provide a modest incentive for minimizing material waste. The advantages of waste reduction for the environment, which are motivated mainly by improving the company's image as a green contractor, suggest that it is somewhat essential for businesses. As a result, while economic, health and welfare benefits are significant motivators for waste reduction, most contractors still miss the environmental benefits.

4.3.3.2 Challenges of Practicing Waste Management

The survey also compiled the respondent's opinions on the challenges of practising waste management in the Sierra Leone construction industry. The challenges from the respondents are under the following categories:

- Site Workers
    - Refusal of workers to clean and manage waste
    - Improper collection of garbage,
    - The mindset of the workers - difficulty in embracing new ideas
    - Efficiency and controlled construction
    - The need for proper site safety/waste management education because most of the labour workforce is uneducated. Sensitization of unskilled labour may hinder the progress of waste management on a construction site in Sierra Leone.
    - Availability of storage for reuse
    - Workers adhering to onsite rules and regulations
    - Another challenge would be trying to sensitize people on why they should make an effort to separate their waste. If people don't understand the need for separation, they simply won't do it.
- Government
    - Implementing and monitoring waste management policies
    - The mindset of the citizens and lack of enforcement
    - Availability of dumping site/ areas
    - Enforcement
    - The country has limited infrastructure or mechanisms to properly process and dispose of waste. We currently don't have adequate waste management facilities to handle all the generated waste. Most waste management facilities are in the capital city, so improper waste disposal is even worse in other country areas. There are also hardly any Recycling facilities.
    - Lack of trained professionals with the relevant authority to monitor and control the management of construction waste on-site
    - Depending on the method of waste management used, it might lead to pollution

    - There are not many waste collection companies, and the ones that exist are usually not effective
    - Poor environmental and quality control
- Companies
    - Most companies operate on a tight budget. Therefore, practising waste management would require more employee training, which could be costly to the employer.
    - Sensitizing foreign contractors, especially the Chinese (who have the most foreign presence in the construction industry in Sierra Leone) on the importance of the subject as they tend to boycott important things on site
    - lack of an overall plan for waste disposal
    - adapting and enforcing the practice. Most companies will not want to create a waste department and employ waste enforcement engineers.
    - striking a balance between the goals of encouraging recycling and safeguarding consumers from hazardous chemicals in recovered products;
    - recycling-related quality issues; waste energy recovery;
    - costs of transporting unused wastes, awareness training could be challenging regarding time and resources, etc.
    - insufficient frequency of trash transport, ineffective automobile routes, separating of waste from premises, and inadequate waste vehicles
- Clients
    - Using offcuts might lead to friction with clients who consider them waste and not good enough for reuse in other areas of the project.
    - Public awareness and knowledge of recycling waste

4.4 Challenges of Administering the Questionnaire

The questionnaire, when prepared, was first shared with family members to help check spelling, grammar, and layout. However, family members did not reliably predict the main target groups' emotional reactions or comprehension difficulties. Due to excessive surveying from companies and websites on feedback requests, many respondents are tired of these constant interruptions. From experience, most academic surveys aim to gather as much information from the respondent by having more open-ended

questions. They force the respondent to think and insert valid points to help their research. As a respondent, I have learned that these surveys are too exhausting to complete. Any study over 5mins to complete is too long. These observations were some factors considered when creating the questionnaire for this research. Another challenge was that the leading target group for this research was working-class people working in construction. It was challenging to complete the survey to get these people to find time in their busy schedules. Most people only get time to complete the surveys when they get home after work. The questionnaire design through google forms is optimized for mobile phones as most respondents may be tired of opening computers after retiring for the day. Administering this questionnaire was also a challenge because the survey was not open to just anyone in the country. It was limited to Sierra Leonean civil engineers with experience working in its construction industry. It was not as easy as sending them links to WhatsApp groups and expecting people to respond willingly. The survey is shared with each respondent individually. The research followed up daily with messages till each respondent completed the survey.

4.5 Conclusion

Freetown suffers from overpopulation due to poverty and the migration of people into the city. As a result, there is a boom in construction activities. Construction employees are in high demand regardless of their degree of experience, qualification, or competency. The contractor must continue raising awareness and supplying a properly trained crew to limit the quantity of trash produced on-site. On their sites, contractors should always be responsible for waste production and management.

This chapter presents the data systematically and chronologically according to the site visit and questionnaire questions. The researcher laid out the study purpose together with the research objectives. References to the literature, where applicable, supported the results. Construction product waste is produced by entities aside from those solely responsible for the construction operation. Waste does not only affect the environment. It also results in developers and contractors incurring extra costs for their projects. Waste management is a significant measure that project sites should implement. It is a profitable solution that will save the environment by reducing the exploration of its natural resources and increasing the lifetime of landfills. Minimizing, reusing, and recycling waste at the project site are all parts of waste management. In conclusion, after

the analysis and observation, material waste generated in the construction industry is the supplier's fault as it is the consumer's fault.

The investigation found that the major contributors to material waste on construction projects in Sierra Leone were personnel attitudes, operational parameters, design and documentation aspects. Also, warehousing and handling of materials and procurement parameters. Last-minute client requirements, errors by artisans or operatives, supplies not meeting specifications, and a lack of onsite materials management, were the leading causes of materials waste. On Sierra Leonean construction sites, the critical materials with a high wastage were timber, nails, material packaging/cardboard, cement, concrete, steel, and bricks. Contractors currently use adequate material storage facilities, an exact quantity of material requested, and motivate site personnel to reduce material waste on projects. Minimizing material waste will improve project performance, increase value for individual enterprises and clients, and benefit the country's economy. Most contractors in construction regard cost savings and increased profitability as the essential benefits and motivations for material waste minimization. Furthermore, consider construction waste during the project's planning and design stages for appropriate waste management.

5. Case Studies

From the analysis chapter, the waste source, unskilled labour leading to rework, is ranked number one by the respondents on the survey. It is no surprise, as I have had personal experiences with unskilled labourers. The consequence has incurred more project costs, which were not in the project budget. This shortage of skilled labour affects the country's most productive economic sectors and the economy. As many as 88 per cent of its workforce is in low-productivity employment or self-employment, of whom 55 per cent are unskilled and unemployed youth. There are several reasons why the country finds itself in this position. These include low basic cognitive skills, lack of funds to complete school, and little access to training programs. There is also the supply-driven approach from companies with little or no input from employers that informs the content of the training.

Rework is the operation of repurposing a non-compliant product to ensure conformance with the relevant drawings or standards, using the initial or an alternative processing techniques.[15] This chapter seeks to consolidate the questionnaire analysis by exploring two (2) case studies in Freetown, Sierra Leone. The first case study is about a retail structure with stores and residential apartments for rent. The facility is uncompleted due to the shoddy work done by unskilled labourers and contractors. The construction is on hold, and a detailed rework plan is ongoing. The second case study is a mixed-use building with a tiled wall façade. This construction was completed in October of 2020. The tiles started to fall off the building walls, and in May of 2022, the client decided to take down all the tiles. This untimely removal was due to unskilled labour employed in the tiling process. The tiles became a hazard to potential customers going to the facility as tiles unexpectedly dropped from the walls. Unskilled labour from this case study can not only lead to rework, but it is a risk to human lives and property as well.

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[15]https://www.eptac.com/faqs/ask-helena-leo/ask/the-difference-between-touch-up-rework-and-repair

5.1 Case Study 1

Figure 24: Case study 1 - A mixed-use building

The first case study explored in this research is a personal family project. The project vision is to provide a mixed-use structure including retail, office, and dwelling spaces. The above image shows the initial approved design from the client. The structure had three staircases, one on the right, one on the left and one at the back of the facility. It was too many staircases for the structure. The initial design did not consider the ground conditions, which is evident that the architect who produced these plans did not visit the site before putting together the strategy. The design included a ground floor with stores in the front and a warehouse at the back to serve as storage space for land owners. The first floor also had store and office spaces, and the second and third floors were dwelling apartments. The client was closely involved in the implementation of this project. As the construction started, it became clear that the design did not incorporate the ground conditions. Therefore the client requested some amendments to the plan.

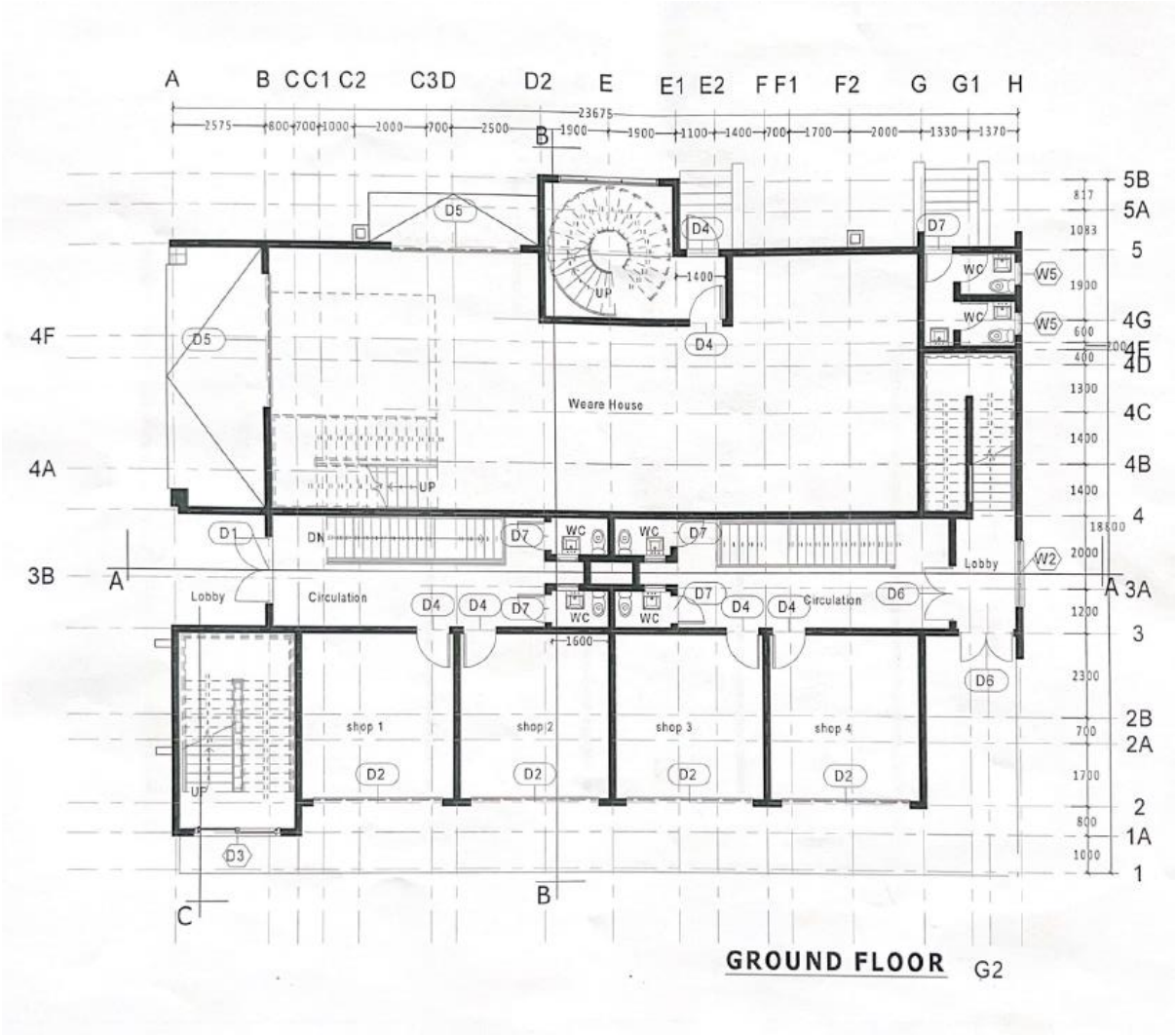


Figure 25: Ground floor plan view

The initial plan changed to accommodate a warehouse in the basement. The back staircase from the original plan was removed. The original plan's ground-floor warehouse became the basement, and there was an extension to the storefronts to the back of the structure. As retail spaces become more extensive than the standard size for store rental, each business has its private washroom (WC). There were no experts on-site to advise on the effects of these alterations. Because the contractor was not skilled enough to notify the customer, the contractor implemented the changes on the site as the client proposed. There were also no structural drawings for the facility; only the architectural drawings were available. The available plan was hardly even used since it did not fit the ground conditions on the site. This project started in January 2022, and the client expected construction to be completed by December 2023. Parts of the structure, like the retail spaces, were to be completed first and rented out. At the same time, construction would continue on the other parts of the facility.

