St. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ASSESSMENT OF CONSTRUCTION MATERIAL WASTE IN ADDIS ABABA: THE CASE OF SELECTED BUILDING CONSTRUCTION PROJECTS

BY

SELAM HAILEMARIAM

June 2021

ADDIS ABABA, ETHIOPIA

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ID NO. SGS/0098/2011B

A THESIS SUBMITTED TO St. MARY'S UNIVERSITY, SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE OF MASTER OF ARTS IN PROJECT MANAGEMENT

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APPROVED BY BOARD OF EXAMINERS

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DECLARATION

I, the undersigned, declare that this thesis is my original work; prepared under the guidance of Muluadam Alemu (Ph.D.). All sources of materials used for the thesis have been duly acknowledged. I further confirm that the thesis has not been submitted either in part or in full to any other higher learning institution for the purpose of earning any degree.

Selam Hailemariam ----------------------------------

Name Signature

St. Mary's University, Addis Ababa **June,2021**

ENDORSEMENT

This thesis has been submitted to St. Mary's University, School of Graduate Studies for examination with my approval as a university advisor.

Muluadam Alemu (Ph.D.)

Advisor Signature

St. Mary's University, Addis Ababa **June, 2021**

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LIST OF ACRONYMS

AAHCPO - Addis Ababa Housing Construction Project Office

BC - Building Contractor

CWM - Construction Waste Management

DS - Disposal System

EPA - Environmental Protection Agency

KII- Key Informant Interview

RII - Relative Importance Index

SD - Standard Deviation

SPSS - Statistical Package for Social Science

WRAP - Waste and Resources Action Program

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ABSTRACT

Construction industry is an industry, which is involved in the planning execution and evaluation (monitoring) of all types of civil works. Physical infrastructures such as buildings, communication & energy related construction works, water supply & sewerage civil works etc. are some of the major projects (program) in the construction industry. Construction industry plays an important role in social, economic & political development of a country. Construction is the largest and accounts from 12% to 25% of the GNP of both developed & developing countries. It consumes the higher percentage of the annual budget of a country; specifically, Ethiopia, it covers 58% of the annual budget. However, the industry has been experiencing such problems on identifying contributing factors of waste in the construction materials in the industry. In many regions of the world, rapid increase in building activities because of rising population and urbanization generates a large amount of construction waste. The objective of this study is to assess the major contributing factors of construction material waste in Addis Ababa building construction projects. From the number of building constructions found in Addis Ababa, building contractors one, two and three were selected as the target population. To meet the objective of the study, a questionnaire and key informant interview were used as data collection tools. Among the distributed 118 questionnaires for the construction companies, 90 were collected. Simple statistical analysis involving tables and percentages were used in analyze the results from the questionnaire. Secondary sources of data were obtained from relevant literature that covered research, publication on the subject matter. The finding of this research indicates that "Frequent design changes at construction stage", "Rework due to workers mistakes" and "Poor quality of materials" were the three major factors of construction material waste among the 44 identified factors. In addition, high amount of concrete wastage was identified as the top major contributing factors in the performance of building construction projects since concrete uses in larger quantity in construction sites. Beside this, the results obtained indicate, the construction material waste minimizing measures are not practiced yet in construction sites. The results of this study recommended that there is a need to establish strong communication towards the scope of work in the design phase of the project based on the client interest. And adoption different technologies like prefabrication and precast units, proper detailing during designing, coordinating dimensions between materials and the design, and planning ahead to minimize design changes are sensible mechanisms.

Key words: Building construction, waste contributing factors, minimization techniques, Addis Ababa, Ethiopia

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The progress in industry and technology over the last few decades has led to a major increase in the amount and type of waste produced. Every year, the problem of waste accumulation increases across the world. When wastes are dumped in landfills, quarries, rivers, or seas, they generate air pollution (dust and very fine particles that travel through the atmosphere). Especially in recent years environmental sustainability has become a major issue in terms of natural resources and waste management. Both processes include the construction and building materials industries, the construction industry is the highest user of natural resources, and demolition of buildings causes a large amount of waste. Saidu, and Shakantu, (2016) mentioned that construction material wastage on sites can contribute to cost overruns, the results on the research showed that the significant percentage contribution of material waste to project-cost overrun ranges from 1.96% to 8.01%, with an average contribution of 4.0% to project-cost overruns. Therefore, Construction wastage needs to be given more attention to minimize wastage.

The construction industry is one amongst the numerous industries that contribute to the socio-economic growth of a country. Bossink, and Brouwers, (1996) stated that the development of the industry plays a very important role that's required for the socio-economic development of a rustic and also directly contributes to the economic process. In spite of its significance, the industry is facing different problems like material wastage, cost, time overrun, poor quality, poor performance and ineffective productivity *(*Abdul-Rahman, *et al., 2013)*. The construction industry faces different problems like time overrun (70% of projects), cost overrun (average 14% of contract cost), and waste generation (approximately 10% of the material cost) *(*Hussin, *et al., 2013).*

According to Andualem (2019), construction material management is an essential role in construction projects that contributes significantly to the project's success. Ineffective management of materials during the construction process will influence the overall cost, time, and quality of the project. One of the main causes of failure of a contractor's business in a developing country is material wastage (Koskela, 1992).

Koskela *et al*., (1994) classified the activities which are carried out in the construction process as value-adding and non-value adding activities. further described that the non-value adding activities as time, space and resource-consuming activities but doesn't add any value to the end output. Related to this, Alwi, *et al*., (2002) recognized wastages and rework as non-value adding endemic symptoms that seriously affects the performance and productivity aspects of construction projects. Koskela, *et al*., (1994) also mentioned that non-value-added activities such as rework, material processing, waiting for time, and worker movement, as well as overproduction, account for more than 30% of construction costs. Waste in construction projects is a major issue in major cities around the world, and it is a source of concern for construction firms.

The performance of the construction industry in Ethiopia has drastically increased over the past few partly thanks to the development of residential and public buildings by the government, many thousands of condominiums were inbuilt the past and therefore the construction of the many more is underway to unravel the severe housing problem. the case of waste generated from the development of building projects, however, isn't well assessed and understood.

The materials management in Ethiopian construction industry, especially on selected public building construction project in Addis Ababa is done usually by experience and using traditional methods it's also viable that lack of proper construction materials management system within the country contributes to the high construction cost and poor quality of construction products in Ethiopia. Therefore, the mentioned issues indicate that require to develop an efficient constructions materials management system in Ethiopia construction projects, generally and handling construction materials was need attention for results of a completed project with good quality and within the schedule. (Asmara, 2015)

In Ethiopia, there were thesis studies undertaken at undergraduate and postgraduate level on the material waste control. A research conducted by Getachew (2009) for his master's thesis on wastage of materials in building construction sites of Addis Ababa, is amongst these academic works. In his survey, questionnaires were spread to 72 respondents and the result showed that 100 % of the respondents strongly agreed upon the existence of material wastage.

According to his study, the top three sources of material wastage in building construction are operational, material handling and design respectively (Getachew, 2009). In addition, other study at undergraduate level also pointed out the existence of wastage at the construction site of condominiums and different building projects (Mulualem, *et al.* 2012). But these studies do not exhaustively work out the major contributing factors of waste, the side effect and minimization techniques of materials wastage on building projects.

The growth of Ethiopian economy and population has brought a significant increase in the construction industry, especially in Addis Ababa. Besides, building projects are becoming progressively larger and more complex in terms of physical size and cost. Due to this, the building industry is using a considerable amount of material resources. On the other hand, if the life cycle of the materials on site is closely examined, it is generally known that there is a relatively large portion of the materials being wasted because of different reasons at building sites (Mulualem, *et al* 2012). As stated by Gereme, (2018) cost is greatly affected by construction material wastage in Addis Ababa, Lideta housing construction branch office of Arabsa site.

This shows that construction material waste in Ethiopia that gets a little attention is affecting the major parameters of projects which are cost time and quality. So having this in mind, this study aims at assessing the major contributing factors for construction material waste and identifying the major factors of waste in the main construction materials in building projects which are located in Addis Ababa so that applicable and efficient minimizing strategies can be identified.

1.2 Statement of the Problem

The construction industry plays an important role in the socio-economic development of a country. Construction projects have their own processes and challenges from initiation to completion of the whole process. The challenges included but not limited to time overrun, cost overrun, and waste generation (Hussin,*et al.*, 2013).

Different researchers around the globe regarded material wastage as a serious problem in the construction industry. For instance, according to the study of Al-Moghany (2006) , material wastage is a serious problem in the construction industry of the Gaza strip and has been identified as an adverse effect on the performance of the construction projects as a whole including in social and environmental aspects. A study carried out in Netherlands reviled that from the total purchased material, an average of 9% of it end up as a waste (Bossink & Brouwers, 1996). Similarly, a study which was carried out in Hong Kong stated that about 5-10% of building materials are grouped as a waste (Yahya & Halim, 2006). According to these results, the additional cost incurred due to building materials waste ranges up to 10% of the total material purchased.

In several countries, construction waste is one of the most common waste sources (C.S Poon *et al.*, 2001). According to Yimam (2011), the construction industry in developing countries failed to meet expectations of governments, clients, and society as a whole. A research which was carried out by Addise (2005), revealed that construction material waste ranges up to 57% of the total budget allocated for the project which clearly shows the seriousness of the issue. Regarding to its severe consequences, limited number of researches regarding material wastage has been carried out in Ethiopia to show the existence of the problem. But most of the studies were carried out by considering a limited targeted population or projects and also need more researches on the major factors of wastes in the main construction materials. For instance, Asmare (2015) carried out his study on managing and minimizing wastage only by considering five public projects. Likewise, another study was made about wastage minimization with a limited target population of housing projects in Bole Bulbula construction site (Amsale, 2017).

Since there is a gap on the study of the top building contracting companies (BC1, BC2 and BC3) which are located in Addis Ababa, the researcher in this study will aims to assess material waste in a wider range by considering current ongoing projects in BC1, BC2 and BC3 which are working so that an exhaustive and more reliable result can be obtained.

1.3 Research Questions

- What are the major contributing factors of construction Material wastage?
- What are the major factors of waste in the main construction materials?
- What measures have been taken for minimizing construction material wastage?

1.4 Research Objectives

1.4.1 General Objective

To assess the construction material wastage in Addis Ababa building construction projects.

1.4.2 Specific Objectives

- To Assess the contributing factors of construction Material waste.
- To identify the major factors of waste in the main construction materials
- To examine the measures taken for minimizing construction material wastage.

1.5 Significance of the Study

The identified major factors are one of the results which are obtained from this study. So, by identifying the major contributing factors for construction material wastage, the researcher can pave a way for construction professionals by proposing the action to be taken in order to minimize wastage. As a result of this, different construction participants like project managers, consultants, contractors, site engineers will be conscious enough to consider about minimizing material wastage in the construction sites.

In addition, this study intends to provide some framework for the development of policies and rules in the management of construction waste based on the identified causes of construction material waste factors.

The study will also introduce new concepts, plans and strategies of construction waste management, which will help construction project stakeholders and entities to properly manage waste in construction. By indicating the problems in construction waste management and its negative impacts the paper will also initiate positive responses from concerned bodies. It is significant as it possibly leads to an in-depth study of the situation of construction waste management and motivates administrative legal and policy measures. The study will also be useful as a reference and steppingstone for academic and practical research on construction waste management.

1.6 Scope Limitation of the Study

The research focused on building projects which are in the construction phase and located in Addis Ababa. In addition, the research focused on building contractor one (BC1), building contractor two (BC2) and building contractor three (BC3) companies that are located in Addis Ababa and registered by Addis Ababa City Construction Bureau.

In addition to this, the term construction wastages consist of different wastage types like material wastage, time wastage, human resource wastage, but this project focused on material wastage because materials covers 65-70% of the construction cost (Meghan 2011) So throughout this study, construction material wastage were the major wastage type that was considered.

1.7 Limitation of the Study

This study was delimited to show the construction material wastage incident in construction phase in the perspective of professionals on contractor's side due to time limitation. But the perspective of client and consultants need to be seen separately in detail.

1.8 Organization of the Study

The first chapter provided a background to the researched topic of the study. The section explained in detail about the problem statement, objective of the study, significance, and limitation of the study. The second chapter of the study reviewed related literatures regarding the topic area and provided exhaustive information about the main subjects of the study by reviewing the works of different authors. The section mainly focused on assessing the construction material wastage and measures to be taken for minimizing material wastage in construction building projects. The third chapter explained about the methodology implemented in order to come up with the findings of the study. Specifically, the chapter clarify about the research approach and design, population, and samples; and data collection methods used to find out the needed data. The fourth chapter explained about the results after analyzing the collected data. The section organized and clarify about the findings of the study which were collected. Finally, in the last chapter of the study, the key findings were summarized and after that the chapter concluded the study and gave recommendations based on the findings.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter provides a detailed review of different works of literature related to the objectives of the study. The chapter commences by reviewing the term waste, construction waste and construction material waste on the point of view of different researchers to come up with the operational definition of the study. Then the review continues with different Contributing factors of construction Material waste and reviewing the construction material wastage from different departments and studies.

2.2 Review of theoretical literature

2.2.1 Definitions of waste

Waste is one of the serious problems in construction industry. Many researchers and practitioners indicate that there are many wasteful activities during design and construction process. Waste should be understood as any inefficiency that results in the use of more equipment, materials, labor, or capital in larger quantities than those considered necessary in the construction of a building. Both the occurrence of material losses and the execution of unnecessary work, which produces extra costs but adds little benefit to the commodity, are examples of waste (Koskela, 1992).

2.2.2 Construction waste

Construction activities generate a large amount of waste compared to other industries (Dania, *et al*., 2006). There have been different definitions of construction waste by different authors. Garas, *et al.,* (2001) defined construction waste as any substance, matter, or item produced as a result of construction work and discarded, whether or not it has been processed or stockpiled before being discarded. It's a set of discarded materials from site clearing, excavation, construction, refurbishment, renovation, demolition, and road work.

According to Shen *et al*., (2002) the difference between the value of materials provided and approved on site and those used properly as specified and accurately measured in the work after deducting the cost savings of substituted materials transported elsewhere, where material wastage can result in unnecessary cost and time.

As defined by Mossman, (2009) Waste is described as something that does not add value to the customer, client, or end-user. For instance, accidents, delays/waiting, rework, over-ordered materials, damaged materials, multiple handling of materials, "making do," multiple insurances, poor payment systems, tendering, as well as procuring facilities on cost are all forms of wastes.

construction waste ranks as design and documentation, human resources, construction methods and planning, and material and procurement, respectively. Meanwhile, factors from each category were also determined as design change, inattentive working attitudes and behaviors, ineffective planning and scheduling, and material storage were among the highest impact factors on construction waste generation (Luangcharoenrat, *et al.*, 2019)

2.2.3 Construction material waste

Construction waste includes unwanted materials produced during construction, such as rejected structures and materials, materials that have been over ordered or are excess to requirements, and materials that have been used and discarded, are all examples of construction waste (Environmental Protection Department, 2000).

According to LY Shen; *et al*., (2000) Construction material wastages are described as the difference between the value of materials supplied and approved on site and those used properly as stated and accurately calculated in the work, after deducting the cost savings of substitutes materials transferred elsewhere, in which materials wastage can result in unnecessary cost and time.

Nagapan, *et al*., (2012) on their study pointed out that construction waste is a major global issue that can damage a project's overall success as well as the city and environment. It can be caused in a variety of ways. Material, time, and cost expenses are wasted as a result of the waste generated. Construction work causes significant physical damage in the form of industrial waste, such as concrete leftovers, collapsed concrete, and metal scrap, among other things.

Construction waste may result from various of activities performed by the contractor during construction and maintenance, including: Wood from formwork and false work, material and equipment wrappings, unusable or surplus cement/ grouting mixes, Damaged/ surplus/ contaminated construction materials (Environmental Protection Department, 2000).

2.2.4 Contributing factors of construction Material waste.

Bekr, (2014) Indicates that Design changes, rework, poor documents, improper and inadequate materials handling, poor waste management strategy, shortage of qualified personnel, poor site conditions, damaged material during transportation, errors in quantity calculation and over allowance, and theft and vandalism were the most common causes of materials wastage on construction sites.

Last-minute client changes, tradesman mistakes, purchased products that do not meet specifications, as well as lack of onsite materials management are sources of materials waste (Agyekum, *et al*.,2013)

Adewuyi and Otali, (2013) assessed the factors causing waste from construction in Nigeria. The results indicated that the three most important factors contributing to material waste in construction were design changes, rework, and waste from unusual shapes and forms.

Construction waste comes from construction, refurbishment, and repairing work. Many wasteful activities can occur during both design and construction processes, consuming both time and energy without adding value to the client. Generation of the stream of waste is influenced by various factors.

Waste can be classified by natural waste and losses as follows:

2.2.4.1 Natural Waste

Natural waste is the wastage that expenses more than what is saved if tried to prevent. There is a certain edge up to which, waste of materials can be prevented. Beyond that limit, any action taken to avoid waste will not be viable, as the cost of saving will surpass the value of materials saved. Thus, natural waste is allowed in the tenders. Amount of natural waste is subjective to the cost effectiveness of the approaches used to manage it. The approaches differ from one situation to another and so do the natural waste. For instance, cost of avoiding wastage in a project with a good material controlling policy will be lesser than that of a project, which lacks such a policy. Thus, the tolerable level of natural waste in the former situation will be lesser than the later (Formoso and Soibelman, 2002).

2.2.4.2 Losses

These include direct or indirect waste.

Direct Waste

Direct waste is the waste that can be prevented, and which involves the actual loss or removal and replacement of material is called direct waste. Most of the times, the cost of direct waste does not end up in the cost of material but followed with the cost of removing and disposing. Thus, by preventing direct waste straightforward financial benefits can be obtained. Direct waste can occur at any stage of the construction process before the delivery of material to the site and after incorporating the materials at the building (Formoso and Soibelman, 2002). Categories of direct waste can be summarized in the table 2.1.

Table 2. 1 Categories of Direct Waste

Category	Reason	Example
Delivery waste	During the transportation of materials to the site, unloading and placing in addition to the initial storage	Bricks, glassing
Cutting and conventional waste	Cutting materials into various sizes and uneconomical shapes	Formwork, tiles
Fixing waste	Dropped, spoiled or discarded materials during fixing	Bricks, roof tiles
Application and residue waste	Hardening of the excess materials in containers and cans	Paint, mortar, plaster
Waste caused by other trades	Damage occurs by succeeding trades	Painted surfaces
Criminal waste	Theft and vandalism	Tiles, cement bags
Managing waste	Lack of supervision or incorrect decisions of the management	Throwing away excess material
Waste due to wrong usage	Wrong selection of materials	Rejection of inferior quality marbles, tiles

Source: (Kulatunga, 2006)

Indirect Waste

Indirect waste occurs when materials are not physically lost, causing only a monetary loss. For example, waste due to concrete slab thickness larger than that specified by the structural design (Kulatunga, 2006). Indirect waste arises principally from substitution of materials, waste caused by over allocation, where materials are applied in superior quantity of those indicated or not clearly defined in contract documents, from errors, and waste caused by negligence, where materials are used in addition to the amount required by the contract due to the construction contractor's own negligence (Shen, 2002).

Table 2. 2 Categories of Indirect Waste

Category	Reason	Example
Substitution waste	Substitution of materials in work, which will incur losses to either contractor or client	Use of facing bricks for common bricks
Production waste	Contractor does not receive any payments for the works he has carried out	Over excavation of foundation resulting in the use of additional concrete
Negligence waste	Site errors because of the condemned work or use of additional material	Over excavation of foundation resulting in the use of additional concrete
Operational waste	Unavailability of proper quantities in the contract documents/ the materials that are left on sites	Formwork

Source: (Kulatunga, 2006)

Construction waste can be subdivided into two main categories (Waste and Resources Action Program (WRAP),2007)

I. Waste generated because of design and specifications

Design and the specifications can contribute significantly to the amount of waste generated during the construction of a project particularly when uneconomical design solutions are selected or when unsuitable materials are specified. Design decisions impact on the level of waste arising, some examples of the type of waste involved are detailed below:

- Drylining: cutting of plasterboard sheets and metal studs to fit wall heights and openings
- Flooring: cuttings of floor tiles to fit room layouts
- Ceilings: cuttings of ceiling tiles and fixings to fit room layouts
- Insulation: cutting of insulation boards to fit openings
- Tiling: cutting of floor and wall tiles to suit design and room shapes
- Paving: cutting of paving slabs to fit layout

Brickwork and blockwork: cuttings of bricks and blocks to suit building dimensions and building services However once the design is in place, the waste arising from the design can be estimated, controlled and reduced at tender stage, particularly for area based packages such as flooring, walling and ceilings or when off-site manufacture is used. For example, plasterboards may be ordered pre-cut to negate the need for so much site cutting; or flooring layouts may be re-arranged to fit the modular size of the flooring product (WRAP, 2007).

II Waste generated by construction activities

The way construction activities are carried out during the construction process also impacts on the quantity of waste produced. This waste is usually accidental and is generated by the following factors:

- Inaccurate or surplus ordering of materials that do not get used
- Damage through handling errors
- Damage through inadequate storage
- Damage generated by poor co-ordination with other trades
- Rework due to low quality of work
- Inefficient use of materials
- Temporary works materials (e.g. formwork, hoarding and so on)

According to Al-Hajj and Hamani, (2011) there are many factors, contribute to the generation of material waste. These factors have been under four categories: (1) design; (2) procurement; (3) handling of materials; and (4) operation. They have concluded that most of the causes of waste are due to design issues. The figure 2.1 shows Origins of construction waste.

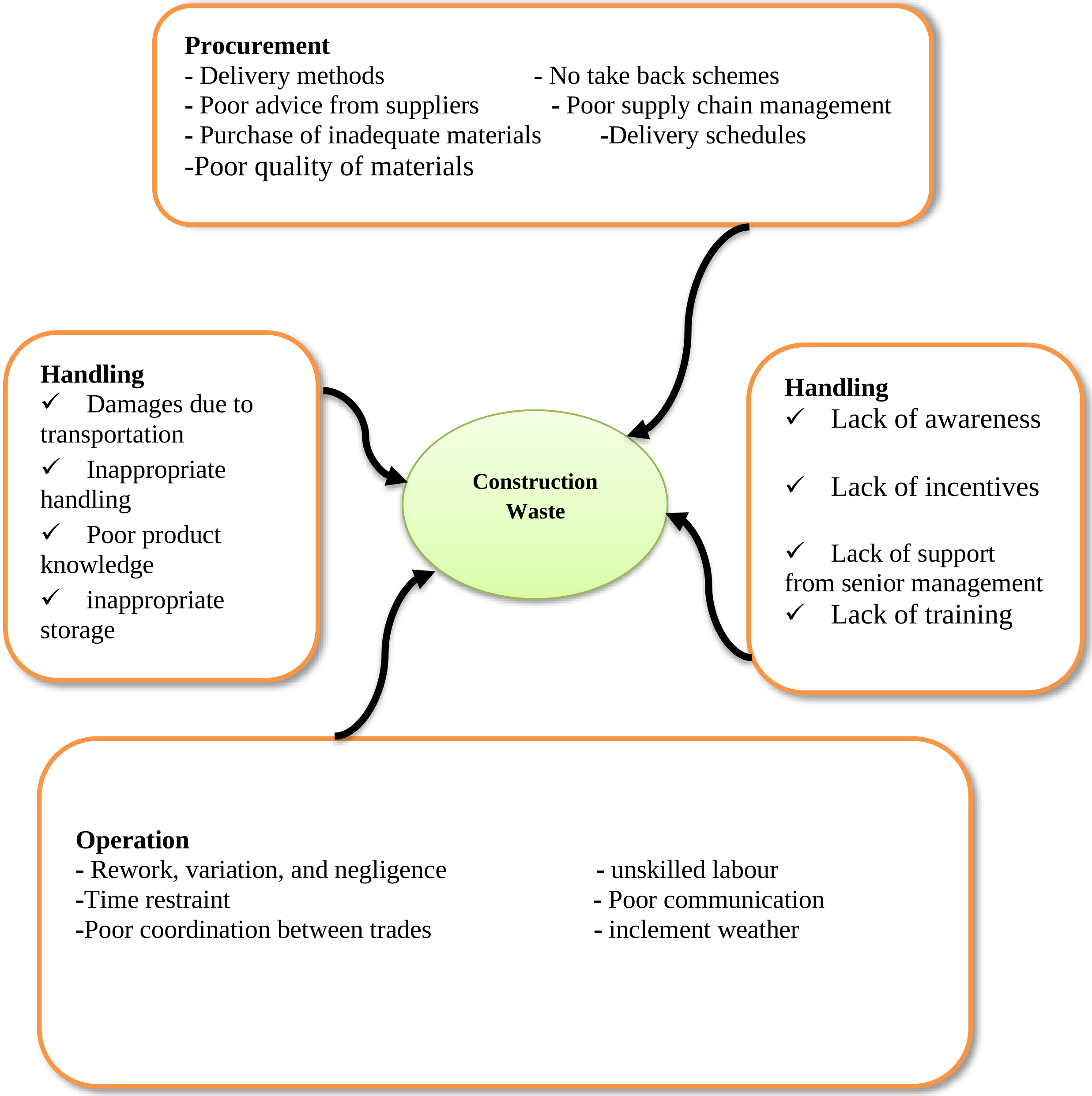

Figure 2. 1 Origins of construction waste

(Source: Lingard, *et al.*, (2000)

2.2.5 Material waste in construction site

construction material wastages can be defined as the difference between the value of materials delivered and accepted on site and those properly used as specified and accurately measured in the work, after deducting the cost saving of substituted materials transferred elsewhere, in which unnecessary cost and time may be incurred by materials wastage. Generally, wastages of building materials can be divided into two types (Skoyles, 1987); one is direct waste and the other is indirect waste. Skoyles (1987) defined direct waste as the loss of those materials, which were damaged and could not be repaired and subsequently used, or which were lost during the building process; indirect waste was distinguished from direct waste because it normally represented only a monetary loss and the materials were not lost physically. Such losses arise principally from substitution of materials, from use of materials in excess of quantities allowable under the contract, and from errors. The failure to recognise and record waste from these causes makes accounting for materials meaningless. Therefore, a simple measure of waste on site would be the difference between that used as specified and the quantity of material delivered to site as a percentage of such deliveries.