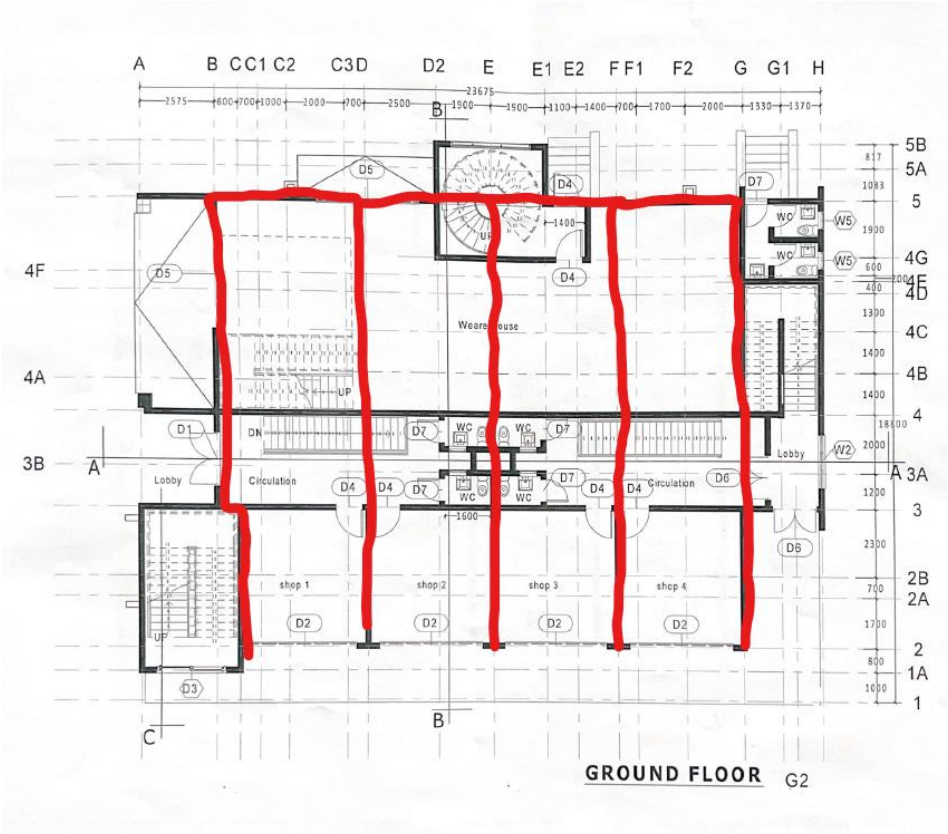


Figure 26: Amendment to original ground floor design

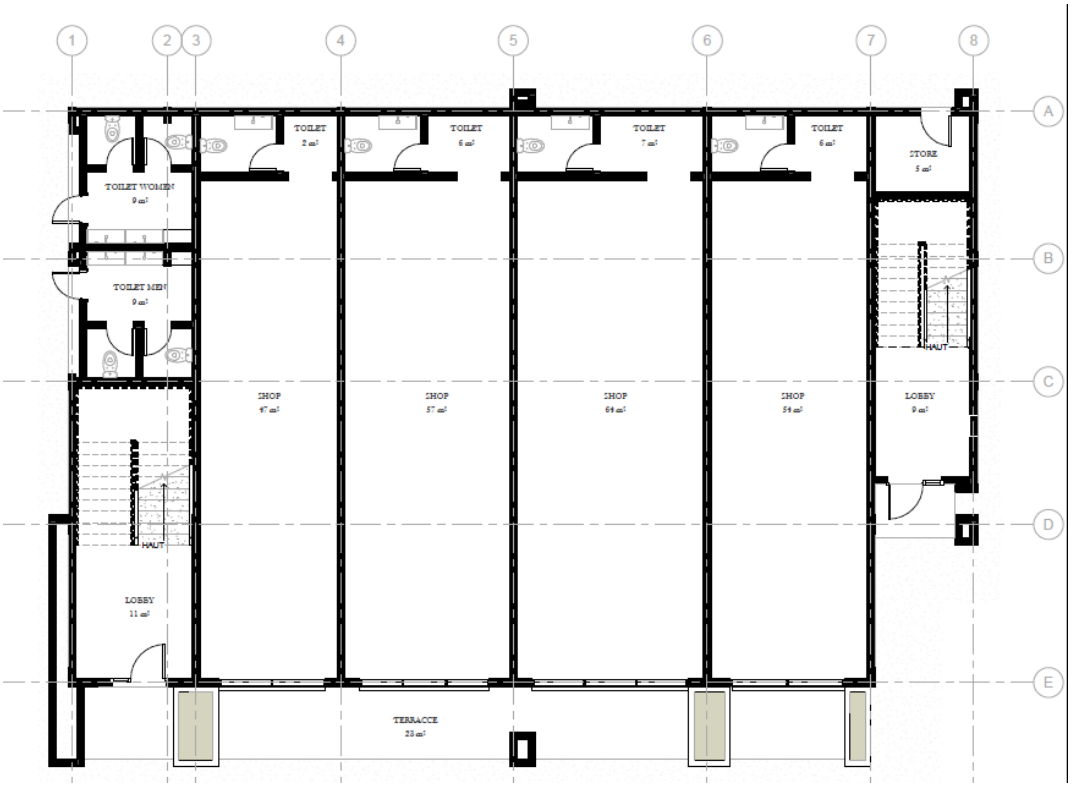


Figure 27: Amended ground floor design

A local contractor was given the construction contract and was responsible for hiring subcontractors and labourers to carry out the job. The construction industry is very competitive when hiring contractors or subcontractors as many people are in the field (both learned and unlearned). The labour cost was meager, which was why this contractor won the contract. During the construction, the client realized that the contractor did not have a realistic estimate of the costs of hiring subcontractors and just wanted to get the contract by all means. Figure 28 is an image of a retaining wall constructed by the contractor and the labourers.

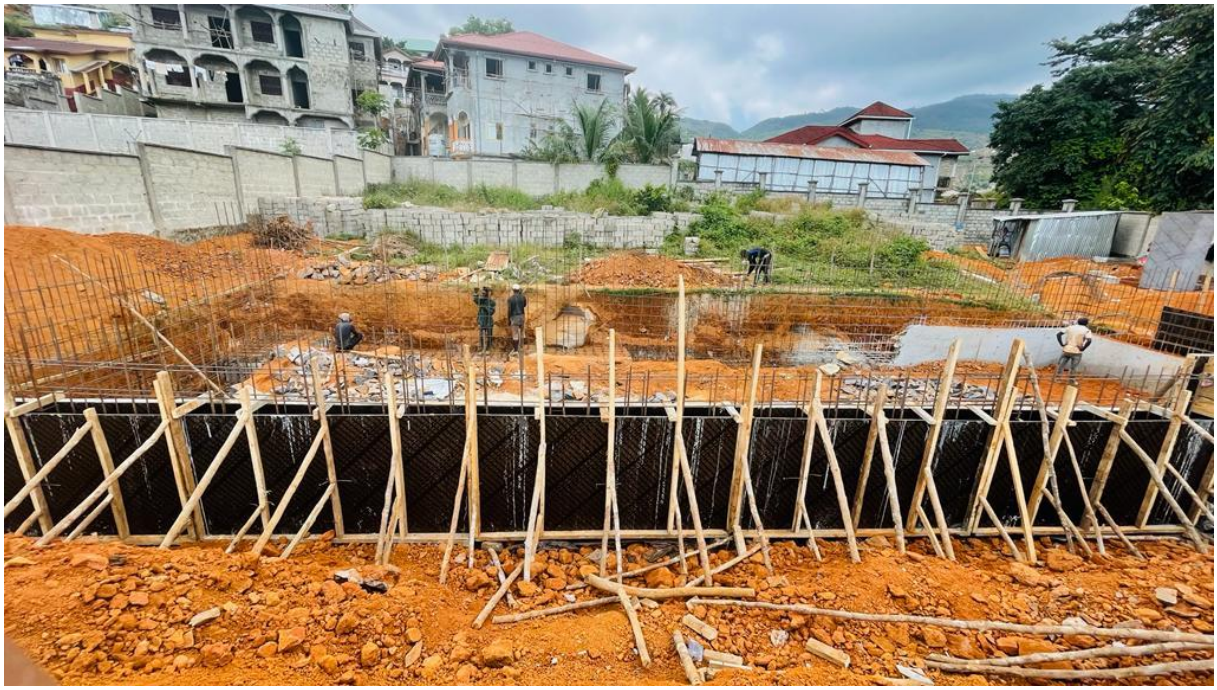


Figure 28: Retaining wall for basement floor

Figure 29 shows the basement floor construction. Inside the basement were stand-alone columns that the workers did not connect to any foundation/footing. The contractors did not consider the load-bearing capacity of the structure. Due to poor educational background, the contractors used this retaining wall and the stand-alone columns as the facility's foundation. With the low-cost estimate for the labour, the contractor could not pay skilled labourers to carry out the tasks on the project site. The client was not impressed with the result as the delivery was prolonged, and the outcome was not good. The client then terminated his contract with the contractor and hired an engineer to take up the task of the remaining construction activities. The engineer was also responsible for bringing in a new set of labourers to continue the job. The work is

currently on hold. So far, the construction is only up to the ground floor level with the stores and the basement underneath the ground floor.

Figure 29: Constructed basement floor

The engineer firstly investigated the type of foundation constructed to determine if the foundation built could carry the load of the floors. The investigation of the foundation involved digging close to the retaining wall of the structure. As shown in figure 30, it was evident that the constructed columns were not connected to any footing and were in suspension within the soil.

Figure 30: Constructed column as a foundation

The engineer discovered that restoring the back staircase was required to gain access to the upper residential floors without passing through the shop rooms. The engineer

went to the site to assess the foundation capacity and establish whether the built foundation was enough for the new plan. The engineer found that the foundation was under-designed and could not support a multi-storey construction. The contractor and the labourers had done a substandard job. The rework began with a complete rewrite of the relevant drawings for the various disciplines inside the structure. Structural, Electrical, and Plumbing drawings and the architectural blueprints are included in these designs. The engineer redid the plan to incorporate the client's previous and new amendments. There will be modifications to strengthen the foundation. There will also be adjustments to the constructed columns that were inadequate to carry the load based on the structural drawings.

Figure 31 shows the new revised architectural plan that now reduces the length of the stores by removing the restrooms at the back of the stores, making space for a dwelling area on the ground floor. This change is not only the most logical approach to fully utilizing the mix-use structure space but also economically feasible. The cost of renting the stores on the ground floor in the initial design is half the cost of renting the stores and dwelling space on the new design’s ground floor. In this new design, the staircase on the right side of the original plan was removed. A new staircase was introduced at the back of the facility to access the residential apartments at the top. Instead of having separate facilities in each business, the design on the ground floor for the demolished right staircase was changed. It is a restroom area for men and women that could be available to all store owners. There was an addition of two 2-bedroom apartments on the second and third floors. A self-contained dwelling apartment on the first floor with three shops and an office space improved the new design's economic viability.

Figure 31: Revised design

Figure 32: Revised ground floor plan

The client will have to pay for the following works on the already constructed ground floor and basement:

- Demolition of existing works (staircase, foundation slab, column cover, wall partitions for restrooms), including the transport of rubble to the public landfill
- Excavations in holes for isolated footings
- Excavations in trenches for basement
- Waterproof cement mortar coating on the base

Rework on projects severely affects performance, schedule, and budget. According to research, rework in development often costs 5 per cent of the total contract value. Furthermore, with an average of 7.1 per cent of the hours worked, time overruns are worse. It is simple to understand how these expenses might mount up. It is critical to reducing the amount of rework on a project since these overruns adversely influence the relationship between general contractors, trade contractors, and clients. This case study validates this research that unskilled labour can lead to rework, which is costly and generates a lot of material waste in landfills.