The economic and environmental benefits to be gained from waste minimisation and recycling are enormous (Guthrie, *et al*.,1999), since it will benefit both the environment and the construction firms in terms of cost reduction. The economic benefits of waste minimisation and recycling include the possibilities of selling specific waste materials and the removal from site of other wastes at no charge or reduced cost, with a subsequent reduction in materials going to landfill at a higher cost (Snook *et al.*, 1995). Therefore, it can increase contractors' competitiveness through lower production costs and a better public image. However, very few contractors have spent efforts in considering the environment and developing the concept of recycling building materials (Lam, 1997). Because contractors rank timing as their top priority, their effort is always focused on completing the project in the shortest time, rather than the environment (Poon *et al*., 2001). Their account books cannot reveal the potential savings resulted from reduction in construction wastes. Managing building material waste can in fact achieve higher construction productivity, save in time and improvement in safety (Skoyles,1987) while extra wastes take extra time and resources for disposal that may slow down the construction progress. The major causes of material wastage including concrete, steel reinforcement, formwork and brick/block, are tabulated below.

Table 2. 3 Causes of material wastage

Construction Material	Causes	Specification
Concrete	Over order	Exact quantity of concrete required is unknown per pour due to deficiency in planning
	Loss during concrete	Method of placing use of aged timber boards
Steel reinforcement	Cutting	Use of steel bars that size does not fit
Formwork	Cutting	Use of timber boards that size does not fit
Brick work	Cutting	Use of products that size does not fit
	Damaged during transportation	Unpacked supply

Source: (Shen, *et al*., 2000)

2.2.5 Material waste in construction site

Key material in site that have the highest level of wastage on building sites includes Concrete, cement/mortar, timber, and blocks (Agyekum, *et al.*,2013). Bossink and Brouwers, (1996) indicated that in Brazil, 20%-30% of the purchased materials are not used well and end up as waste.

2.2.5.1 Concrete

Formoso, *et al.*, (2002) classified mixed concrete as concrete ready mixed concrete (premixed concrete) and concrete site mixed. Concrete is the most widely used material both for substructure and superstructure parts of a building. According to Shen *et al*., 2002) the wastage that occurs when a ready-mix concrete supply is not ordered according to the quantity of concrete that is required is caused by the mismatch between the quantity ordered and the required amount. The improper handling of concrete wastes can result in over ordering and delays in the construction of projects. In a survey which was carried out by Poon and Jailon (2002) of 22 construction sites in Hong Kong, 80% of the work was made from ready mixed concrete. On average, 3–5% of the material was wasted and most of it was lost through excessive material ordering, broken formwork and redoing due to poor concrete placement quality. According to Bossink and Brouwers, (1996) The construction contractor may not know the exact quantity of concrete that is needed for a given project. This leads to over-ordering and overfilling of the formwork. If the formwork is overfilled, skimming becomes necessary i.e. leveling off the concrete poured into the formwork.

2.2.5.2 Cement/ Mortar

Ayrkwa, (2012) mentioned that Understanding the waste of cement can be challenging due to its various uses and the various processes involved. such as brick work, plastering, and floor screed. As stated by Formoso, *et al.,* (2002) cement is a relatively expensive material that has high levels of waste in Brazil. In addition, Sand and mortar are usually delivered in trucks, and so there may be additional losses related to the lack of control in the delivery operation and the necessary handling it demands. As concluded by (Formoso, *et al.,* 2002), Although not enough data are available, there are indications that such changes have reduced the waste of mortar, in comparison to the traditional method of producing mortar on site.

2.2.5.3 Steel Reinforcement

According to Tam, *et at.,* (2007), Steel reinforcement bars are usually utilized materials in building construction. The main factor for steel wastage is because of cutting. Damaged and rusting during storage are also the major part for steel reinforcement wastage.

Shen *et al.,* (2002) stated that steel reinforcement bars are common materials used in building construction and the main causes of wastage of steel are as a result of cutting, damages during storage and rusting. According to Formoso, *et al.,* (2002) controlling the use of steel reinforcement in building sites is relatively difficult because it is cumbersome to handle due to its weight and shape. As stated by Poon and Jailon, (2002) the reasons of likely waste of steel reinforcement are damage to mesh and bars, loss in mud and excess use of tying wire.(Formoso, *et al*., 2002) pointed out the three main reasons for steel reinforcement waste, Short unusable pieces that are produced when bars are cut, Some bars may have an excessively large diameter due to fabrication problem and trespassing and Structural design that is poor in terms of standardization and detailing, causing waste due to non-optimized cutting of bars.

2.2.5.4 Sand

According to Formoso, *et al.,* (2002) in some parts of the world like Brazil, Sand and mortar are usually delivered in trucks, and so there may be additional losses related to the delivery process. As concluded by Formoso, *et al.,* (2002), Although not enough data are available, there are indications that such changes have reduced the waste of mortar, in comparison to the traditional method of producing mortar on site.

2.2.5.5 Timber Formwork

As stated by Shen *et al.,* (2002) among 30% of all wastes identified in construction sites of Hong-Kong, formwork (timber) is a major contributor. According to Agyekem, (2012) timber is a popular construction material due to its various advantages. Its low weight and high load bearing capacity make it a good choice for construction.

But it is a wastage because of its low durability and reusability. Shen *et al.,* (2002) stated that the main causes of wastage are natural deterioration and the usage and cutting of waste. One of the most commonly used materials for formwork is timber board. The main causes of wastage are those that result from usage and cutting waste. A study undertaken on construction sites in Hong-Kong Poon and Jailon, (2002) showed that the majority of timber waste generated from formwork was diverted to other uses such as timber cutting for internal finishing and fittings. In the case of formwork, most of the timber materials delivered to site were eventually discarded as waste (100% wastage) after several reuses.

2.2.5.6 Brick and block

Bricks and blocks are the most common walling materials. The main cause of brick and block waste is cutting.

Since the nature of the material is fragile the unpacked supply may increase wastage of broken damage. Similarly, the unused bricks left on site is ending up in the trash. (Shen *et al*., 2002). According to Ayrkwa, (2012) wastage of bricks and blocks are directly related to the lack of control in the amount of bricks or blocks delivered as well as the bricks that are the damaged.

2.2.6 Waste Minimization

Hoe, (2006), described waste minimization as the process of reducing or preventing waste. It involves the identification and changing processes for reduction of raw materials, water, and energy consumption. The Environmental Protection Agency (EPA) of the United States of America views waste minimization as; any method that reduces the volume or toxicity of a waste that requires disposal.

According to Poon and Jailon, (2002), waste minimization involves any technique, process or activity which avoids, eliminates, or reduces waste at its source or allows reuse or recycling of the waste.

According to Hoe, (2006) Waste minimization is about common sense and a change of attitude, rather than new technologies and waste minimization is the first stage of a whole waste management plan so that, it's clear that the best option for waste is not to be crated at all. In addition to this Hoe, (2006) stated that the process of minimization involves surveying the flow of materials into as well as out of a site and assessing what steps could be employed to reduce the quality and range of material discarded.

According to Al-Moghany, (2006) the process of waste minimization consists of two basic operations source reduction and recycling. To avoid waste generation, their need to be source reduction, while recycling is useful to use the resources and prevent materials from entering the waste stream.

2.2.7 Waste Minimization In construction

According to Formoso, *et al.,* (2002) he building industry is using a considerable amount of resources, but if the life cycle of the material on site is closely examined, it is generally known that a large portion of the materials used on construction sites are wasted because of poor material control.

Coventry, *et al.,* (2001) stated that the potential for minimizing construction and demolition waste is considerable. To find a practical waste minimization strategy, it requires a detailed understanding of what causes construction waste (Hoe, 2006). Faniran and Caban, (1998) on the other hand examined waste minimization strategies and the relative significance of construction waste sources using survey. The researchers found that a significant number of firms lacked waste-reduction policies. Furthermore, while most companies with explicit waste reduction policies attempted to reduce waste at the source, such as by avoiding waste generation in the first place, this effort was limited to waste generated by site offices and services. Their study concluded that by addressing the origins of all waste created throughout the building phase, there is potential for enhancing the efficacy of waste reduction at source.

According to Teo and Loosemore, (2001) People changing their wasteful behavior makes a significant contribution to waste reduction in the construction industry, according to them. Waste is an unavoidable by-product of construction activity; its management is a low project priority with an absence of appropriate resources and incentives to support it. The availability of local infrastructure and top management support were recognized as the most important determinants of waste reduction behavior on projects, according to their research. Their recommendations for managers to change operators' attitudes about waste include clear communication of waste management policies, the provision of appropriate waste infrastructure, and the collaboration and promotion of senior management.

2.2.7.1 Reduction, Reuse and Recycling

The 3 “R”s of construction waste minimization refers to the 3 waste minimization techniques namely reduction, reuse and recycling. According to Hoe, (2006) waste reduction or source reduction, means preventing the creation of the waste in the first place and is one of the basic principles of sustainable. According to (Coventry *et al.*, 2001), if contractors aim for zero waste, they are not only conserve natural resources and avoid the associated impacts of their extraction and processing but also save money .there are different strategies to minimize waste for instance as Hoe, (2006) stated, designing with standard building material sizes in mind reduce purchasing, handling and disposal costs and also Re-use is another form of waste reduction that: (1) extends resource supplies; (2) keeps high-quality-matter resources from being reduced to low-matter-quality waste; and (3) saves even more energy and pollutants than recycling (Begum *et al.*, 2006). On the other hand, according to Hoe, (2006), recycling waste without sufficient scientific study and development might result in environmental concerns that are worse than the waste itself. Successful research and development of new construction materials or components using waste as a raw material is a multidisciplinary process that involves technical, environmental, financial, marketing, legal, and social concerns. Source Reduction

As defined by Begum *et al.*, (2006) source reduction is defined as any activity that reduces or eliminates the generation of waste at the source. As stated by Hoe, (2006), source reduction is usually within a process and it is highest on the construction waste management hierarchy and also it has the most positive environmental impact due to the action having a direct result in addition to that, he recommended Contractors to apply source reduction on site, by ordering materials in varying lengths to meet construction project conditions, rather than ordering single lengths of materials. According to Al-Ansary,*et al.*, (2004) many design and job site practices can significantly reduce waste and cost of materials on a construction project while requiring only slight modifications of standard procedures.

A. Reuse/Salvage of materials

According to Hoe, (2006), reuse is to salvage and reprocess materials as much as possible in a construction project. This includes materials removed during demolition, scrap generated on site and used materials or scraps from other jobs. As stated by Coventry *et al.*, (2001) many of the materials in demolished structures can be removed, cleaned, renovated, and used in the same construction project or in other projects. When reusing materials, the contractor should ensure that the material is appropriate for the use of proper quality and is prepared for its reuse. The contractor should also exercise care in installation and removal of materials and provide warehousing to facilitate their reuse in the future. Provision for alterations and remodeling can be made during the initial construction process. According to Hoe, (2006) main contractors in controlling sub-Contractors usage of materials through separation of waste for reuse would reduce the amount of waste generated.

B. Recycling

According to Al-Moghany, (2006), recycling is commonly defined as a process of separating recyclable materials from non-recyclable materials and supplying them to a hauler or business so they can be processed to make new products and buying building materials with recycled content helps develop a market for the waste material one recycles from the job site.

It is important to understand the principles of waste minimization. The figure 2.2 illustrates the waste minimization hierarchy.

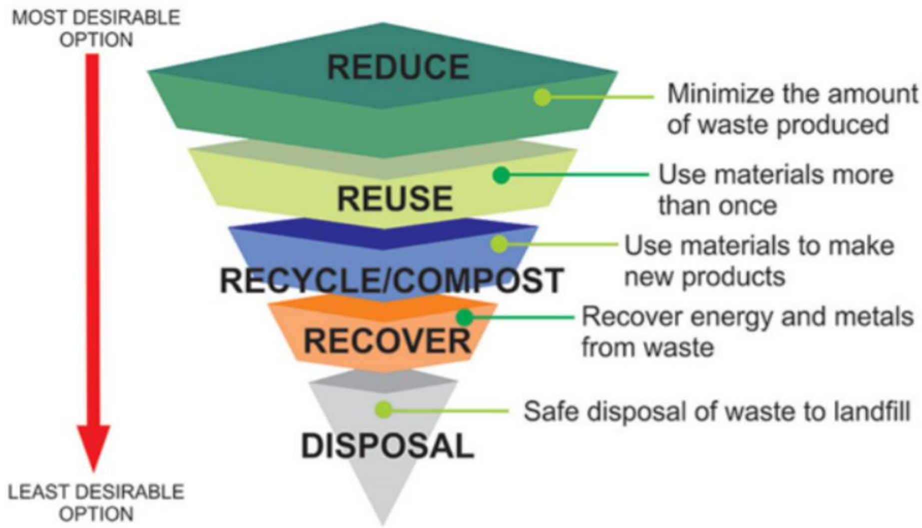

Figure 2. 2 Waste Minimization hierarchy

Source (Sharif, et al., 2017)

As Figure 2.2 shows recycling is the last option after rethinking to reduce the amount of waste produced and reusing waste that are produced. Minimization of waste at source should be given the highest priority when developing strategies for waste minimization. This is because, conceptually, it makes more sense to avoid or minimize the generation of waste than to develop extensive schemes for treating waste. Reusing and recycling do not avoid the generation of waste rather reduce the volume of waste material to be disposed of and discharged into the environment, thereby allowing waste materials to be put to beneficial use.

2.3 Review of Empirical review

A study with the title of *Assessment of construction waste management and disposal strategies. the case of Gelan condominium construction project site* was carried out by Endale teferi (2017) To identify waste management and disposal strategy of the Gelan condominium construction projects located in Addis Ababa Ethiopia. The main objective of the research was to assess building construction waste management and waste disposal strategy. To do that its objective is to assess the economic, health and environmental effects of the CWM&DS (Construction Waste Management and Disposal System). It is significant as it identifies the challenges in the CWM&DS and possible solutions to prevent its negative consequences. The research used primary and secondary data collected through qualitative and quantitative methods. It collected data through survey questions, face-to-face interviews and field survey. The research found out Gelan Project site does not have CWM&DS plan and strategy and the CWM&DS is ineffective. Among other things, storage facilities are inadequate, materials are mishandled, deteriorate, and are exposed to theft. There is delay in waste disposal and the manner is averse to health and the environment. Procurement inefficiency, poor storage, material mishandling, lack of proper CWM&DS, inadequate management attention, weak law enforcement, theft, and lack of awareness of CWM&DS are major challenges. The study recommends improved supervision, security and storage, CWM&DS training, systematic CWM&DS plan, due management attention and stronger legal enforcement for stakeholders and policy makers. It is expected that the findings and the recommendations will serve as a benchmark for future knowledge and as an input to improve the CWM&DS of AAHCPO.

A study titled *Managing and Minimizing Wastage of Construction Materials On Selected Public Building Projects In Addis Ababa* was carried out to assess the current situation of managing and minimizing wastage of construction materials in Addis Ababa on selected public building construction projects and formulate and give recommendations with respect to handling of construction materials in accordance with the outcome of the paper. The researcher used questionnaires, interviews, and site visit to identify the various efforts that have been made in the past to evaluate and examine the causes and sources of construction materials waste on building construction project.

The results of the study showed that the level of contribution of the waste sources to the generation of waste saw differences between the perceptions of the respondents (Contractors, consultants, and client). The results from analysis ranked from the first to fifth position by contractors, consultants and owners that the most significant factors causing construction waste on building construction projects are: -Site supervision factors, Materials handling and storage factors, Design and documentation factors, Site management and practices factors and Operations factors.

The study recommended that there is a need to establish a new construction waste department to develop waste management policies and develop the effective strategy to reduce construction waste. The study recommended the owners to take the waste management history of the contractors as a criterion in awarding contracts. The study recommended the consultants to give attention to avoid design and planning errors at the design and planning stages. The study also recommended the contractors to assign qualification staff and workforce in construction projects and to prepare waste management plan.

2.4 Issues of the study

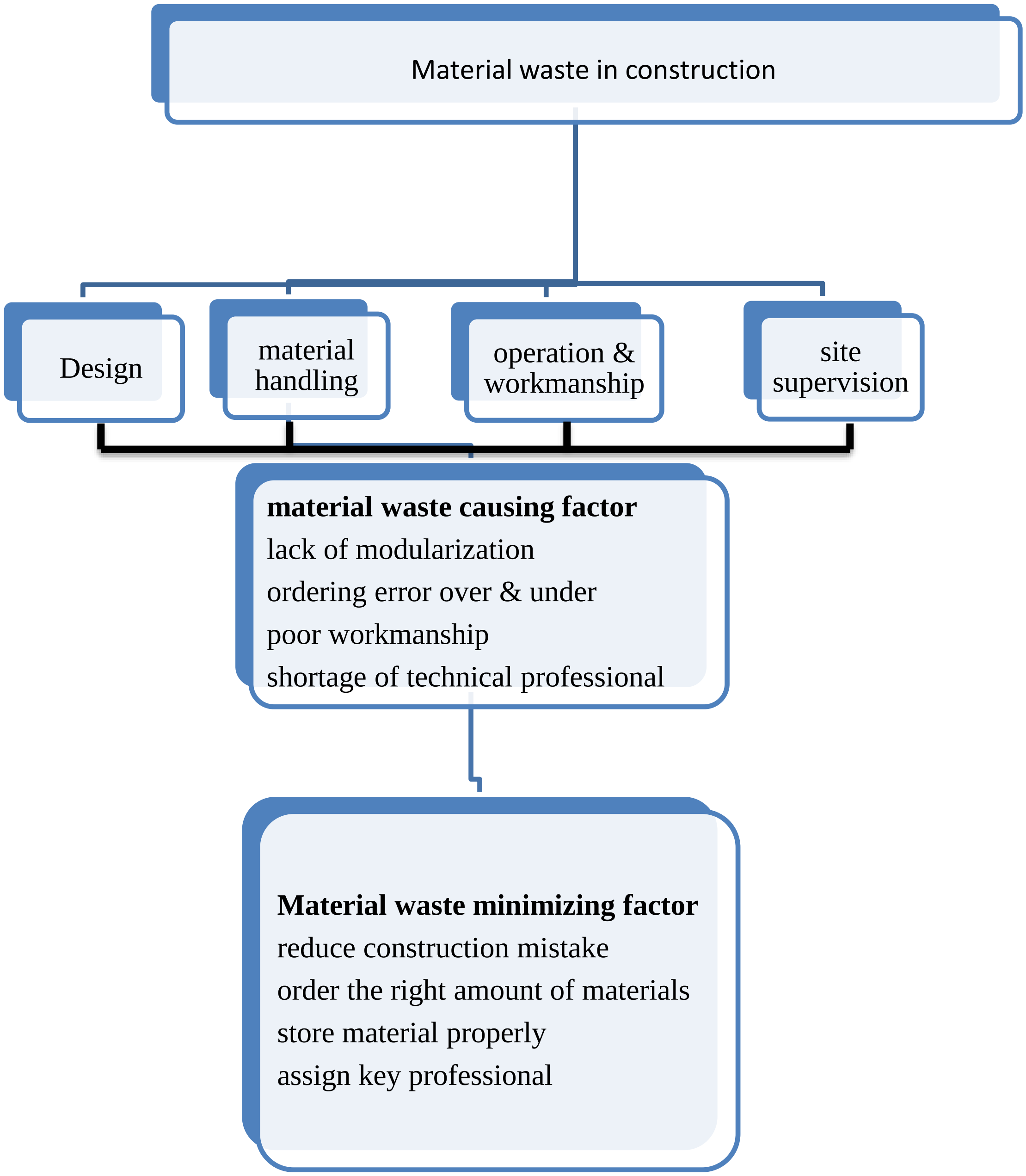

Figure 2. 3 Issues of the study

2.5 Summary of Literature Review

Generally, there is inherent material wastage associated with all types of materials. Due to this all estimators allow wastage factors in pricing a bill of quantities. But the actual material waste is far higher than the nominal figures assumed by the companies in their cost estimate. Thus, the literature review involves critical review of published literatures related to construction materials waste so that to identify the gap, contributing factors and bring the important concept for this thesis.

Studies have shown that not all materials procured and delivered to sites are used for the purposes for which they are ordered because of a number of reasons and become wasted. Previous studies have demonstrated that material wastage has a large effect on the financial performance of construction projects. Besides, managing building materials waste can in fact achieve higher construction productivity, save on time, and improve safety while disposal of extra waste takes extra time and resources that may slow down the progress of construction. Construction waste originates from various sources in the whole process of implementing a construction project due to one or a combination of many causes. Various researches across the world have been undertaken in order to know the causes and factors that lead to material waste in construction projects. This is because in order to reduce the amount of construction waste, the question occurs as to what the main causes are.

Therefore, by identifying the main causes, construction industry players can avoid excessive waste generated on construction sites. In addition, there are different studies on effect of material wastage reduction and minimizing strategy, including reusing and recycling on construction projects. From each of the literature reviews on construction waste minimization, different gaps were identified. The critical gaps identified from these studies are lack of identifying the root causes of material waste in order to minimize construction waste. On the other hand, wastage control needs serious consideration and due attention since the construction industry consumes large amount of raw material. Therefore, this research is necessary by identifying the contributing factors for construction waste and develop an appropriate construction waste minimization practice that will set out procedures to fill the knowledge gaps mentioned above. An effective and proper identification of waste types and categories, predicting the waste quantity, establish causes and origins of these wastes and providing waste reduction strategies in order to effectively reduce the waste amount of construction sites.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter includes the methodology used in order to meet the objective of the study. This section specifically explains in detail about the research approach and design, population and samples, data collection tools used, data analysis and ethical considerations.

3.2 Research approach and design

To meet the objectives of the study, both quantitative and qualitative (mixed) research approach is adopted. The advantage of using a mixed approach is to cover the weakness of each approach with the strength of the other approach (Mark, 2009).

According to Creswell (2003), quantitative research approach count things, data statistically and quotes results in numeric forms. This approach is used to find facts based on evidence or records. The method relies on experiments and surveys to collect measurable data (Creswell, 2003). Therefore, a quantitative research approach is adopted to rank the wastage contributing factors, to identify the major factors of waste in the main construction materials during construction operations and to find out measures taken for minimizing construction material wastage.

As a research design, decriptive design was selected based on the research questions. According to Naoum (2007), descriptive research is used to describe a specific population or a phenomenon and to answer the "what" question. As it is stated earlier, the objectives of this study are mainly to identify the wastage contributing factors, identify the major factors of waste in the main construction materials during construction operations and to find out measures taken for minimizing construction material wastage. So, the reason behind using the descriptive design is because all the research questions are towards answering the "what" and are explaining or describing the construction material wastage phenomenon.

As a research strategy, a survey was used to answer the study questions. The survey strategy was used to assess the construction material wastage in Addis Ababa building construction projects.