5.2 Case Study 2

Figure 33: Case study 2 - Retail and commercial building

This second case study is a retail structure built in 2020, as shown in figure 33. The facility includes a basement floor, a ground floor of four shop spaces, and office space on the first and second floors. The facility's architecture had tiled outside walls. Using wall tiles as a substitute for wall paint to beautify and improve quality has become quite popular. Wall tiles have a significant advantage: protecting the wall from mould, odour, and stains and ensuring the aesthetics of our home in the long term. The wall tiling also saves you time for daily cleaning. Especially in the rainy season, the painted walls are also not resistant to water, causing water spills and leaks. The downside of wall tiling is that it is expensive compared to painting the house. It takes longer to build than to paint the house. Another downside is that you cannot change the colour without changing the entire tiles, unlike painted walls where the colour could modify anytime. That wall covering will be challenging to disassemble.

Figure 34: Removing tiles from the building

The tiling was contracted to a local contractor who hired his labourers to carry out the tiling. These were not specialized outdoor wall tilers, but they have previously had experience tiling indoor floors. The contractor failed to consider the weather conditions

that may affect the outdoor walls. By 2021 the tiles started falling off the walls, and the tiler contracted could not find any solution to fix the problem. The tiles falling off became a hazard to potential customers going to the stores. By 2022, all the tiles were removed from the structure. As mentioned earlier, the client chose the tiling approach over painting the walls because it is believed that the tiles would make the building look beautiful, sound and long-lasting. Painting outside walls in the streets is not a good economic decision. In Sierra Leone, we have two seasons. The rainy and dry season. Because of paint that has peeled or cracked after some years, some places may need restoration. If dampness is in one of the walls, it may develop even quicker because it may cause the paint to bubble and flake off.

Composed due to the weather are painted outside walls, which causes the colour to fade or alter gradually. Within several years, red paint begins to turn pinkish, while the white colour may become slightly yellow. Repaint the surfaces to keep the colour from fading and becoming discoloured. Eventually, the tile approach was costly for the client and did not yield the expected result. There will be reworking on the walls because of the lack of skill employed during the job. This case study proves that unskilled labour does not only lead to revision, which generates material waste. In this case, tiles also lead to unplanned maintenance costs in a newly completed project.

Figure 35: Current look of the building

5.3 Conclusion

Most clients in Sierra Leone, be it an individual or a company, tend to go for contractors with the lowest price. This approach is adopted mainly to save money for the project, but in most cases, the opposite is the result. The contractor with the least cost has that because he has not considered the current market prices for highly skilled subcontractors or labourers. Also, contractors have preconceived notions that labourers do not require skill; they can do any job they ask. In the field of construction, attention to labourers is seldom. But for every job, it is not the engineer or contractor that gets the task done. The labourers do all the physical work. Labourers work for construction companies or contractors to perform physical labour throughout the process. They get the least payment on construction sites and do the most challenging job. They are significant in any project, and a project will achieve more success if we help develop the capability of labourers.

6. Proposed Solution for Effective Waste Minimization – A Lean Production Approach

6.1 Introduction

By eliminating non-value-adding tasks, we increase the efficiency of value-adding activities while reducing waste. Controlling waste to an acceptable level is through significant improvement in production system conditions. Implementing inexpensive preventative methods related to managerial enhancements helps avoid waste. As seen in the analysis chapter, the construction industry is the biggest in Sierra Leone, especially in Freetown. Due to the overpopulation in the capital city, most construction projects are for residential purposes, and a high percentage of these belong to private individuals. This chapter will look at a solution to eliminating unskilled labour as a waste source completely. It will reduce the number of reworks in construction projects and its benefit to the construction industry in Sierra Leone.

A description of the widely adopted contracting sequence in the Sierra Leone construction industry concerning hiring labourers is in figure 36 below:

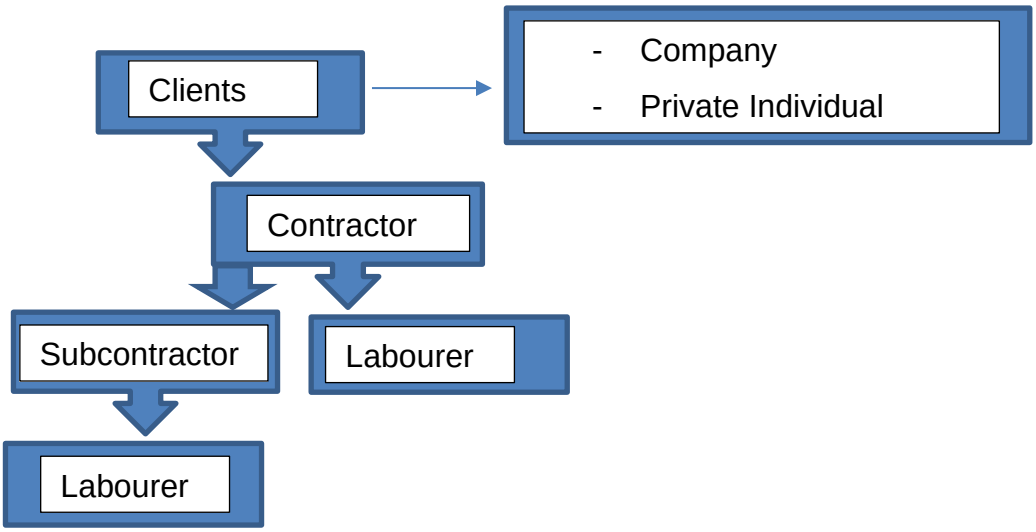


Figure 36: Contracting sequence in the Sierra Leone construction industry

Employing competent contractors to carry out construction work is deemed expensive. It is because of the country's economic situation and the earning power of local land owners wanting to carry out construction work primarily for residential purposes. This is because the local landowners do not believe they will see a return on their

investment if they only stay in the houses. Landowners who build retail spaces for rent or other commercial spaces for which they receive a return prefer the less expensive contractors. These less costly contractors constitute the majority in the country. They are primarily people with no formal education in the field with years of experience. These contractors gain experience in the field by moving through the ranks of first becoming a labourer. A Masoner and then learning other trades from just doing whatever work was available on site, and after many years of working in construction, they gain the title of being a contractor. It is the case for many contractors in the country. Because there are no regulations that require someone to have a level of qualification to be called a contractor, they go ahead with the title to take on more projects in construction. Often, the projects they construct under a sound engineer's supervision turn out well, so there has never been an issue. Another type of contractor is the one that is educated and has the experience. He bids a meager price to win a contract and cannot hire skilled labourers to perform the job on-site, so they have to go for the low-priced unskilled labourers. The labourers are hired mainly because of their physical ability to do the job and not because they have skills in the field. The labourers are hardly ever educated and may have a little educational background. Still, it may not be much at all. Due to the economic situation in the country, most of these labourers are only financially motivated to take up these tasks. They know their payment depends on their work hours and sometimes on the amount of work they can do. Hence, they are never really motivated to learn the trades they are working in as labourers to get their payment.

What is surprising is that unsatisfactory performance in construction project delivery continues, given the built environment's importance and the financial investment's size. This investment can be anything from 5 to >10 per cent and is often the most considerable expenditure of individuals and companies. Construction is an important industry, yet it is often the last career choice for people. It is even thought of as the job you do if you can’t do anything else. As a construction manager, I cannot ask that all labourers get an education in the field before hiring them for a project. I cannot ask local land owners only to employ educated contractors with experience. I cannot ask people to do what they cannot afford or go for what is not available in the country. I have to develop a solution to help the contractors who hire unskilled labourers. The answer has to be something that could quickly be adopted on sites to combat the issue. The

solution must leverage current practices and introduce a common-sense approach to solving the problem. Solving the rework issue is one way to reduce the waste generated on the construction site and eventually the amount of waste deposited in landfills.

6.2 Lean Construction

In lean construction, we encounter the principles of right first time and built-in quality. As the theory and practice of lean construction have matured, the most important of these is the need for collaboration. Successful collaboration brings into play the language-action perspective to shape communication and ensure adequate commitments. Defects are not permitted to enter the construction process.

A lean mindset includes:

- Reducing waste and using fewer materials can considerably lower overall expenses. Employing this practice has been demonstrated to improve the bottom line, even though the lean construction philosophy emphasizes total minimization rather than only for gain.
- Better preparation and tactical awareness can significantly shorten the duration of construction.
- Lower accident rates and improved safety due to better workforce concentration and comprehension.
- Improved dependability and consistency of the schedule.
- Better overall outcomes as a result of better collaboration and fewer employees.
- Less stress for management and employees as a result of fewer employees.
- More outstanding productivity overall as a result of more systematic planning.
- Greater customer satisfaction along with higher profitability and turnovers.
- Expanded workforce responsibility.
- Increased dedication to performance based on improved work fulfilment.

6.2.1 The Last Planner System

Planning and preparation drive performance. The Last Planner System (LPS) was developed over several years but began when Ballard et al., 2012 became aware that planning and execution did not match. The tasks executed each day were only about

50 per cent of the planned jobs. A 50 per cent improvement in reliability has an equally significant improvement for the productivity of a project, allowing on-time completion of assignments every time and without extra resources. (Ballard et al., 2012)

All plans are forecasts, and all estimates are not 100 per cent correct. The farther into the future we forecast, the more wrong we become. The higher the level of detail you try to predict, the worse the results will be. A lean construction (LC) method is the LPS. It is a technique for planning and controlling that promotes workers' cooperation and increases plans' dependability. The principle goal of LPS is to reduce the variation between planning and execution. The LPS bring stability to the delivery process and improves them by around 50 per cent to settle on reliably delivering around 80 per cent of the planned tasks each week. Unlike conventional construction planning, where planning and management are independent, the LPS integrates planning and control as two dependent processes (Daniel et al., 2017).

In lean construction, the people who prepare the first plan believe planning is a specific activity within an organization using sophisticated software to design a program of work activities. The first plan usually becomes a contract document that sets start and completion dates for the project or phases of the project and often bears little relationship to the actual work. The last plan is prepared by the last planner immediately before the work takes place and provides specific information for the crew or gang who will do the job. Because of the effort put into preparing the first plans and their level of detail, it is assumed that no further planning is required to keep to the programme. Of course, projects never keep to this programme. Ballard et al., 2012 confirmed that only 50 per cent of planned tasks get done. It is disruptive to workflow, meaning that contractors and suppliers never really know what will happen from one week to the next, despite a programme of great detail. Effectively this means that traditional planning is more or less a plan of chance.

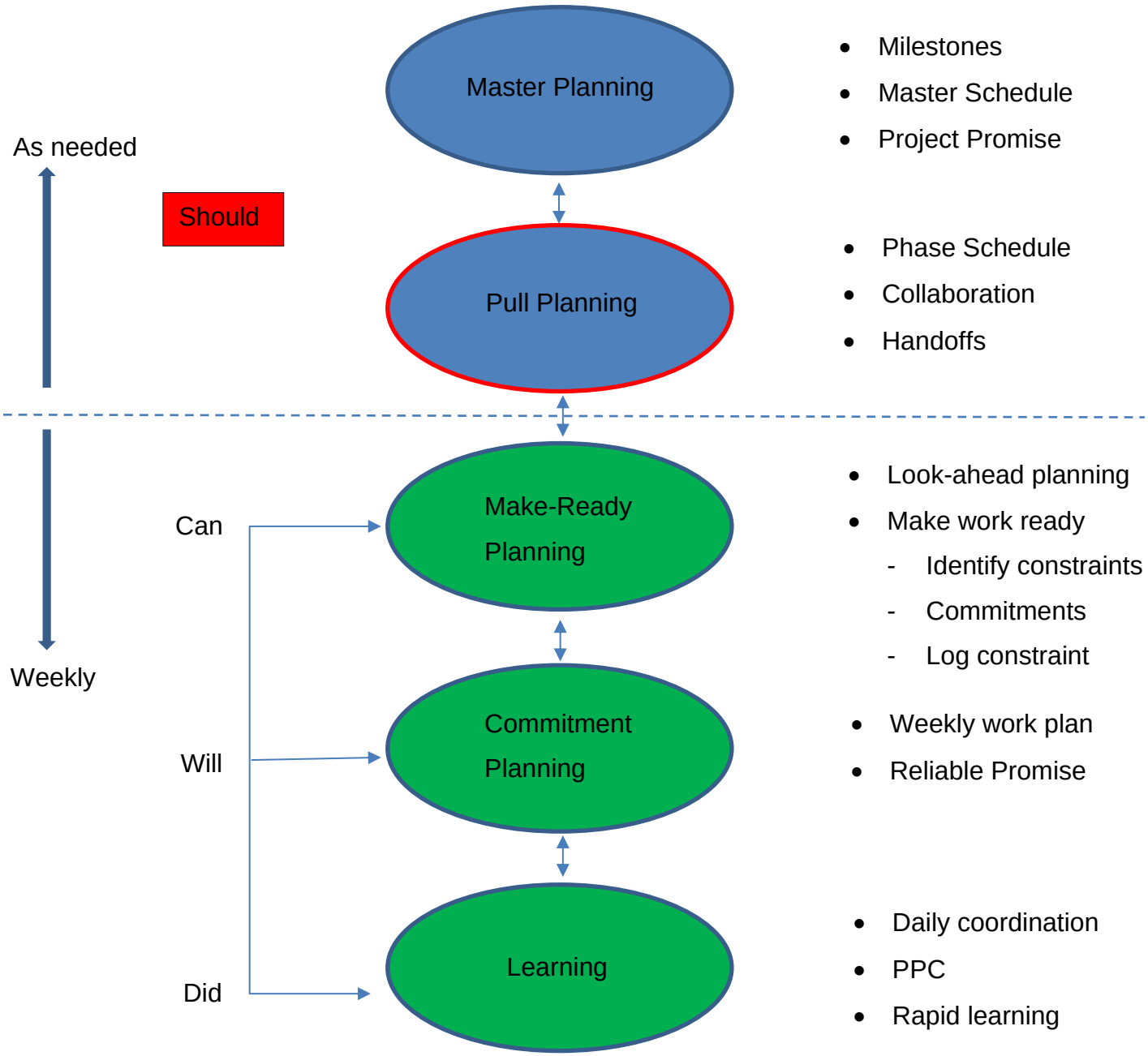


Figure 37: Last Planner System

Source: 2014 Lean Project Consulting, Inc.)

6.2.2 Comparing Last Planner System to Traditional Planning

The traditional planning, based on the critical path method (CPM) of scheduling and production planning using the Last Planner System (LPS), is shown in the table. The

table shows the underlying logic of CPM as embedded in software, whereas LPS is a common-sense approach.

Table 10: Comparing Traditional planning to LPS

Historic Method		**Production Planning**
Critical Path Method		**Last Planner**
Embedded in software	**Logic**	Applied common sense
High	**Maintenance**	Low
Critical Path	**Managing**	Variability
Work dates	**Focus on Managing**	Workflow
Contracts	**Planning based on**	Inter-dependencies

The management subject of CPM is the critical path of the activities in the schedule, whilst LPS addresses workflow variability. The CPM schedule requires a high level of maintenance to keep up to date. Still, LPS is embedded in managing the work and does not require separate updating. Traditional or prevailing planning methods focus on the conditions of the varying contracts whilst LPS manages the interdependencies of work activities. It can be seen these are significant differences in the practice and philosophy of the two approaches.

TRADITIONAL PLANNING:

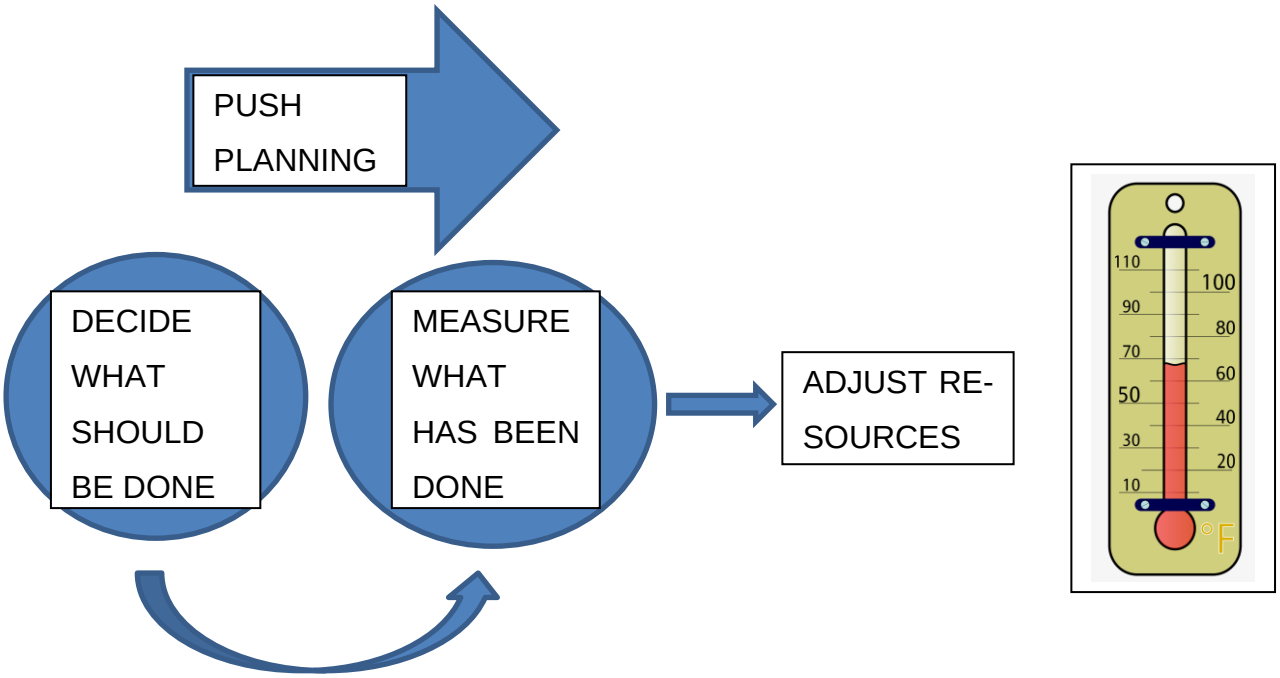
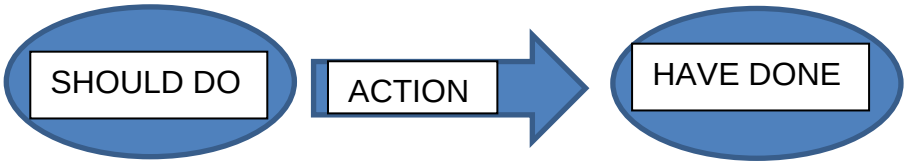


Figure 38: Traditional planning

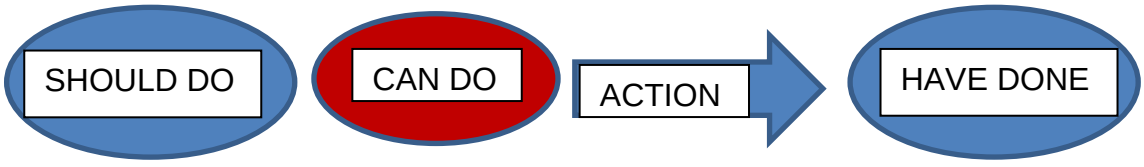
To sum these differences up, we can say that the prevailing planning approaches embedded in software using computers form a technical process. In contrast, the Last Planner System is based on common sense. The involvement of the Last Planners is a social approach to planning and control requiring conversations among the participants. Whatever the planning method, we need to know what should be done. In traditional planning approaches, we simply execute the plan and measure what has been done afterwards. We then maintain project control by adjusting the resources utilized. In the so-called 'thermometer' management model (the traditional approach to planning), the action is to adjust resources after action. This model is also an example of push planning in lean project production. The project program lists the activities, and project managers push the work to meet this program.

There are three distinct elements in all project planning: should do, action (do) and have done.



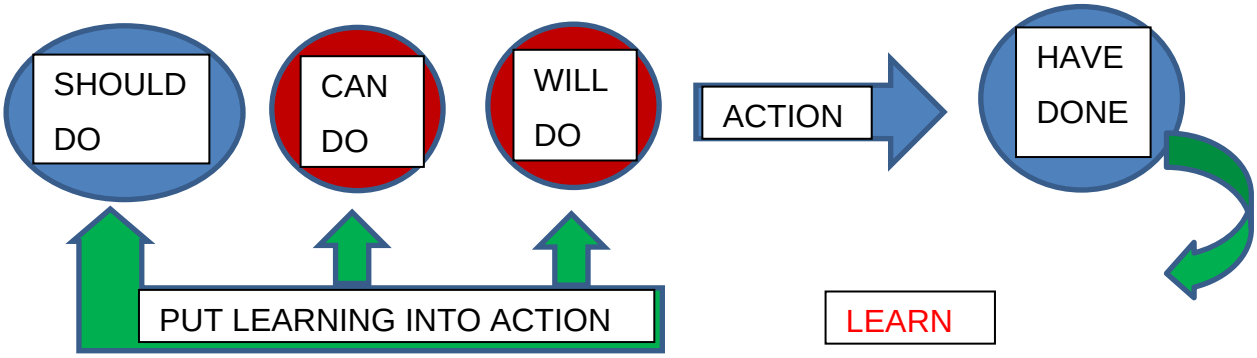
The first additional element in Lean project planning is the insertion into the “can-do” process.

The first additional element in Lean project planning is the insertion into the “can-do” process. It means that before committing resources, you should do some checks first. This ensures that what should be done can be done and is not blocked by a constraint.



The operation of LPS is like a rolling wave across the project program. After checking what we can do, we then insert a final stage of committing to doing the screened activities before we put them into the final production plan. So now, not only do we

know what we should do to complete the work, we have checked that we can do it and then made the commitment that we will do it. Of course, this takes time, and we plan in greater detail as we get closer to the specific item of work.



When the task is done, the lessons learnt are incorporated into the can-do phase to ensure that more successful activities go into the will-do stage. The feedback goes into the should-do stage. In this way, we improve the reliability of the planning process. The result of the Last Planner System is an expanded planning and control system that pulls what we will do from what we can do, which comes from what we should do. We can achieve this if we work in much smaller batches of work. The system has the flexibility to respond quickly to change and ensure the work doesn't get out of sequence. We also shorten the planning horizons within the programme instead of planning everything in one large batch at the beginning of the project. In the LPS, we move through a series of planning cycles getting progressively more detailed as we get closer to doing the specific work. This use of look-ahead and make-ready strategies in the can and will do stages effectively shields the doing or production stage from disruption. The insertion of these stages effectively forms a new way to think about doing work, what we call last planner thinking. In this way, we can view LPS as a learning system.

6.3 Approach to the Solution

The solution will incorporate the can-do or make-ready phase (6 weeks before the tasks), the will-do or weekly work commitment phase, and the did or daily huddle level of planning from the Last Planner System of planning.

Make-Ready Planning - this is the 'can' stage of the LPS. The principal purpose of the make-ready process is to ensure that tasks from the should-do phase can be done. Here, the last planner team screens all activities of the pull plan phase for possible

constraints. It requires a look-ahead window of a specified duration (about six weeks). Tasks are screened for constraints by screening anything with the potential to interfere or disrupt work progress. The individual responsible for the assignment and execution of that work is responsible for removing constraints from that work. Constraint removal is usually done outside the collaborative meetings but forms a vital information stream into those meetings. When there is no direct control over a constraint, whoever has control should provide a reliable promise over it. Reliable promising is difficult in traditional projects and is one of the changed behaviours observed in lean projects. Suppose the team member cannot resolve a constraint reliably; the rest of the team should get a notification as soon as possible. This process helps shape the work execution because it considers the desired speed and sequence concerning capacity. At this point in the process, tasks should have clear method statements. The make-ready process aims to have a supply of available work ready to be implemented.