As stated by Naoum (2007), surveys are used to obtain data from a large number of samples within a short period of time. Thus, when data is collected from a defined sample, a generalized result can be obtained. The total number of the sample for this study is 118. As a result, to obtain data from this number of samples within a limited time, a survey was chosen as an applicable research strategy. In addition, Mark *et al.*, (2016) stated that a survey strategy is usually used and allows the researcher to collect quantitative data. As it is stated above, this study has a mixed method approach followed by descriptive design and to obtain data from a number of samples, a survey strategy is used.

3.3 Population and sampling

This study focused on Construction material wastage in the construction phase of a building project. As a result, the targeted populations of the study were registered contracting companies who are working in Addis Ababa. According to the list, which was collected from the Addis Ababa construction bureau, there are a total number of around 1720 building contracting companies who are registered from level one to level six. As a result, it will be possible to take all these groups. There is a need to use representative sample.

From the general population of the study, as a sampling frame, building contractor one (BC1), building contractor two (BC2), and building contractor three (BC3) were selected as a sampling frame for the study.

Based on the obtained list of registered contacting companies from the Addis Ababa Construction Bureau, the total number of registered contracting companies as building contractors one, two and three are 149.

BC1= 65

BC2= 37

BC3= 47

Total = 149 building construction companies

Therefore, the sampling frame was contracting companies of BC1, BC2 and BC3 who are registered by the Addis Ababa construction bureau were selected for this study. So, the targeted survey respondents were construction professionals who are working on these construction companies. This includes project managers, site engineers, and office engineers.

Since it is impractical and costly to take all the targeted population, there is a need to take a sample. Due to this, the sample size for this study is calculated using Yamane's formula (1967). This equation is applicable to calculate a sample size with a known sampling frame. The sample size was calculated as follows

$n_{Yamane} = N / (1 + Ne^2)$

Where, n = sample size

N= known population size

e = error level (in this case it is 5% with a confidential interval of 95%)

For Building Contractor 1 (BC1)

Total Number of BC1= 65

$n_{Yamane} = N / (1 + Ne^2)$

= 65/ (1+65*0.0025)

= 56

For Building Contractor 2 (BC2)

Total Number of BC2= 37

$n_{Yamane} = N / (1 + Ne^2)$

= 37/ (1+37*0.0025)

= 20

For Building Contractor 3 (BC3)

Total Number of BC3 = 47

$n_{Yamane} = N / (1 + Ne^2)$

= 47/ (1+47*0.0025)

= 42

Table 3. 1 Sample size of the study

Class	Number of companies (population)	Sample
BC1	65	56
BC2	37	20
BC3	47	42
Total	149	**118**

Simple random probability sampling method was used to give equal opportunity for the targeted population of the study. This sampling method is most commonly associated with survey research strategies (Mark *et al.*, 2016). As opined by the authors, selecting random numbers allows us to select a sample without bias. So, the sample which is selected randomly can be said it is representative to the targeted population. Besides, the authors stated that, simple random sampling is best used when there is an easy and accessible sampling frame that lists the population and for a few hundred target population. Otherwise, the sample selected will have a probability of being biased. As a result, to give the targeted population an equal probability of getting into the sample, its high accuracy of representation and the availability of the lists of contracting companies, simple random sampling using lottery method was used to select the sample for this study.

3.4 Data sources and data collection tools

Data sources

The study used both primary and secondary data sources to obtain sufficient and relevant data that was used to answer the research questions. The primary sources were gathered through questionnaires and key informant interview which includes a discussion made with the construction professionals. Whereas the secondary data sources were collected from available organizational documents.

Data collection tools

I. Questionnaire

As it is stated by Mark *et al.,* (2016), a questionnaire is the most widely used method in survey strategy. As the authors suggested, it is because the respondents were asked to respond to the same questions which will provide an effective way to collects responses from a large sample before making quantitative analysis. To obtain the needed data, questionnaire was used as a data collection tool, due to the sample size and the quantitative approach of the study.

Questionnaire Design

The questionnaire was undertaken as a data collection tool to identify the major factors of construction material wastage, major factors of waste in the main construction materials and the measures taken for minimizing it. The questions were prepared to be filled with construction professionals who are directly involved in the construction phase. Based on the objective of the study the questions were classified into four sections. All the questions are closed-ended except the last two questions.

Section A: Respondent’s identification

This section is included to obtain information about the respondents. The questionnaire includes the three important questions which are category of the firm, position, and year of experience in the company they are working.

Section B: Wastage Factors

This section is of the questionnaire was added to answer the first question of the research. About 44 factors with five groups were identified from different literature reviews and then the respondents were asked to identify the level of influence for wastage factors on their project.

Section C: Major factors of waste in the main construction materials during construction operations

This section of the questionnaire was added to answer the second question of the study. In this section major factors were collected from the literature review were listed. The respondents were asked to identify the level of influence on the identified factors of construction material wastage.

Section D: Measures Taken for Minimizing Construction Material Wastage

This section of the questionnaire was added to answer the third question of the study. This section was asked if there are any measures taken to minimize construction material wastage. At last, an open-ended question was raised for the respondents to add if there are any recommendation, they want to give to minimize construction material wastage in building projects (attached on appendix A).

Measurement of scales

As stated by Naoum (2007), understanding the level of measurement is essential to be able to select the appropriate method of analysis and for each type of measurement. According to the author, the Likert scale, an assumption that shows each item on the scale has equal attitudinal value.

In this research, a five-level Likert scale was used depending on the questions. To rate the wastage factors a range from very high influence to very low influence were used.

II. Key informant interview (KII)

In addition to the above, key informant interview was used to gather relevant information. As stated by UCLA Center for Health Policy Research, Key informant interviews are qualitative in-depth interviews with people who know what is going on in the community. The data was collected from 19 experienced building construction professionals which have more than 10 year experience, the particular reason for circumstance is that since they are experienced they will recommend a better techniques, so the researcher will identify the measures taken to minimize wastage as well as the techniques used, and also the external factors which leads to construction material wastage. This will enable the researcher to propose more applicable and better techniques. (attached on appendix B).

3.5 Procedures of data collection

The first step taken to collect the needed data was preparing the questionnaire. So, based on the reviewed literature, Wastage causing factors were identified. After that, the content validity and reliability of the questionnaire were checked using the following two tests.

A. Validity

"Validity, in essence, refers to the appropriateness of the measures used, the accuracy of the analysis of the results and generalisability of the findings" (Mark *et al.*, 2016). According to the authors, validity in terms of questionnaire refers to the ability of the instrument to measure what was intended to measure. Among the different types of validity, content validity is one of the types which show whether the investigated questions are covered by the instrument or not. To do this a pilot study was carried out before distributing the questionnaire. The process involves giving the questionnaire to some number of respondents who have knowledge of that area to give comments on it. To test the content validity, the questionnaire was distributed by attaching it with the objective and research questions to ten experienced professionals who are currently working on the construction industry and academic areas. After that, the questionnaire was modified based on the received comments and distributed to the targeted populations.

B. Reliability

As stated by Mark Saunders *et al.,* (2016) reliability refers to "replication and consistency" which means if a study can be replicated by an earlier design and one can achieve the same results, that study can be seen as reliable. According to the authors, Cronbach's alpha is a value that ranges between 0 to 1 and used to measure the internal consistency by checking if the items in the data collection instrument measure similar things or not. In this study, this coefficient was used to measure the reliability of the questionnaire. As shown in the table 3.2, the alpha coefficient was calculated for each scaled group factors and the entire questionnaire.

Table 3. 2 Summary of Cronbach's Alpha results

Factors	Cronbach's Alpha Coefficient
Design and Documentation	0.882
Material Procurement and handling	0.862
Operation and workmanship	0.824
External factors	0.629
Site Supervision and Management	0.819
All	**0.860**
Construction materials	
Concrete Steel	0.719
Steel reinforcement	0.868
Timber Formwork	0.880
Cement	0.826
Sand	0.775
Aggregate	0.821
Tile	0.850
Block	0.794
All	**0.762**

3.6 Methods of data analysis

Since the research design used to meet the objectives is descriptive, descriptive statistics that involve both measures of central tendency (mean, median, and mode) and measures of dispersion (standard deviation) were used to analyze the data using SPSS software. At last, the collected data were presented in tables and graphs.

Relative Importance Index (RII)

The RII method was implemented to determine the ranks of all factors that listed in the questionnaire. The score for each factor was calculated by summing up the scores given to it by the respondents. After calculating the RII value, the factors were ranked based on their respective values. The relative importance index (RII) can be calculated using the following formula (Sambasivan and Soon, 2007).

$$RII = \frac{\sum PiUi}{N\,(n)}$$

($0 \leq RII \leq 1$) Where,

RII = Relative Importance Index

Pi = respondent's rating of cause construction material waste (From 1 to 5)

Ui = number of respondents placing identical weighting/rating on cause construction material waste

N = sample size

n = the highest attainable score on cause construction material waste (i.e. 5 in this case)

3.7 Ethical Consideration

Throughout the process of doing the study, the ethical requirements of a study were carried out. First, when reviewing secondary data from journals, articles, proceedings and related sources, every source used was acknowledged both in-text citation and referencing. Secondly, making any interaction with participants was carried out after giving the letter the university prepared for this purpose. It is specifically declared on the questionnaire that the participation of the respondents is purely voluntarily. Finally, the respondent's name and the organization were not stated in any of the study parts, so every respondent was anonyms and their response were confidential.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter illustrates in detail the results and discussion of the collected data using survey. The contributing factors of construction material waste, the major factors of waste in the main construction materials during construction operations and the measures taken for minimizing construction material wastage were identified in the survey results.

The questionnaire has four major sections which includes respondents identification, Wastage Factors categorized in five groups, major factors of waste in the main construction materials during construction operations, measures taken for minimizing construction material wastage as an open-ended question which was used to collect the opinion of the respondents towards minimizing material wastage in Ethiopian construction industry.

A. Respondent's firm level

This section of the questionnaire was prepared to classify the respondents contracting firm. As shown in Table 4-1, the respondents were consisted (46%) construction companies of BC1, 18 construction companies of BC2 and 30 construction companies of BC3 depending on the population number.

Table 4. 1 Respondent's level

Firm level		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	BC1	42	46.7	46.7	46.7
	BC2	18	20.0	20.0	66.7
	BC3	30	33.3	33.3	100.0
	Total	90	100.0	100.0	

Source: Own Survey (2021)

Out of 118 questionnaires distributed in three construction companies, 90 of them were received with a response rate of 76.3%. The rest of the questionnaires were not used in the analysis process because 11 of them were not received and the rest 17 of the respondents gave incomplete and illogical responses.

B. Respondent's Position

The questionnaires were received from 90 professionals who are working in different position within their construction company. As shown in Table 4.2, the respondents position illustrated that 73.3% of the respondents were Project Managers and site engineers. This illustrates that since project managers are well experienced, the data collected from them will be more reliable and the site engineers works more in to the action so they have practical experience on waste so collected data from those experienced site engineers will be more reliable

Table 4. 2 Respondent's Position

Position		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Project Manager	31	34.4	34.4	34.4
	Site Engineer	35	38.9	38.9	73.3
	Office Engineer	16	17.8	17.8	91.1
	Forman	8	8.9	8.9	100.0
	Total	90	100.0	100.0	

Source: Own Survey (2021)

C. Years of Work experience

The data in table 4.3 revealed that 21 (23.3%) of the respondents have 1-5 years of experience, 30 (33.3%) have 6-10 years of experience, 24 (26.7%) have 11-15 years of experience and 15 (16.7%) of the respondents have more than 15 years of experience. In general, more that 50% of the respondents have ≥ 10 years of work experience. This illustrates that the data collected is more reliable data.

Table 4. 3 Respondent's years of experience

Work Experience		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-5 years	21	23.3	23.3	23.3
	6-10 years	30	33.3	33.3	56.7
	11-15 years	24	26.7	26.7	83.3
	>15 years	15	16.7	16.7	100.0
	Total	90	100.0	100.0	

Source: Own Survey (2021)

4.2 Wastage factors

This section of the questionnaire was designed to obtain data about the top major rework causing factors among the three construction companies. In order to obtain that, a list of frequent wastage factors were identified from literature review and modified based on the feedbacks collected from the pilot study. Five groups of wastage factors were selected which are related to Design and Documentation, Material procurement and handling, operation and workmanship, external factors and site supervision and management.

The rank of the five categories and each 44 wastage factors were analyzed and ranked. According to the obtained results the five groups were ranked as follows.

Table 4. 4 Construction material wastage factor categories

Construction wastage factor categories	N	Mean	SD	Rank
Site Supervision and Management	90	3.63	.596	1st
Design and Documentation	90	3.58	.596	2nd
Material Procurement	90	3.46	.566	3rd
Operation and Workmanship	90	3.37	.564	4th
External Factors	90	3.09	.918	5th

Source: Own Survey (2021)

As shown in the table 4.4, the top three major wastage factors are found to be in the categories of Site supervision and management, design and documentation, material procurement. Each of five groups are discussed in detail. After that the top three wastage factors from each category are discussed below.

4.2.1 Design and Documentation

Seven wastage factors were selected under design and documentation category. Respondents were asked to indicate their level of influence on the listed wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.5.

Table 4. 5 Design and Documentation

Design and Documentation	**Mean**	**SD**	**RII**	**Rank**	**Overall Rank**
Frequent design changes at construction stage	4.31	0.882	0.86	1st	1st
Lack of information in the drawings	3.63	0.756	0.8	2nd	21st
Error in contract documents	3.51	0.723	0.7	3rd	22nd
Complexity and error of drawing details	3.51	0.723	0.7	3rd	22nd
Design changes and revisions	3.47	0.737	0.69	5th	24th
Designs which do not consider modulization	3.37	0.71	0.67	6th	27th
Blueprint error	3.27	0.897	0.65	7th	29th

Source: Own Survey (2021)

Respondents ranked *"Frequent design changes at construction stage"* as the first wastage factor with the mean value of 4.31 and RII value of 0.86. This wastage factor is further ranked 1st from total 44 factors. This result indicates that during the design stages, the client and the contractor must sit down and agree on the project's final decision. This is very important during the construction phase as it will affect the building projects by having material wastage. Therefore, to overcome this problem, more attention should be given in waste reduction during design phase. The parties, who involve in any construction projects, should always have a good communication with clients to avoid the last minutes changes.

Nagapan, *et al.,* (2007) found Frequent design changes as the most dominant cause for generating construction wastage. Osmani and Price, (2008) Ranked design change as the secound major factor for wastage.

Based on the responses, *"Lack of information in the drawings"* Who is ranked as the second wastage factor with mean value of 3.63 and RII 0.8. This wastage factor further ranked 21st from the total 44 factors. Similarly Said (2006), ranked it as third major factor for construction material wastage. Correspondingly it is found out that lack of information in the drawing is the most significant cause for construction material waste. This factor illustrates the fact that lacking information in the drawing is the major contributing factor for construction material wastage.

According to the responses collected, respondents ranked both *"Error in contract documents" and "Complexity and error of drawing details"* as 3rd factor with mean value of 3.51 and RII value of 0.70. This wastage factor further ranked 22nd from the total 44 factors.

Error in contract documents, this factor illustrates that lack of adequate time to prepare documents and design management experience among other may cause error in contract document which leads to construction material wastage. On the other hand, complex and error on the drawing details may lead workers make mistake on the project, which will increase the amount of wastage.

4.2.2 Material Procurement and handling

Respondents were asked to indicate their level of influence on listed wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.6.

Table 4. 6 Material Procurement and handling

Material Procurement and handling	**Mean**	**SD**	**RII**	**Rank**	**Overall Rank**
Poor quality of materials	4.07	1.026	0.81	1st	3rd
Ordering error, over ordering, under ordering	4.02	0.983	0.80	2nd	5th
Inappropriate storage leading to damage or deterioration	3.94	0.998	0.79	3rd	10th
Damage during transport and delivery	3.93	0.992	0.79	4th	12th
Lack of material storage space near to the construction site	3.91	1.002	0.78	5th	13th
Wrong storage of materials	3.9	0.984	0.78	6th	15th
Theft and vandalism	3.89	1.011	0.78	7th	16th
Inadequate stacking and insufficient storage on site	3.3	0.694	0.66	8th	28th
Purchased materials that don't comply with specification	3.09	0.907	0.62	9th	32nd
Suppliers error	2.77	0.849	0.55	10th	39th
Lack of possibilities to order small quantities	2.41	0.579	0.48	11th	43rd
Changes in material prices	2.34	0.564	0.47	12th	44th

Source: Own Survey (2021)

On material and procurement and handling castigatory respondents ranked *"Poor quality of materials"* as the first wastage factor with the mean value of 4.07 and RII value of 0.81. This wastage factor was ranked 3rd from total 44 factors. This illustrates that construction material quality have a high impact to prevent wastage. Studies related to wastages included this factor as the major factor for wastage. For instance, Yadeta and Eshetie, (2019), stated that the major causes of construction materials wastage of building projects are selection of low-quality products.

The second factor identified based on the responses was *"Ordering error, over ordering, under ordering"* with mean value of 4.02 and RII value of 0.80. This wastage factor ranked 5th from the total 44 factors. Ordering material error have an impact on wastage, for instance the excess material because of over ordering material will be damaged until there will be another reason to use the extra material. A study related wastage mentioned that over ordering is a major cause of materials leftover and subsequent waste generation in construction projects (Faniran and Caban, 1998). Apart from this, sometimes poor ordering of materials does not fit in terms of quality, type and dimensions for the actual works at site. This type of mistakes happen and at last ends up as material waste. Thus, proper material ordering plays an important part and helps to reduce material losses and damage for construction projects.

As indicated in Table 4.6, "*Inappropriate storage leading to damage or deterioration*" ranked third from the category with the mean value of 3.94 and RII value of 0.79. This factor ranked 10th from the total identified 44 factors. This illustrates inappropriate storage leads to wastage since the material will be damaged and deteriorated. This illustrates that adequate storage of material is one of the significant waste minimization measures. Sasidharani, *et al*., (2015) mentioned wrong material storage as a key factor for waste generation on its own category the same as this study.

4.2.3 Operation and workmanship

Under Operation and workmanship 11 wastage factors were selected. Respondents were asked to indicate their level of influence on the list of wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.7.

Table 4. 7 Operation and workmanship

Operation and workmanship	Mean	SD	RII	Rank	Overall Rank
Rework due to workers mistakes	4.11	1.022	0.82	1st	2nd
Use of incorrect materials, thus requiring replacement	4.02	0.971	0.80	2nd	5th
Lack of coordination among crews	3.94	1.01	0.79	3rd	10th
Lack of communication between the contractors and sub- contractors	3.87	1.008	0.77	4th	18th
Unfriendly attitudes of project team and labors	3.82	0.978	0.76	5th	19th
Required quantity of products unknown due to imperfect planning	3.08	0.864	0.62	6th	33rd
Using untrained labors	2.98	0.936	0.60	7th	35th
Choice of wrong construction method	2.93	0.859	0.59	8th	37th
Poor workmanship	2.84	0.873	0.57	9th	38th
Equipment malfunction	2.77	0.862	0.55	10th	39th
Information about types and sizes of products that arrives too late at the contractor	2.76	0.903	0.55	11th	41st

Source: Own Survey (2021)

Respondents ranked *"Rework due to workers mistakes"* as the first wastage factor with the mean value of 4.11 and RII value of 0.82. This wastage factor is also ranked 2nd from the total 44 factors. As stated by Saker, (2006) Rework due to workers mistakes is one of the major and frequently happening factor with the means rank of 4.13.

Workers' mistakes may be as a result of their inefficiency, inexperience, or the contractor's bad supervision. As indicated by Ekanayake and Ofori (2000), Errors by trades persons or labours were considered the main cause of material waste in operational group in Singapore construction industry. According to Yadeta and Eshetie, (2019) Workers mistake may result from different issues such as lack of knowledge and negligence of workers. This actively demonstrates that workers need to have knowledge, experience as well as supervision from the contractor.

The wastage factor ranked second in this category was *"Use of incorrect materials, thus requiring replacement"* with mean value of 4.02 and RII value of 0.80. This wastage factor is ranked 5th from total of 44 factors.

According to Saker, (2006), using the incorrect material is one of the major factors with means rank of 3.94. This illustrates that use of incorrect materials and replacing the materials will form a wastage on the materials used before. Ekanayake and Ofori (2000), also indicates that the use of incorrect material that requiring replacement was considered the main cause of material waste in the operating group with t-value 5.95. Bossink and Brouwers (1996) found in their study about the causes of waste generation in the Dutch construction industry that the use of incorrect material requiring replacement more frequently and was the main cause of waste in operation group.

The third responses collected, *"Lack of coordination among crews"* ranked third from the category with mean value of 3.94 and RII value of 0.79. This wastage factor ranked 10th from the total identified wastage factors. This illustrates that coordination among crews is very essential because there will be no rework and wastage if they are properly coordinated to know the schedule of different activities for instance, masons doing plaster work should be coordinated with porters mixing mortar such that the right quantity is mixed depending on the area to be plastered.

4.2.4 External factors

A total of three external factors were identified. Respondents were asked to indicate their level of agreement on the listed wastage factors. Based on the received responses the factors were ranked as indicted in the table 4.8.

Table 4. 8 External factors

External factor	Mean	SD	RII	Rank	Overall Rank
Inclement weather Conditions	3.39	1.296	0.68	1st	25th
vandalism	3.18	1.337	0.64	2nd	30th
Accidents	2.69	.967	0.54	3rd	42nd

Source: Own Survey (2021)

Based on the results obtained from survey, respondents ranked *"Inclement weather Conditions"* as the first wastage factor with the mean value of 3.39 and RII value of 0.68. This wastage factor is ranked 25th from the total 44 factors. This illustrates that wastage in the construction sites caused by weather inclement condition is a common occurrence. However, the waste due to weather can avoided with good decision making and management skills. Construction waste could be minimized with proper planning by the management.

The wastage factor ranked second in this category was *"vandalism"* with mean value of 3.18 and RII value of 0.64. This wastage factor is ranked 30th from the total identified 44 factors.

The wastage factor ranked 3rd by the respondents in the external factor category was *"Accidents"* with a mean value of 2.69 and RII value of 0.54. This factor is ranked 42nd from the overall factors.

Based on discussion on the key informant interview lack of legislative enforcement by the government, competition among contracting parties to take and win the project with low costs and price escalation on building construction material have a major significant effect and bold wastage contributing factor in Addis Ababa building construction projects.

4.2.5 Site Supervision and Management

A total of 11 factors attribute to Site Supervision and Management categories were identified. Respondents were asked to indicate their level of influence on the listed wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.9.

Table 4. 9 Site Supervision and Management

Site Supervision and Management	Mean	SD	RII	Rank	Overall Rank
Change orders by the client	4.04	.982	0.81	1st	4th
Owner's poor communication with the construction parties and government authorities	3.97	1.022	0.79	2nd	7th
Lack of strategy to material waste minimization	3.96	1.005	0.79	3rd	8th
Lack of good site supervision	3.94	1.010	0.79	4th	9th
Poor coordination and communication by the contractor with the parties involved in	3.90	1.061	0.78	5th	14th
Suspension of work by the owner	3.88	1.037	0.78	6th	17th
Ineffective control of the project progress by the contractor	3.76	.987	0.75	7th	20th
Ineffective planning and scheduling of the Project by the contractor	3.38	1.214	0.68	8th	26th
Poor qualification of contractor's technical staff assigned to the project	3.14	.894	0.63	9th	31st
Shortage of technical professionals in the contractor's organization	3.03	.814	0.61	10th	34th
Poor site layout	2.98	.912	0.60	11th	36th

Source: Own Survey (2021)

Respondents ranked *"Change orders by the client"* as the first wastage factor with the mean value of 4.04 and RII value of 0.81. This wastage factor is ranked 4th from the total 44 factors. This illustrates that the change orders by the clients is the major factor for construction material wastage. According to the study of Ghanim., (2014) one of the major cause factor of material wastage on construction site in Jordan are change orders by the client. In fact, clients may request any change or additional requirement and facility in their project; however, if the request happens during the construction work is in progress, this may result in demolishing and rework activities which will lead to construction material wastage.

According to the responses collected ***"****Owner's poor communication with the construction parties and government authorities****"*** *was* ranked 2nd from the category with mean value of 3.97 and RII value of 0.793. This wastage factor is ranked 7th from the total 44 factors.

A similar result was found by Al-Khalil and AL-Ghafly (1999) which indicated that the owner's poor communication with the construction parties and government authorities was ranked in the seventh position among sixty factors which causes waste.

The wastage factor ranked 3rd by the respondents in Site Supervision and Management category was "*Lack of strategy to material waste minimization****"*** with a mean value of 3.96 and RII value of 0.791. This factor is ranked 8th from the overall factors. most contractors use a strategy of minimizing waste at the source but there is no reusing or recycling strategy, so a lot of materials as wastes go to landfill. Poon and Jaillon (2002), in their study in Hong Kong stated that lack of strategy to waste minimization was the main source of construction waste.