Commitment Planning - When we distinguish between the will-do stage and the can-do stage, LPS's next phase comes into play. It is commitment planning because it occurs when the final plan includes collaboration and a commitment to the deliverables are established. It is done weekly (at least) and is called production planning. The output is a weekly work plan based on reliable promises made collaboratively, not a plan based on instructions from the project manager. The weekly work plan should only include work that is clearly defined, constraint-free, appropriately sized and in a proper sequence. The make-ready stage must have considered these aspects of the work as the tasks move closer in the look-ahead window. At the commitment-planning stage, we need to examine the operations with the last planners. They inherently understand the actions involved in executing the tasks under consideration. Therefore, they can commit and assign the crews or workers.

Reliable production requires a reliable workflow. Reliable workflows require the last planner team to collectively:

- Manage commitments/promises
- Coordinate actions
- Continue to make tasks ready.

LPS assumes that planning is a conversational process between all the parties involved. The conversations are in preparation for the weekly production-planning

meeting, where we review performance. The discussions will include an amount of negotiation as the last planners discuss the final logistics associated with agreeing on who will do what, where and when during the coming week. Once everyone is happy that the plan is achievable and constraint-free, they commit to doing the work as agreed. Committing is not a simple action. Collaboration helps dissolve the silo mentality that dominates the industry and recognises that the knowledge needed for improved delivery resides within the individuals from the supply chain. The conversations must agree on who does what, where and when. The outcome of the discussions is a set of agreements, which we call commitments. Commitment suggests a more formal approach than simple agreement.

Reliable Agreement Cycle

There is a need for some ground rules to facilitate reliable promises to supplement this cycle. These rules include:

- You can say no - The first of these ground rules must be that the parties (contractors and labourers) can say no to a request. Of course, there must be a reason why. Saying no is delivering bad news as early as possible, which can turn into good news when addressed. It facilitates the correcting action necessary in the make-ready process of LPS. It must be accepted if we want our systems to become more reliable.
- Be honest about competencies - The following rule is the need for the promisee (labourer) to be honest about their competence or access to competence. In some ways, this is related to feeling able to say no. It doesn't help anybody if you promise to do something you cannot do.
- Properly assess timescales - Next comes the promisee's ability to properly assess how long the task will take. Suppose it is not possible to determine the time. In that case, the commitment must be conditional and no longer reliable.
- Have capacity - The following rule is critical for construction where the contractors conduct their businesses in a multi-project environment and frequently juggle resources (labourers) between many jobs. The idea is for the project to be the first choice for resource allocation by contractors and suppliers. It is more likely to be the case if the systems operating can be trusted. Traditionally, project managers request contractors to come on-site before work is ready, believing this is better for their project. In reality, contractors are wary of committing

resources because they don’t believe or trust the project manager. For projects to become more reliable, the focus should be on how to help contractors commit.

- Don’t overpromise - A further consequence of the construction industry's multi-party environment is that a promisee can already be promising another project in a separate commitment cycle. It could be that several projects are all approaching a stage when this resource is needed. It means the contractor may split the resource, thus slowing the progress or start of a project. Contractors may resort to doing a little work on one side and then dropping onto an alternative scheme to demonstrate to clients that work is happening. Overpromising is a significant contributor to variable performance in the construction industry and one that is hard to break because the uncertainty of gaining new work encourages companies to try for everything.
- Take responsibility - The last rule is the requirement for people to take responsibility and not walk away saying 'it’s not my problem'. The team should move towards better quality and a right-first-time approach. Examples include picking up dropped and discarded materials or more considerate behaviour such as leaving a small quantity of paint or caulking for the next trade to touch up.

These rules help all parties (project managers, contractors and labourers) to make reliable promises, and these are through conversation. Project management becomes successful through the repeated implementation of the Last Planner System. The success is down to a coherent network of commitments made collaboratively between the last planners on a project. Actions become more coordinated because the workflow is more reliable, and there is trust between the parties.

Daily Huddles - This is the stage where the task is already in progress, and the team meets up to review what they had committed to doing the previous day. It consists of the daily, usually stand-up, brief discussions held by groups of interdependent participants. Each player reveals the responsibilities they have fulfilled and those they cannot fulfil or for which they need assistance. It is accomplished between front-line managers of design teams or construction workers and within each group or unit. The team must fully comprehend that daily huddles do not address every problem. Leaders can discuss circumstances when they need assistance from others in the huddles, and the group can then determine who or what is required.

6.4 The Solution

During milestone or phase planning, anyone who has the potential to impact the timetable significantly is referred to as the Last Planner. Typical Last Planners needed include, but are not restricted to, client executives, such as project managers, engineers, etc., the main contractor, construction managers, or crucial vendors. They must be able to decide what to do and allocate the necessary funds on behalf of their business or group. This research provides a checklist that the Last Planner could administer to the labourers before implementing a particular task on site. Before any session, the checklists could be used to remind the team to stay on target with the essential components.

Additionally, the LPS facilitator can utilize it to evaluate how well they ran the meeting. The checklists are not exhaustive and present a foundation for more research. This research focuses on Labourers as the team members that will do a task. The team may juggle assignable tasks backwards or forwards to maintain the appropriate utilization of resources. If necessary, there may be adjustments to the phase schedule or even the master schedule in extreme cases. A successful make-ready process means the project team can confidently approach the next phase. If the team could not remove constraints that emerge during make-ready planning, they may need to replan.

Table 11: Checklist for Make-Ready Planning

Project Name		Facilitator Name	
Date		Facilitator title	
Weather Condition		No. of Attendees	
MAKE- READY PLANNING (6 Weeks to Implementation)			
Description of Job			
Breakdown of the tasks to be done		• Activity 1 • Activity 2	
What are the current operations going on?			
LABOUR			
How many labourers do we need for the job?			
Is any particular skill required for any of the tasks?			Yes/No
If yes, which expertise is required?			
Does any of the labourers have the needed skills?			Yes/No
What activities should we complete to start this work?			
Are you working on lots of other projects?			Yes/No
Are you mentally prepared to take up this task?			Yes/No
DURATION			
How long will it take to complete the tasks?			days/weeks/months
MATERIALS			
What materials/machinery do we need to carry out the tasks?			• Material 1 • Material 2
Are they available on site?			Yes/No
What is the available access to the site for machinery, materials and personnel?			
CONSTRAINTS			
Are there any constraints in achieving any of the tasks?		• Activity 1 – Constraint 1 • Activity 2 – Constraint 2	
What actions are required to clear the constraints?		• Constraint 1 – Action 1 • Constraint 2 – Action 2	
Signature of Facilitator			

Table 12: Checklist for Commitment Planning

Project Name			Facilitator Name				
Date			Facilitator title				
COMMITMENT PLANNING (1 Week to Implementation)							
LAST WEEK							
Lessons learnt from the previous week	• Lesson 1 • Lesson 2						
CURRENT WEEK							
Is the project progressing as planned?						Yes/No	
Incomplete tasks for the week							
NEXT WEEK							
Task Identifier 1	• Description						
Deliverables	• Deliverable 1 • Deliverable 2						
Names of Labourers doing the task	• Labourer 1 • Labourer 2						
Period to perform the task	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Number of persons							
A task from the current week that should complete before this task							
Task Identifier 2	• Description						
Deliverables	• Deliverable 1 • Deliverable 2						
Names of Labourers doing the task	• Labourer 1 • Labourer 2						
Period to perform the task	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Number of persons							
A task from the current week that should complete before this task							
END OF WEEK (For each Task)							
Percentage Planned/Promised Complete (PPC) for Task						Yes	No
Reason for variation							
Signature of Facilitator							

Table 13: Daily Huddles Checklist

Project Name		Facilitator Name	
Date		Facilitator title	
DAILY HUDDLES (Daily During Implementation)			
		Yes	No
Are we starting the commitments as planned?			
Were the previous commitments completed as planned?			
Is there any limitation to starting the tasks today?			
What activities will be worked on today?		• Activity 1 • Activity 2	
Are all the team members for today's commitments present?			
Do we need to replace any absent team members?			
Are there any commitments that the team needs assistance with?			
What are these commitments?		• Commitment 1 • Commitment 2	
Is there any commitment that the team cannot deliver?			
What are these commitments?		• Commitment 1 • Commitment 2	
Are the daily commitments complete?			
Are there opportunities to improve the task?			
What lessons were learnt?		• Lesson 1 • Lesson 2	

7. Implementing Waste Management in the Sierra Leone Construction Industry

7.1 The Benefits of Using LPS to Manage Waste in the Sierra Leone Construction Industry

It has been shown on many projects worldwide that the Last Planner System has many benefits. It achieves plan compression, reduces variability and uncertainty, reduces costs and supports collaboration by structuring decision making, creating flow and supporting collaboration and learning through language action (managing and conversations for learning). Because waste has a cost, reducing waste can save money. Many people working in the construction business can benefit from waste reduction. Utilizing their resources more effectively will help subcontractors. Sub-contractors can benefit from reducing material waste because it can result in either total project savings or a projected increase. They can boost their chances of being known as preferred bidders in this situation by assisting main contractors in meeting their waste targets.

Decreasing the environmental harm entails using fewer landfills and mitigating the impact of raw material extraction, transportation, and manufacture on the environment. Owners and contractors might also gain when waste is reduced. The waste expense is borne by clients and is included in project proposals. Reducing the volume of garbage generated may lead to a reduction in the project price. Project cost-saving is the responsibility of the leading contractors, sub-contractors and clients. Clients, major contractors, and subcontractors can benefit from the waste reduction. The following are some of the benefits:

- It proves that a company is dedicated to sustainable development.
- Carbon footprint in the environment is reduced.
- It fosters the mindset of material efficiency throughout all work packages.
- It reduces the use of natural resources.

7.2 Challenges of Implementing Waste Management in the Sierra Leone Construction Industry

The confusion over lean construction demonstrates a low level of maturity in practice and the use of LPS, particularly as Daniel et al. (2017) reported. A significant finding from this research was that its approach had a narrow focus on project site level only, which translated into problems with implementing LPS.

Daniel et al., 2017 also observed that LPS implementations stalled at the pull-planning stage. The researchers also observed that the level of collaboration was limited, with parties unwilling to share bad news. Bad news early is good news for enabling corrective action and improving project reliability. The continuing reluctance of companies to embrace this makes it challenging to effectively implement the LPS to its full potential. The failure to use the make-ready and learning parts of LPS also limit its effectiveness. However, collaborative pull planning is successful enough to act effectively as an intervention once projects start to fall behind the programme. It isn't easy to understand why it is used to correct assignments but is not used from the beginning to keep them on track. Similar observations have also been made in other countries such as Denmark, Norway and South Korea. So we have a situation in construction that reports partial implementations of LPS around the world, meaning this is a common problem. Further research has identified an absence of formal guidance in the performance of LPS and how to create the right environment and context for success.

It is still novel for different parties in a construction project to talk to each other. Unless we make a special effort through the formal meetings embedded in the implementation of LPS, these conversations don’t happen, and the flow of work is disjointed and unpredictable. It is customary in construction for people to fear saying no and agreeing to do things when they may not be able to do them. Sadly, saying no is discouraged in the construction industry, where the risk of not doing something is passed down the supply chain and forms the basis for compensation claims.

8. Conclusion

The reduction of waste is a commonly recognized concept. Throughout this report, it is evident that waste in the Sierra Leone construction industry is a genuine concern and can be generated easily through all construction phases. The researcher observed that the leading cause or source of waste is unskilled labour leading to rework. However, Letcher & Vallero, 2019 noted that waste management has been challenging to implement. There have been minimal attempts to assess and handle construction waste at the implementation level. This, they stated, was because waste eradication in construction operations is believed to be unachievable. They added that the construction industry has been slow to change its habits, despite evidence that waste reduction is advantageous commercially. Waste creation might have behavioural implications brought about by technological ones. According to Teo et al., 2000, the labour-intensive character of construction raises the possibility that environmental issues brought on by behavioural variables may substantially impact waste quantities. This claim was backed by Lingard et al., 2000. They suggested that effective waste minimization relied on how construction industry personnel altered their behaviour in response to waste issues. People seem to be becoming less concerned with the welfare of society and more focused on obtaining their basic requirements. People need to be aware of the adverse effects of incorrect waste management and their obligation to protect the ecosystem in which they live. It provides food and other essential resources.