The following are the top five major wastage factors from the overall 44 factors. All are discussed above in detail in their own category.

Table 4. 10 Top five wastage factors

Wastage Factor	Categories	Mean	SD	RII	Overall Rank
Frequent design changes at construction stage	Design and Documentation	4.31	0.882	0.86	1st
Rework due to workers mistakes	Operation and workmanship	4.11	1.022	0.82	2nd
Poor quality of materials	Material procurement and handling	4.07	1.026	0.81	3rd
Change orders by the client	Site supervision and management	4.04	.982	0.81	4th
Ordering error, over ordering, under ordering	Material procurement and handling	4.02	0.983	0.80	5th
Use of incorrect materials, thus requiring replacement	Operation and workmanship	4.02	0.971	0.80	5th

Source: Own Survey (2021)

4.3 Major factors of waste in the main construction materials during construction operations

The respondents were asked to identify the main factors for construction material wastage. So, by this the researcher will identify the major factors of waste in the main construction materials during construction operations

4.3.1 Concrete

Concreting is a major building process. Site managers often express about the difficulty of controlling the amount of concrete deliveries.

Nine wastage factors were selected under Concrete. Respondents were asked to indicate their level of influence, based on the received responses the mean and rank of each factor of the concrete waste are presented in the table 4.11.

Table 4. 11 Concrete wastage factors

Concrete	Mean	SD	Rank	Overall Rank
Ordering an additional allowance of Concrete	4.42	0.807	1st	12th
Poor performance leading to rework	4.02	0.936	2nd	31st
Far distance between place of mixing and casting	3.97	1.022	3rd	34th
Inadequate use of vibration which leads to Honey combing	3.11	0.854	4th	51st
Excessive dimensions of concrete structure	2.91	0.856	5th	52nd
Use of inadequate tools and equipment's	2.83	0.797	6th	53rd
Flaws in the framework assembling process	2.37	0.55	7th	62nd
Lack of proper maintained pathways	2.12	0.846	8th	64th
Some suppliers often deliver quantities of material smaller than what are paid for	1.99	0.786	9th	65th

Source: Own Survey (2021)

As shown in the table 4.11, the top 3 respondents ranked for concrete wastage factors are Inadequate use of vibration which leads to Honey combing, Poor performance leading to rework and far distance between place of mixing and casting.

Respondents ranked ***"****Ordering an additional allowance of Concrete****"*** as the first factor for concrete wastage with the mean value of 4.42. As per the respondents this is the major factor for concrete wastage, site managers often order and additional allowance of concrete in order to avoid interruptions in the concrete-pouring process, sometimes these results in surplus of concrete that is not used. Kazaza, *et al.*, (2015) in their study stated that compared to various categories of the concrete waste, over-order of concrete is the major contributor among others, According to Kou, et al. (2012) about 8-10 tons of the fresh concrete waste can be produced every day from a batching plant with a daily output of 1000m^2 of concrete.

Based on the responses, *"Poor performance leading to rework"* was ranked as the second wastage factor with the mean value of 4.02. The factor illustrates about the poor performance of workers which leads to redoing and material wastage due to poor concrete placement quality. For instance, the building contractor may not know the necessary quantity because of imperfect planning. This leads to overordering and overfilling of the means of transport and formwork. If the formwork is overfilled, skimming becomes necessary, that is leveling off the concrete poured into the formwork. According to the responses collected, respondents ranked *"Far distance between place of mixing and casting"* as a 3rd factor with mean value of 3.97.

4.3.2 Steel Reinforcement

Under this material, seven wastage factors are selected. Respondents were asked to indicate their level of influence on the listed wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.12.

Table 4. 12 Steel Reinforcement

Steel Reinforcement	Mean	SD	Rank	Overall Rank
Damage during storage and rusting	4.47	0.81	1st	4th
Nonoptimized cutting of bars	4.43	0.808	2nd	9th
Structure design was poor in terms of standardization and detailing	4.41	0.806	3rd	15th
Short unusable pieces are produced when bars are cut	4.38	0.801	4th	21st
Poor handling because its cumbersome to handle due to weight and shape	3.5	0.675	5th	41st
Using longer bars than what are required	2.46	0.564	6th	55th
Unnecessary replacement of some bars by others of large diameter	2.39	0.555	7th	61st

Source: Own Survey (2021)

Respondents ranked "*Damage during storage and rusting"* as the first wastage factor for steel reinforcement with the mean value of 4.47. Exposing materials to extreme weather such as steel bars which rust needs to have proper storage to avoid construction material wastage. The second cause identified based on the responses was "*Nonoptimized cutting of bars*" with mean value of 4.43. According to the responses collected, "*Structure design was poor in terms of standardization and detailing*" ranked third from the category with mean value of 4.41. Despite the 5th ranked factor was *Poor handling because its cumbersome to handle due to weight and shape*. It was considered the main reason for steel reinforcement waste in Brazilian construction projects (Formoso, *et al*., 2002).

4.3.3 Timber Formwork

This category indicates timber formwork wastage factors, under this category eight factor was selected. Respondents were asked to indicate their level of influence on the listed factors. Based on the received responses the factors were ranked as indicated in the table 4.13.

Table 4. 13 Timber Formwork

Timber Formwork	Mean	SD	Rank	Overall Rank
Use of low-quality timber	4.42	0.807	1st	12th
Wrong storage	4.39	0.803	2nd	18th
Deterioration resulting from unpainted before use and unclean after use	4.39	0.803	2nd	18th
Using for other purposes	4.38	0.801	4th	21st
Nonoptimized cutting of timber boards	4.37	0.8	5th	25th
Breaking of timber boards during the removal of the frames	4.32	0.791	6th	27th
Cutting the longer timber although the required are found	3.47	0.674	7th	46th
Cutting for internal finishing and fittings	1.88	0.805	8th	66th

Source: Own Survey (2021)

Based on the results obtained from the survey, respondents ranked **"***use of low-quality timber"* as the first wastage factor for timber formwork with the mean value of 4.42. The use of low-quality timber is an important source of timber indirect waste. Based on the result, most respondents request low quality timber because it is inexpensive. The wastage factor ranked second in this category was *"Wrong storage"* and *"Deterioration resulting from unpainted before use and unclean after use***"** with mean value of 4.39. The natural deterioration resulted from usage and negligible for board such as unpainted before use and uncleaned after use.

4.3.4 Cement

A total of fourteen factors were identified. Respondents were asked to indicate their level of agreement on the listed wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.14.

Table 4. 14 Cement

Cement	Mean	SD	Rank	Overall Rank
Wrong storage	4.54	0.621	1st	1st
Loading the cement manually in the mixer using inadequate equipment's and tools	4.48	0.622	2nd	2nd
Inappropriate way of transportation	4.47	0.622	3rd	4th
Damage the external plaster due to rainfall	4.44	0.62	4th	8th
Mixing in unsuitable places	4.43	0.619	5th	9th
Damage the fall mortar during plastering	4.43	0.619	5th	9th
Damage resulting from severe weather conditions	4.38	0.61	7th	21st
Excessive thickness of plaster	4.14	0.829	8th	28th
Excessive quantities during mixing more than the required	4.08	0.753	9th	29th
Excessive thickness for concrete floor screed	4.06	0.866	10th	30th
Poor performance causing redoing	3.89	0.827	11th	35th
Excessive consumption of mortar in joints	3.56	0.563	12th	37th
Multiple handling of the same batch of mortar	3.52	0.565	13th	39th
Mixing of quantities greater than the required	3.49	0.566	14th	43rd

Source: Own Survey (2021)

Respondents ranked "*Wrong storage*" of cement at the first wastage factor with the mean value of 4.54. unstacking cement bags on pallet and disorganized stocks which leading to broken bags. Khorate & Pataskar, (2014) in their study raked this factor as the 3rd factor. According to the responses collected, "*Loading the cement manually in the mixer using inadequate equipment's and tools*" was ranked 2nd from the category with mean value of 4.48. The wastage factor ranked 3rd by the respondents in cement category was "*Inappropriate way of transportation*" with a mean value of 4.47.

4.3.5 Sand

Under these category four factors were selected. Respondents were asked to indicate their level of influence on the listed wastage factors. Based on the received responses the factors were ranked as indicate in the table 4.15.

Table 4. 15 Sand

Sand	Mean	SD	Rank	Overall Rank
Poor storage	4.36	1.02	1st	26th
Excessive consumption of sand	3.78	1.13	2nd	36th
Weather condition	2.46	0.603	3rd	55th
Damage the remained quantities in the place work	2.33	0.6	4th	63rd

Source: Own Survey (2021)

Respondents ranked "Poor storage" as the first wastage factor with the mean value of 4.36. Based on the responses, "Excessive consumption of sand" was ranked as the second wastage factor with mean value of 3.78. This result from insufficient information about the used quantities and poor supervision. According to the responses collected, respondents ranked both "*Weather condition*" as 3rd factor with mean value of 2.46.

4.3.6 Aggregate

Seven wastage factors were selected under Aggregate. Respondents were asked to indicate their level of influence, based on the received responses the mean and rank of each factor of the concrete waste are presented in the table 4.16.

Table 4. 16 Aggregate

Aggregate	Mean	SD	Rank	Overall Rank
Mixing quantities greater than the required	4.46	0.721	1st	6th
Excessive quantities during mixing	4.38	0.712	2nd	21st
Poor distribution of material in site	3.54	0.621	3rd	38th
Wrong handling	3.51	0.623	4th	40th
Far distance between place of mixing and casting	3.48	0.622	5th	44th
Neglecting the aggregate remainder	3.48	0.622	5th	44th
Losing the aggregate during passing the equipment's on it	2.51	0.546	7th	54th

Source: Own Survey (2021)

As shown in the table 4.16, the top 3 respondents ranked for concrete wastage factors are Mixing quantities greater than the required, Excessive quantities during mixing and Poor distribution of material in site. Respondents ranked ***"Mixing quantities greater than the required"*** as the first factor for concrete wastage with the mean value of 4.46. This is due to lack of information available to construction labor for producing the required quantities. Based on the responses, ***"Excessive quantities during mixing"*** was ranked as the second wastage factor with the mean value of 4.38. According to the responses collected, respondents ranked ***"Poor distribution of material in site"*** as a 3rd factor with mean value of 3.54.

4.3.7 Tile

Under this material, eleven wastage factors were selected. Respondents were asked to indicate their level of influence on the listed wastage factors. Based on the received responses the factors were ranked as indicated in the table 4.17.

Table 4. 17 Tiles

Tiles	Mean	SD	Rank	Overall Rank
Damage of the remains left on site	4.48	0.722	1st	2nd
Cutting the tiles in great quantities	4.46	0.721	2nd	6th
Damaging the tile during the necessary cutting process	4.42	0.719	3rd	12th
Rework because of executive mistakes	4.41	0.806	4th	15th
Damage during transportation	3.5	0.623	5th	41st
Damage during finishing	3.47	0.622	6th	46th
Manufacturing defects	3.41	0.616	7th	50th
Unpacked supply (fragile)	2.44	0.543	8th	57th
Excessive quantities of tiles on site	2.41	0.538	9th	58th
Poor distribution of tiles in site	2.41	0.538	9th	58th
Inadequate workers	2.41	0.538	9th	58th

Source: Own Survey (2021)

Respondents ranked *''Damage of the remains left on site''* as the first wastage factor for Tile with the mean value of 4.48. such waste was mostly related to inadequate tools and equipment used for cut, and inadequate training of labor. The second cause identified based on the responses was ***"****Cutting the tiles in great quantities''* with mean value of 4.46. This results when insufficient attention is paid to the dimensions of the available tiles in the design stage so lake of modular coordination between architectural and structural design was the main cause of cuts. According to the responses collected, ***"****Damaging the tile during the necessary cutting process****"*** ranked third from the category with mean value of 4.42. This waste was mostly related to inadequate tools and equipment used for cut, and inadequate training of labor.

4.3.8 Block

This category indicates Block wastage factors, under these category six factors were selected. Respondents were asked to indicate their level of influence on the listed factors. Based on the received responses the factors were ranked as indicated in the table 4.18.