This research provided a relationship between the landfill site and the Sierra Leone construction industry. The researcher offers a systematic approach to eventually reducing the amount of waste deposited in landfill sites. The research provides a solution to one of the waste sources, which is now determined to be the primary source of waste in the Sierra Leone construction industry. This problem could be addressed using the checklists designed by the researcher, reducing waste in construction. Waste management is crucial to reduce the waste effect on projects and the surrounding environment to minimize quantity of waste that end up in landfills. Managing waste will help limit the waste generated and the cost of having to dispose of waste that could not be reused, recycled or recovered. It should be mandatory for construction companies to adopt and implement waste management practices in all construction projects. Companies that demonstrate they're doing their part to achieve these goals will develop a positive reputation and improve their relationships with customers and clients. It helps

them gain opportunities with government-funded projects often requiring specific waste management standards. The research questions include:

- How could the Sierra Leone construction industry contribute to reducing wastes deposited in landfill sites? – The research answers this question by first studying the different types of waste currently generated in the industry. It then goes on to look at the sources of these waste types and the leading causes of them. From the survey, the researcher limited the research to provide a solution to the top most ranked waste source. The researcher believes that if this solution is implemented on construction projects, the waste from the industry will be reduced, ultimately reducing the amount of waste going to landfills.
- What are the benefits of waste management in the construction industry to the country? – The answer to this is in the research title and related to the first question. Proper management of waste in construction does not only saves project cost, which directly affects the clients. It also does not only protect or increase the construction company's reputation in the industry, thereby bringing more business to that company. It goes beyond the small construction industry and affects the entire country. There is a limitation in the waste management system in the country. The government already struggles to manage the waste generated by households and commercial properties. These limitations are discussed in detail in the research. Any form of waste management in the construction industry will help reduce waste and help the government allocate the limited available resources to other more pressing waste issues in the country.
- What challenges would practising waste management in the country’s construction industry bring? – Waste management is good, but currently, in Sierra Leone, many people are unaware of the implications or benefits of managing waste. Companies provide no incentives or motivation to their employees to practice waste management; construction workers consider waste inevitable in the industry. A significant challenge will be to change the mindset of people and have people follow a new system. These challenges are in detail in the research.

Below is a summarized breakdown of the content in each chapter of the research:

Chapter 1 of the thesis gives a general introduction to the research study. It explains the current waste situation in Sierra Leone. It is the motivation for this research because the study's main aim is to reduce the amount of waste going to landfill sites. This chapter describes the main types of waste going to landfills. This introduction showed the different waste materials in landfills, revealing that most materials were construction related.

Chapter 2 gives detailed research on the subject area of waste. It provides a definition and detailed explanation of what waste means in the context of construction. Additionally, it covers the categorization and order of waste, the various waste sources, its causes, and the primary categories of waste found in construction. It then elaborates on the meaning of waste reduction or minimization. It explains the existing waste minimization measures in the industry worldwide. It also looks into some of the industry's challenges in practising waste minimization. It broadly also looks into the term Waste Management of which waste minimization is a part, and suggested ways to manage material waste in construction efficiently.

Chapter 3 comprises six main sections describing the methodology used in the study. The data collected is primary, and the first four sections represent the data collection sources. The three sections each contain details on the data collection and study techniques. The fifth section describes how the data collected was analyzed. It explains the analytical approach of interviews and questionnaires briefly. The sixth section briefly discusses some of the challenges of the field research methodologies. The intended participants were project managers and contractors in different construction companies, not less than ten companies, with a target of at least five participants per company. The intended plan was not achievable in reality. There were responses from 25 companies, with three as the highest number of responses per company.

Chapter 4 presents an analysis of the data from the research survey. The researcher visited four construction sites in different locations at various construction stages to investigate the waste management practices for material waste on Sierra Leone construction sites. With the site visit and literature review analysis, the survey questionnaire was designed. The questionnaire was sent out to construction companies and contractors in Freetown, Sierra Leone, using a random sampling approach. The survey results were frequency counts that changed to percentages and pie diagrams

Chapter 5 presents two case studies that consolidate the findings from Chapter 4. The researcher only focused on addressing the highest-ranked waste sources in detail. These two case studies confirmed that unskilled labour is the highest construction waste source, leading to rework in tasks. Finally, Chapter 6 presents a solution to eliminating unskilled labour as a waste source entirely as it will reduce the number of reworks and benefit the construction industry in Sierra Leone. The answer is something that could quickly be adopted on sites to combat the issue. The solution leverages the current practices and introduces a common-sense approach to solving the problem. The system used to achieve this is the Last Planner System, with three (3) checklists provided for different timelines before the start of an activity.

Declaration of Authorship

I hereby declare that this Master's thesis was completed independently and without the prohibited assistance of third parties and that no sources or help were used other than those listed. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published. All passages whose content or wording originates from another publication have been cited.

Berlin, 26/06/2022

Location, Date

Signature of the student

Appendix

Appendix A – Survey Questionnaire

Section 1 of 3

Reducing Landfill Waste in Sierra Leone with Construction Industry Material Waste Management

Hello All,

I am currently in the final stages of completing my International Master of Science in Construction and Real Estate Management - Joint Study Programme of Metropolia University of Applied Sciences, Finland and Hochschule für Technik und Wirtschaft Berlin, Germany. As part of my dissertation, I need to collate some data on the current waste management practices in construction sites in Sierra Leone, mostly in the capital region.

Sierra Leone is facing the challenge of achieving sustainability on construction sites. One of the main barriers is the increasing amounts of material waste generated from construction activities and dumped in landfills. The World Bank, 2004 reported that more than three million kilograms of trash are generated each day in the capital city, Freetown, with no safe way of disposing of it. The World Bank report also stated that the country's waste collection was about 40% of the total waste generated, and areas around the city's landfill sites present environmental and health risk. Gogra et al., 2010 stated that the limited Freetown industry contributes approximately 20 tons of wastes per day and that municipal solid waste management is one of the most severe environmental and public health issues in Freetown, Sierra Leone. Indiscriminate generation and dumping of waste, coupled with deficiencies in waste collection, transportation and disposal, create a municipality of daily and episodic hazards that affect the city's entire population at different scales. Russillo, 2018 quoted from the environmental and social officer of the Freetown City Council (FCC), "Both dumpsites in Freetown have exhausted their capacities. In addition, these projects are capital-intensive, and we have experienced struggles with effective enforcement of legal and financial policies."

As the population increases, so do the need for construction, generating more waste as there are no waste management practices adopted for the construction industry in the country. This research therefore seeks to provide answers to the following questions:

- How could the Sierra Leone construction industry contribute to reducing wastes deposited in landfill sites?
- How would practising waste management in the construction industry benefit the country?
- What challenges would practising waste management in the country's construction industry bring?

This survey is focused on understanding the perceptions of project managers, contractors and all construction workers on the problems and causes of material waste, waste minimisation measures and their benefits in the industry.

Miriam Mosiatta Sesay is undertaking this survey as part of the final thesis data collection. This information shall be used for research purposes only and all information shall be anonymous.
It is not compulsory to participate in this survey. However, I would be really grateful if you did!

Thank you and kind regards.

PERSONAL DETAILS

Please answer the questions as honestly as you can. Kindly choose from the range of responses and please insert data in the areas where there are no data to choose from. Feel free to include as much data as you can. Every perspective counts!

Name

Short-answer text

Do you work/ have you worked on a construction site/project?

- ○ Yes
- ○ No

Do you work for a construction company?

- ○ Yes
- ○ No
- ○ Other...

Name of construction company?

Short-answer text

What type of construction project are you working on/ have you worked on?

- Buildings
- Roads
- Both
- Other...

What role have you worked in that was related to construction or project management?

Long-answer text

Section 2 of 3

CONSTRUCTION INDUSTRY MATERIAL WASTE

Please answer the questions as honestly as you can. Kindly choose from the range of responses and please insert data in the areas where there are no data to choose from. Feel free to include as much data as you can. Every perspective counts!

What waste materials are generated on site? *

	Yes	No
Timber	○	○
Bricks	○	○
Plastic	○	○
Concrete	○	○
Steel	○	○
Cardboard	○	○
Cement	○	○
Tiles	○	○
Nails/Screws	○	○
Material Packaging	○	○

WASTE GENERATION

Scale: Always (4); Sometimes (3); Rarely (2); Never (1)

What do you think are the Sources/Causes of waste? *

	1	2	3	4
Lack of workers' awareness	○	○	○	○
Poor design (resulting into off-cuts)	○	○	○	○
Unskilled labour and rework	○	○	○	○
Time Pressure	○	○	○	○
Problems of handling	○	○	○	○
Inappropriate storage	○	○	○	○
Inclement weather	○	○	○	○
Damages during delivery and transport	○	○	○	○

Poor quality of products	○	○	○	○
Purchase of inadequate materials	○	○	○	○
Poor advice from suppliers	○	○	○	○
Over ordering of materials	○	○	○	○
Inadequate packaging	○	○	○	○

What waste minimisation measures are currently practised on your site? *

	1	2	3	4
Adequate material storage facility	○	○	○	○
Accurate quantity of material ordered	○	○	○	○
Training workers to enhance awareness	○	○	○	○
Measuring and recording waste generated	○	○	○	○
Proper handling and transportation of materials	○	○	○	○
Waste segregation on site	○	○	○	○

Ordering exact material sizes	○	○	○	○
Take-back scheme with suppliers	○	○	○	○
Reusing off-cuts	○	○	○	○
Motivating site workers	○	○	○	○
Recycling on and off site	○	○	○	○
Appointing a waste manager on site	○	○	○	○

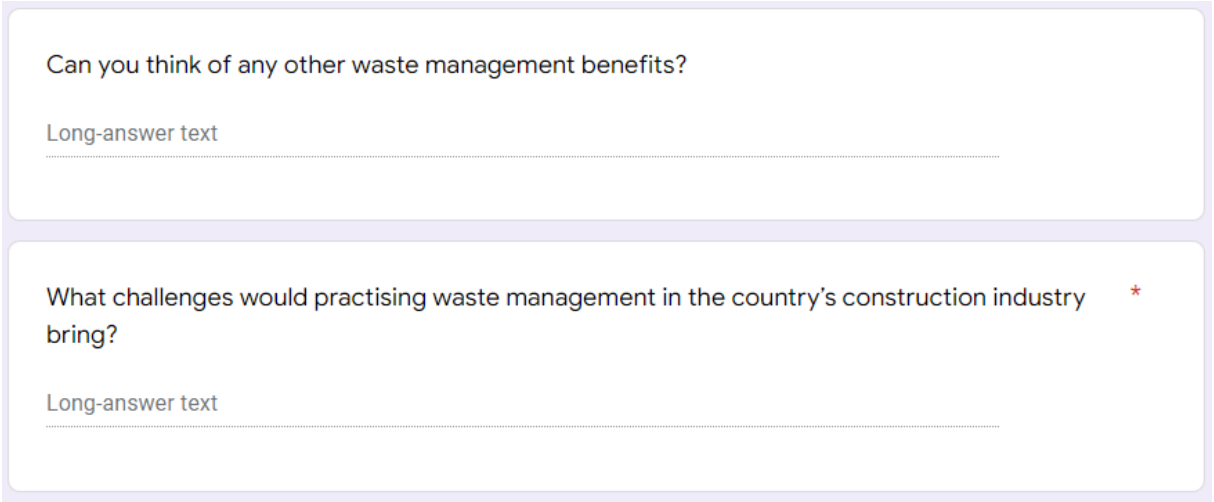
Section 3 of 3

BENEFITS AND CHALLENGES

Please answer the questions as honestly as you can. Kindly choose from the range of responses and please insert data in the areas where there are no data to choose from. Feel free to include as much data as you can. Every perspective counts!

What benefits do you believe practising waste minimisation could bring? *

	Yes	No
Saves project costs	○	○
Protect the environment and enha...	○	○
Improves the health and safety of ...	○	○
Enhances the corporate image an...	○	○



Appendix B – Questionnaire Responses

No	Name	Do you work/ have you worked on a construction site/project?	Do you work for a construction company?	Name of a construction company?	What construction project are you working on/ have you worked on?
1	Abu Kamara	Yes	Yes	NIMO CONSTRUCTION	Buildings
2	Ibrahim Joshua Sesay	Yes	Yes	Pavifort AL Associate Ltd	Both
3	Jalikatu Conteh	Yes	Yes	UNOPS	Buildings
4	Bockarie Samai	Yes	Yes	GUANGJIN INTERNATIONAL	Both
5	Esther AdeWilliams	Yes	Consultant and supervisory agency	UNOPS	Buildings

6	Abdul Ibrahim Kamara	Yes	Yes	Frederick Bruce and associate	Buildings
7	Morrison Jusu	Yes	Yes	HUTA	Both
8	Reynold Edwin-Jones	Yes	Save the Children		Buildings
9	James Nyakeh Kamara	Yes	No		Buildings
10	Ing. Sheik Umar Jam-Jalloh	Yes	No	Pavifort	Roads
11	Obinna Browne	Yes	No		Buildings
12		Yes	No		Buildings
13	Anonymous	Yes	No	N/A	Buildings
14		Yes	Yes	Ezra SL Limited / Frederick Bruce Limited	Both
15	Mohamed Fornah	Yes	No	Pavifort Al-Associate	Roads
16	Hentin Samuels	Yes	Yes	CL Group Limited	Both
17	Abdulai Bah	Yes	Yes	Gbindi Construction Enterprise	Both
18	CSK	Yes	No	N/A	Buildings
19	Gabriel Sannoh	Yes	Currently working for a palm oil production company	SOCFIN Agricultural Company	Both

20	Osman Deen Turay	Yes	Studying		Both
21	Momoh Massaquoi	Yes	No	Innovative Solutions Consultancy SL Ltd	Buildings
22		Yes	No		Buildings
23	Emmanuel Koroma	Yes	UNOPS	UNOPS	Both
24	Ramadan Hamoud	Yes	Yes	International Construction Company	Buildings
25	PIERRE PALMER	Yes	No	GUMA VALLEY WATER COMPANY	Buildings
26	Nenneh	Yes	No		Both
27	Tom Taylor-Morgan	Yes	Yes	Trine Investment Limited	Buildings
28	Sanpha Bilo Kamara	Yes	No		Buildings
29	Vandy Sesay	Yes	No		Both
30	Ivory Robert	Yes	Yes	WSP in the UK	Bridges, Tunnels
31	Nyaveh Keili	Yes	No		Buildings
32	Ibrahim Musa Sesay	Yes	Yes	Carryer Salone Limited	Buildings
33	David Nyuma Bundor	Yes	Yes	D & F Construction SL Ltd	Buildings

34	Francis Charley	Yes	No	Ideas Limited	Buildings
35	Josrai Ellen Orairatu Obed-Cole	Yes	Yes	JOSDELVIA TRADING AND CONSTRUC-TION COM-PANY	Buildings
36	Winfred Ade-Wil-liams	Yes	No		Buildings
37	Mariama Ganda	Yes	Yes	Centurion Engi-neering Limited	Both
38	Mohammed. Ga-dri. Jalloh	Yes	Yes	Pathway Engi-neering & Gen-eral Services	Both
39	Lawrence Patewa	Yes	Yes	Bakar Lift	Both
40		Yes	Yes	AIIAC LTD	Both
41	Reginald Howard Cummings	Yes	Yes	Black and Ve-atch	Roads

No	**What role have you worked in related to con-struction or project man-agement?**	**What are waste mate-rials gener-ated on-site? [Tim-ber]**	**What are waste ma-terials gen-erated on-site? [Bricks]**	**What are waste mate-rials gener-ated on-site? [Plas-tic]**	**What are waste ma-terials gen-erated on-site? [Con-crete]**
1	Site Supervisor	Yes	No	Yes	Yes
2	Project Manager	Yes	Yes	Yes	Yes
3	Project Engineer	Yes	Yes	No	Yes

4	Site Engineer	Yes	Yes	No	Yes
5	Project Engineer	Yes	Yes	Yes	Yes
6	Construction Engineer	No	Yes	No	Yes
7	Site Engineer	Yes	No	No	No
8	Construction Coordinator	Yes	Yes	Yes	Yes
9	Initially worked as a Site Engineer and progressed to Project Engineer	Yes	Yes	Yes	Yes
10	Construction	Yes	No	No	Yes
11	Supervising Engineer	Yes	Yes	Yes	Yes
12	Foreman	Yes	Yes	Yes	No
13	Site Engineer	Yes	No	Yes	No
14	Project Engineer	Yes	Yes	Yes	Yes
15	Supervisor	Yes	Yes	Yes	Yes
16	Civil Engineer	Yes	Yes	No	Yes
17	Project Manager	Yes	No	Yes	Yes
18	Site Engineer	Yes	No	Yes	No
19	Project engineer	Yes	Yes	Yes	Yes
20	Civil Works Engineer	Yes	Yes	No	Yes
21	Internship	No	Yes	Yes	Yes
22	Supervisor	Yes	No	Yes	No
23	Project Engineer	Yes	Yes	Yes	Yes
24	Site supervisor	Yes	No	Yes	Yes

25	ENGINEER	Yes	Yes	Yes	Yes
26	Project Manager	Yes	Yes	Yes	Yes
27	Project Manager	Yes	Yes	Yes	Yes
28	Building storage stores	Yes	Yes	No	Yes
29	Supervisor	Yes	Yes	Yes	Yes
30	Civil Engineer	No	Yes	No	Yes
31	Project engineer	No	No	Yes	Yes
32	Senior Project Engineer	Yes	Yes	No	Yes
33	Project Engineer	Yes	Yes	No	No
34	Site Engineer	Yes	Yes	Yes	Yes
35	Engineer	Yes	Yes	No	Yes
36	Site Supervisor, Construction Management Engineer & Project Manager	Yes	Yes	Yes	No
37	Project Engineer	No	Yes	No	Yes
38	Project Manager	Yes	Yes	Yes	Yes
39	Site Engineer	Yes	Yes	Yes	Yes
40	Project Manager	Yes	Yes	Yes	Yes
41	Civil Highway engineer (intern)	Yes	Yes	No	Yes

No	**What are waste materials generated**	**What are waste materials generated on-**	**What are waste materials generated**	**What are waste materials generated**	**What are waste materials**	**What are waste materials generated on-**

	on-site? [Steel]	site? [Card-board]	on-site? [Cement]	on-site? [Tiles]	generated on-site? [Nails/Screws]	site? [Mate-rial Packag-ing]
1	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	Yes	Yes
3	Yes	No	No	Yes	No	No
4	Yes	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes	Yes
6	No	No	No	No	No	Yes
7	Yes	No	Yes	No	Yes	No
8	Yes	Yes	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	No	Yes	No
11	Yes	Yes	Yes	Yes	Yes	Yes
12	No	No	Yes	No	No	No
13	No	Yes	No	No	Yes	Yes
14	Yes	Yes	Yes	Yes	Yes	Yes
15	Yes	Yes	Yes	No	Yes	No
16	Yes	Yes	Yes	Yes	Yes	Yes
17	No	Yes	No	Yes	Yes	Yes
18	Yes	Yes	No	No	Yes	Yes
19	Yes	No	Yes	No	Yes	Yes
20	Yes	Yes	Yes	No	Yes	Yes

21	No	Yes	Yes	Yes	Yes	Yes
22	No	Yes	No	No	Yes	Yes
23	Yes	Yes	Yes	Yes	Yes	Yes
24	Yes	Yes	Yes	Yes	Yes	No
25	Yes	Yes	Yes	Yes	Yes	Yes
26	Yes	Yes	Yes	Yes	Yes	Yes
27	Yes	Yes	Yes	Yes	Yes	Yes
28	Yes	Yes	Yes	Yes	Yes	Yes
29	Yes	Yes	Yes	Yes	Yes	Yes
30	Yes	No	Yes	No	Yes	Yes
31	No	Yes	Yes	Yes	Yes	Yes
32	No	No	No	No	No	Yes
33	Yes	Yes	No	Yes	Yes	Yes
34	Yes	Yes	Yes	Yes	Yes	Yes
35	Yes	Yes	No	Yes	Yes	No
36	No	Yes	No	Yes	No	Yes
37	No	No	No	No	No	No
38	Yes	Yes	Yes	Yes	Yes	Yes
39	Yes	Yes	Yes	Yes	Yes	Yes
40	Yes	Yes	Yes	Yes	Yes	Yes
41	Yes	Yes	Yes	No	Yes	No

No	What do you think are the Sources/Causes of waste? [Lack of workers' awareness]	What do you think are the Sources/Causes of waste? [Poor design (resulting in off-cuts)]	What do you think are the Sources/Causes of waste? [Unskilled labour and rework]	What do you think are the Sources/Causes of waste? [Time Pressure]	What do you think are the Sources/Causes of garbage? [Problems of handling]	What do you think are the Sources/Causes of waste? [Inappropriate storage]
1	4	3	2	1	3	2
2	2	3	3	3	3	4
3	2	2	2	2	4	2
4	3	4	4	4	1	3
5	3	4	4	3	3	4
6	1	4	3	1	3	3
7	2	3	1	1	3	3
8	3	2	3	3	3	2
9	4	3	4	2	3	3
10	3	2	1	3	2	1
11	2	1	3	3	3	3
12	3	1	3	4	4	2
13	3	3	2	2	2	2
14	3	3	3	3	3	2
15	3	3	4	4	4	3
16	2	2	3	1	2	2

17	4	3	4	2	2	3
18	3	2	2	3	2	3
19	3	4	3	2	3	3
20	3	2	4	1	4	3
21	4	2	4	3	4	2
22	1	2	2	1	3	1
23	2	2	3	3	1	1
24	3	2	3	3	3	3
25	2	3	2	3	2	2
26	4	1	4	2	1	2
27	3	2	3	2	3	3
28	2	3	3	3	3	2
29	3	3	3	3	3	3
30	3	2	3	2	3	4
31	2	3	3	3	3	3
32	4	4	4	4	4	4
33	3	4	3	2	4	4
34	2	3	2	1	4	4
35	4	3	3	2	2	2
36	3	1	3	1	1	1
37	4	4	3	2	3	3
38	4	3	3	2	3	2

39	3	3	4	3	3	4
40	3	3	3	2	2	3
41	4	2	2	2	2	2

No	**What do you think are the Sources/Causes of waste? [Inclement weather]**	**What do you think are the Sources/Causes of garbage? [Damages during delivery and transport]**	**What do you think are the Sources/Causes of waste? [Poor quality of products]**	**What do you think are the Sources/Causes of garbage? [Purchase of inadequate materials]**	**What do you think are the Sources/Causes of waste? [Poor advice from suppliers]**	**What do you think are the Sources/Causes of garbage? [Over ordering of materials]**
1	1	3	1	1	2	3
2	2	4	4	2	2	2
3	4	2	4	4	4	2
4	4	2	2	2	2	2
5	4	4	3	3	4	4
6	4	1	1	4	1	3
7	1	1	1	1	1	1
8	2	2	2	2	2	3
9	2	4	4	3	2	4
10	3	4	3	1	2	1
11	1	2	3	2	2	1
12	4	4	4	4	4	1

13	2	1	1	2	3	1
14	2	2	3	3	2	2
15	2	2	3	3	3	3
16	2	3	2	1	1	2
17	3	3	4	1	2	4
18	3	3	2	2	3	2
19	3	2	3	2	2	3
20	3	4	3	3	3	3
21	2	2	2	2	4	2
22	1	1	3	3	3	3
23	1	1	2	2	1	1
24	2	2	2	2	1	2
25	1	2	2	3	2	3
26	2	1	1	2	2	2
27	2	2	2	2	2	2
28	2	3	3	2	2	3
29	3	3	3	3	2	2
30	2	2	2	1	2	3
31	3	2	3	1	3	3
32	3	4	4	4	3	2
33	2	3	2	1	2	3
34	3	3	2	2	1	2

35	3	4	3	3	3	3
36	1	2	2	1	3	1
37	1	3	4	1	3	2
38	2	2	1	1	1	1
39	3	3	3	2	2	3
40	2	3	3	3	2	3
41	1	1	1	1	1	2

No	**What do you think are the Sources/Causes of waste? [Inadequate packaging]**	**What are waste minimisation measures currently practised on your site? [Adequate material storage facility]**	**What are waste minimisation measures currently practised on your site? [Accurate quantity of material ordered]**	**What are waste minimisation measures currently practised on your site? [Training workers to enhance awareness]**	**What are waste minimisation measures currently practised on your site? [Measuring and recording waste generated]**	**What are waste minimisation measures currently practised on your site? [Proper handling and transportation of materials]**
1	3	4	4	3	4	1
2	2	3	4	3	3	3
3	2	4	4	2	3	3
4	2	4	4	1	1	3
5	4	4	3	3	2	3

6	1	1	1	1	3	1
7	1	4	4	2	1	4
8	2	4	3	3	2	4
9	3	4	4	4	2	3
10	2	4	3	3	2	2
11	1	3	1	3	3	3
12	4	1	4	1	2	2
13	2	2	1	2	3	2
14	2	3	2	3	2	3
15	2	3	3	2	2	2
16	1	2	3	2	2	3
17	4	4	3	4	2	1
18	2	2	3	2	3	2
19	3	4	4	4	2	4
20	3	4	3	2	4	4
21	2	3	4	1	1	3
22	2	4	3	1	2	4
23	1	3	2	2	2	3
24	1	3	3	2	2	2
25	3	3	2	1	1	3
26	2	4	3	1	2	1
27	3	3	2	3	2	2

28	3	3	3	3	3	3
29	2	2	2	3	3	3
30	2	1	1	1	1	1
31	2	1	1	3	1	4
32	3	4	3	4	3	4
33	3	3	4	3	2	3
34	3	4	4	4	3	4
35	4	4	4	3	4	4
36	1	4	1	4	2	4
37	2	4	4	4	3	4
38	1	4	4	3	1	3
39	3	4	4	4	3	3
40	2	4	3	4	2	2
41	1	3	4	4	4	4

No	**What are waste minimisation measures currently practised on your site? [Waste segregation on site]**	**What are waste minimisation measures currently practised on your site? [Ordering exact material sizes]**	**What are waste minimisation measures currently practised on your site? [Take-back scheme with suppliers]**	**What are waste minimisation measures currently practised on your site? [Reusing off-cuts]**	**What are waste minimisation measures currently practised on your site? [Motivating site workers]**	**What are waste minimisation measures currently practised on your site? [Recycling on and off site]**

1	4	4	3	4	4	4
2	2	2	2	1	2	1
3	3	4	4	3	3	3
4	3	4	4	4	3	1
5	4	3	3	3	3	2
6	1	1	1	1	1	1
7	2	4	4	2	4	3
8	3	3	3	3	3	3
9	2	3	1	3	3	2
10	1	3	2	3	4	1
11	2	1	3	3	3	3
12	3	2	1	1	3	1
13	1	2	2	1	3	1
14	3	2	2	3	3	3
15	2	3	3	2	3	1
16	2	1	1	3	1	1
17	2	1	1	2	2	1
18	3	2	3	2	3	2
19	4	3	3	2	3	2
20	3	4	2	3	2	3
21	1	3	2	1	1	1
22	3	4	1	2	3	1

23	3	1	1	1	2	1
24	2	2	2	2	2	1
25	1	3	1	2	3	1
26	2	1	1	1	1	1
27	3	3	3	2	3	3
28	3	3	3	2	3	3
29	2	2	2	3	3	2
30	1	2	1	1	2	1
31	2	3	2	3	4	2
32	4	1	2	2	4	3
33	3	1	1	3	4	2
34	4	3	2	3	4	3
35	3	3	2	3	4	3
36	4	4	1	2	4	1
37	2	4	4	2	4	1
38	1	3	1	3	4	1
39	4	3	3	3	4	4
40	4	1	2	4	1	4
41	4	3	3	3	3	4

No	**What are waste minimisation measures currently practised**	**What benefits do you believe practising**	**What benefits do you believe practising waste**	**What benefits do you believe practising waste**	**What benefits do you believe practising waste**

	on your site? [Appointing a waste manager on site]	waste minimisation could bring? [Saves project costs]	minimisation could bring? [Protect the environment and enhance sustainable development]	minimisation could bring? [Improves the health and safety of the workers]	minimisation could bring? [Enhances the corporate image and reputation of the company]
1	4	Yes	Yes	Yes	Yes
2	2	Yes	Yes	Yes	Yes
3	3	Yes	Yes	Yes	Yes
4	1	Yes	Yes	Yes	Yes
5	3	Yes	Yes	Yes	Yes
6	1	Yes	Yes	Yes	Yes
7	2	Yes	Yes	Yes	Yes
8	3	Yes	Yes	Yes	Yes
9	2	Yes	Yes	Yes	Yes
10	4	Yes	Yes	Yes	Yes
11	3	Yes	Yes	Yes	No
12	1	Yes	Yes	Yes	Yes
13	3	Yes	Yes	No	No
14	2	Yes	Yes	Yes	Yes
15	1	Yes	Yes	Yes	Yes
16	1	Yes	No	Yes	Yes
17	1	Yes	Yes	Yes	Yes

18	3	Yes	Yes	Yes	No
19	4	Yes	Yes	Yes	Yes
20	1	Yes	Yes	Yes	Yes
21	1	No	Yes	Yes	Yes
22	1	Yes	Yes	Yes	Yes
23	1	Yes	Yes	Yes	Yes
24	1	Yes	Yes	Yes	Yes
25	1	Yes	Yes	Yes	Yes
26	1	Yes	Yes	Yes	Yes
27	3	Yes	Yes	Yes	Yes
28	3	Yes	Yes	Yes	Yes
29	2	Yes	Yes	Yes	Yes
30	1	Yes	Yes	Yes	Yes
31	1	Yes	Yes	Yes	Yes
32	4	No	Yes	Yes	Yes
33	3	Yes	Yes	Yes	Yes
34	4	Yes	Yes	Yes	Yes
35	2	Yes	Yes	Yes	Yes
36	2	Yes	Yes	Yes	Yes
37	4	Yes	Yes	Yes	Yes
38	1	Yes	Yes	Yes	Yes
39	4	Yes	Yes	Yes	Yes

40	2	Yes	Yes	Yes	Yes
41	4	Yes	Yes	Yes	No

No	**Can you think of any other waste management benefits?**	**What challenges would practising waste management in the country's construction industry bring?**
1	Helps in time-sensitive projects.	Workers are adhering to on-site rules and regulations.
2		Poor environmental and quality control
3	None	Our biggest challenge will be implementing this waste management practice will be hard on my country. We see engineering practices on our work site as a waste of time.
4	Enhances the site's security as intruders mostly invade the area to take and make use of some of the waste. Changes the perception of the workers making an effort to use materials efficiently	The mindset of the workers - difficulty in embracing new ideas Dumbing sites/ areas will be another challenge. Sensitizing foreign contractors, especially the Chinese, on the importance of the subject as they tend to boycott important things on site Enforcement
5		Depending on the method of waste management used, it might lead to pollution
6		Abdul

7	Employs waste management workers	I can’t think of any
8	Waste Management can be used as a source of fuel, e.g. Methane gas, which could be used as fuel, can be obtained from proper material waste management	The Government will implement and monitor waste management policies
9	Reduces carbon footprint and sustainability significantly reduces waste disposal cost, possibility of generating revenue from waste (resources) and increases the opportunities for the business	Improper collection of waste, a mindset of the citizens and lack of enforcement
10	Recycling provides jobs	Public awareness and knowledge of recycling waste
11		None
12	No	The question will be, will the sensitization reach many individuals?
13	management: Proper waste removal helps improve air and water quality and reduces greenhouse gas emissions.	lack of adequate waste transport vehicles; an inadequate waste transport frequency; inefficient vehicle routes; and segregation of wastage from site
14	Proper in-house storage of materials on the site	Refusal of workers to clean and manage waste
15	Keeps the site clean	It won't be easy to accept, but people will get used to it
16	Improve in time delivery of projects	None
17		Acceptance
18	less waste going to landfill less use of natural resources lower CO2 emissions - e.g. from	Lack of proper waste disposal, thus increasing the cost of disposal fees

	producing, transporting and using materials and recycling or disposing of the waste materials lower risk of pollution incidents	lack of an overall plan for waste disposal Packaging of materials
19	Good waste management helps promote the reuse of the said wastes for the benefit of other people and industries.	Worker awareness.
20	Profit-making for contractors, prevention of environmental degradation, and the sufficiency of materials on site.	Cost of transporting unused wastes, awareness training could be challenging regarding time and resources, etc.
21	I believe when wastages of construction materials and packages/containers of construction materials are correctly executed. It will give the workers a sense of professionalism and dignity, especially when they realise that such an act has less hazardous health and safety effects on them and the environment.	From my observations, contractors and big construction companies in the country don't care about how their site activities could negatively impact the environment. In my view, such practices would bring about delays in the project completion date, such as project cost inflation. As a supplement to construction site waste, I recommend soils be included. There's a whole lot on this to be researched in the context of Sierra Leone. I did some work on it as my dissertation project.
22	Improved aesthetics and working environment	Availability of transport Distance of site from the nearest supplier Inadequate planning and calculation of BOQ Approximate measurements of materials rather than following a fixed calculation
23	Awareness	Learning to be discipline

24		Adapting and enforcing the practice itself could be the most significant challenge. Most companies will not want to create a waste department and employ waste enforcement engineers.
25	N/A	Lack of surface area for storing construction waste
26	Healthy environment	Education and enforcement
27	1. Reduces pest infestation that impacts the spread of diseases like malaria 2. Enhances environmental protection and the negative impact on climate change	1. Lack of trained professionals with the relevant authority to monitor and control construction waste management on-site. 2. Limited infrastructure or mechanism in-country correctly processing and disposing of waste.
28	No	Efficiency and controlled construction
29	Good services	Disposal of waste
30		Educating the labourer about waste management's benefits to the environment as most have no educational background.
31		The major challenge would be what we do with the trash when segregating and collecting it. The first step should be to provide Waste Management facilities that can handle the waste. We currently don’t have adequate waste management facilities to take all the trash we generate. There are also hardly any Recycling facilities. Most waste management facilities are based in the capital city, so improper waste disposal is even worse in other areas of the country.

		For example, many mining companies based outside of Freetown complain of wanting to properly dispose of their construction waste, waste oils, etc., but not having access to proper waste disposal facilities. Another challenge would be trying to sensitize people on why they should make an effort to separate and properly dispose of their waste. If people don't understand the need for separation and proper disposal, especially break, they won't do it.
32	Enhance quality work environment	The behaviour of human
33	Help to recover tools and equipment easily	Disposal
34		Availability of storage for reuse
35	improve air and water quality as well as reduce greenhouse gas emissions.	Balancing objectives between promoting recycling and protecting consumers against harmful chemical substances in recycled materials; insufficient data collection; quality aspects related to recycling; energy recovery of waste;
36		It would cause people to pile rubbish all over the place because waste collecting companies are usually not effective
37	Promote quality control and quality assurance	unskilled workers compliance
38	Enhance productivity and reduce delays in project delivery.	Using off-cuts might lead to friction with clients who consider them waste and not

		good enough for reuse in other areas of the project.
39	Eliminates/reduces the demand for landfill space.	The need for proper site safety/waste management education because most of the labour workforce is uneducated. This may hinder the progress of waste management on a construction site in my country.
40	Recycling waste items for reuse in the same project or other purposes.	Sensitisation of unskilled labour
41	Waste Management helps to protect our ecosystem and wildlife. It also helps to cut down on climate-changing carbon emissions	Most companies operate on a tight budget. Therefore, practising waste management would require more employee training, which could be costly to the employer.

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