Table 4. 18 Block

Block	**N**	**Mean**	**SD**	**Rank**	**Overall Rank**
Lack of halves and quarters of blocks	90	4.41	0.717	1st	15th
Damage of the unused quantities left on site	90	4.39	0.714	2nd	18th
Damage the blocks during unloading and transportation operation	90	4	0.924	3rd	32nd
Manufacturing defects	90	3.98	0.948	4th	33rd
Excessive cutting of blocks	90	3.47	0.622	5th	46th
Block damage during the process of cutting	90	3.47	0.622	5th	46th

Source: Own Survey (2021)

Based on the results obtained from the survey, respondents ranked **"***Lack of halves and quarters of blocks***"** as the first wastage factor for Block with the mean value of 4.41. The wastage factor ranked second in this category was *"Damage of the unused quantities left on site***"** with mean value of 4.39. This illustrates that leftover materials on site is one of the causes of construction waste and can see thru naked eyed after construction. This cause is ranked on the tops of other factors. According to the responses collected, respondents ranked "*Damage the blocks during unloading and transportation operation*" as 3rd factor with mean value of 4. During transportation due to their fragile nature the material will have high wastage.

The following are the top five major wastage factors from the overall 66 factors. All are discussed above in detail in their own category.

Table 4. 19 Top five construction material wastage factors

Categories	Wastage Factor	Mean	SD	Rank
Cement	Wrong storage	4.54	0.621	1st
Cement	Loading the cement manually in the mixer using inadequate equipment's and tools	4.48	0.622	2nd
Tile	Damage of the remains left on site	4.48	0.722	2nd
Steel reinforcement	Damage during storage and rusting	4.47	0.81	4th
Cement	Inappropriate way of transportation	4.47	0.622	4th

Source: Own Survey (2021)

4.4 Responses of open-ended question

In this section of the questionnaire the respondents were asked if there are any techniques used to minimize construction material wastage and if so, respondents were requested to indicate what techniques were employed by their firms to reduce waste generated.

Figure 4.1 shows that 79% of the respondents do not have waste minimization techniques on building construction sites. While 21% have waste minimization techniques.

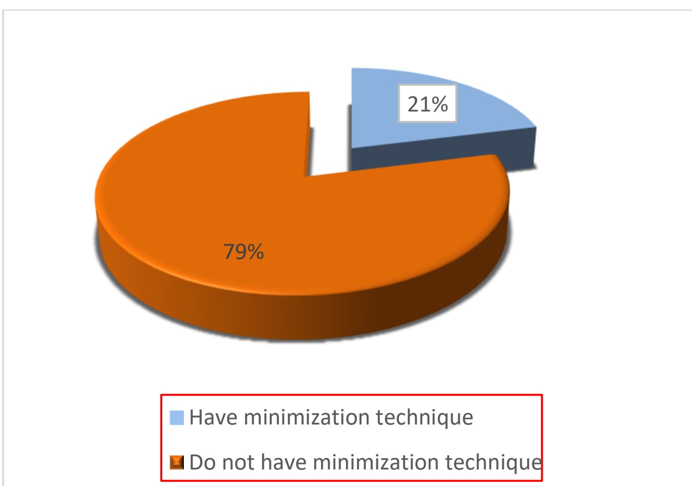

Figure 4. 1 Usage of waste minimization techniques

Source: Own Survey (2021)

The data in Figure 4.2 shows the distribution of the waste minimization adopted by respondents who have waste minimization techniques. The major three techniques are mentioned. Around 33.3% of respondents in this category use the waste minimization by reusing the scrap metal, while the other 27.8% use optimization of resource technique and 14.4% are reducing the use of packaging material. The finding of the paper on waste minimization techniques on both open ended questionnaire and key informant interview shows that there is few techniques used to minimize wastage in the construction sites but few respondents have tried to use a simple technique as shows on figure 4.2 on the reduction of wastage.

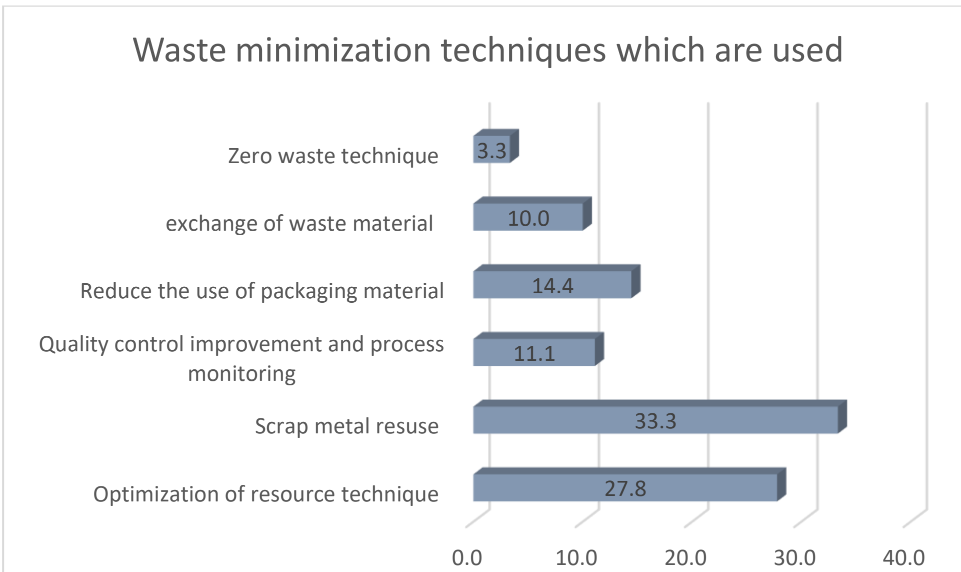

Figure 4. 2 Waste minimization techniques which are used

Source: Own Survey (2021)

Similarly, the respondents were also asked to state any of their recommendations towards minimizing construction material wastage in building projects. The following results were obtained by collecting all the responses in six categories in the discussion of key informant interview as well as on the open ended questionnaire. According to the results, Combination of re-using waste, recycling waste, and minimizing waste at the source of origin, assigning key professional and Proper storage facilities and improved store control and monitoring system were the major waste minimization strategies recommended by the respondents.

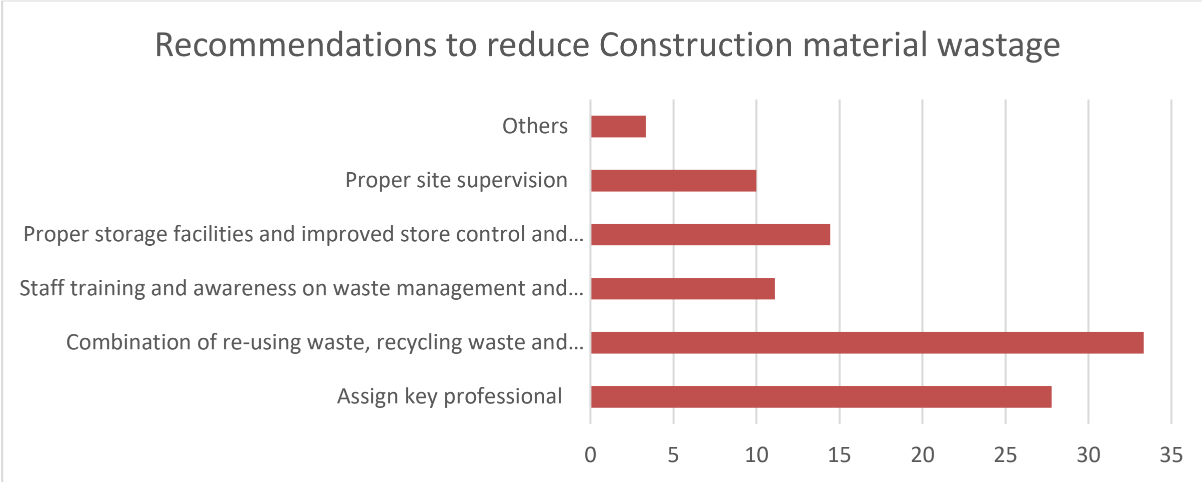

Figure 4. 3 Recommendations to reduce construction material wastage

Source: Own Survey (2021)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter is consisted of three sections. The first section presented summary of major findings of the study. The second section explained about the general conclusions reached depending on the findings and finally gave recommendations for concerned bodies who can contribute towards reducing construction material wastage.

5.2 Summary of major findings

According to the collected data through questionnaires and key informant interviews the study revealed the following results based on different categories in order of their contribution to construction material waste.

A. site supervision and management

The finding shows that change orders by the client, owner's poor communication with the construction parties and government authorities and lack of strategy to material waste minimization has ranked the top three contributing factor in construction material wastage in managing and supervising building construction projects.

B. design and documentation

The results of the study demonstrate that frequent design changes at construction stages, lack of information in the drawings and error in contract documents are the key contributing factors in building construction projects in the category of design and documentation.

C. Material procurement

Poor quality of material, ordering error over or under ordering and damage during transport and delivery presented as the main factors causing wastage in building construction projects in the procedure of procuring a material for use in operation.

D. operation and workmanship

The study indicates rework due to workers mistake, use of incorrect material which require replacement and lack of coordination among crews increased the generation of waste in operating and working on site.

E. External factors

The results of the study showed that inclement weather condition, vandalism and accidents are the major wastage causing factors in building projects of Addis Ababa. In an interview lack of legislative enforcement, competition among contracting parties to take the project and price escalation are the different external contributing factors for building construction project wastage.

F. The major factors of waste from the main construction materials

The major causes of concrete waste demonstrate that ordering an additional allowance of concrete, poor performance leading to rework and far distance between place of mixing and casting is among the major factors of waste in concreting process. As a result, high amount of concrete wastage was identified as the top major contributing factors in the performance of building construction projects since concrete uses in larger quantity in these construction sites. For reinforcement bar, the study has revealed that waste generated on site is directly related to design process. Damage during storage and rusting, non-optimized cutting of bars and poor design of structure in terms of standardization and detailing is the key factors in depletion of steel reinforcement.

Use of low-quality timber, wrong storage and deterioration resulting from unpainted before use and unclean after use are the main factor in wasting timber formwork. wrong storage, manual loading process inappropriate ways of transportation and excessive consumptions and poor distributions are among the major wastage causing factors of the main constituting ingredients of concrete (cement, sand, and aggregate)

The top three causes of hollow concrete block wastage found to be lack of half and quarter of blocks damage of unused quantities left on site and Damage the block during unloading and transportation operation or improper storage of materials, respectively.

5.3 Conclusion

The purpose of this study was to identify the major contributing factors of construction material waste, a problem the construction industry is facing but does not obtain sufficient attention. Before coming to construction material wastage minimization strategies, Identifying the major root causes of the problem is the first and helpful intervention.

The study identified the major contributing factors of construction material waste that needs a serious intervention by the construction professionals. According to the identified causes, the top construction material wastage factors mainly lies in the category Design and documentation and Operation and workmanship. In the Design and documentation category, Frequent design changes at construction stage were the major contributing factor for the occurrence of construction material wastage. It has been frequently stated that communication is vital for the success of a project especially for a construction project which needs teamwork.so this requires the collaboration and sufficient communication between the client, consultant and contractor before the construction begins in order to avoid frequent design changes at the construction stage.

Lack of supervision and management, inefficiency in procurement, inefficient storage facilities and system, mishandling of materials, design and ordering errors and, lack of skill, material deterioration, absence of modern waste management strategy, lack of proper attention by management, weak enforcement of contractual obligation, weak security /theft and vandalism, lack of awareness and knowledge of waste management practices underlie the causes of waste.

Moreover, this study also provided empirical evidences on the levels of contribution and the levels of practice of waste minimization measures for each of the above main construction materials in building construction projects. It has shown that for all of the main construction project materials measures which have a high level of contribution in the minimization of waste are not practiced on the basis of their level of significance on the sites.

5.4 Recommendation

Based on the obtained results, the following recommendations were given to the major project participants to reduce construction material wastage on construction phase of building projects.

- In the design phase of the project, the consultant and the client need to communicate exhaustively towards the scope of work based on the client's interest. They need to make a scheduled meeting program with a specific time interval like at the beginning of the design, after the completion of 20% of the design, after the completion of the 60% of the design and after the final completion. In these processes, if the client is not able to do this, he/she can hire a professional consultant to do the task who will facilitate the communication between the contract parties. This will be helpful to minimize the client's change instruction and frequent design changes after work had been carried out. Much work needs to be carried out in the design stage because it is better to change the design before the construction begins to minimize construction material wastage.
- To minimize wastage happened due to design problem in building construction projects, practicing highly off-site construction by adopting different technologies like prefabrication and precast units, proper detailing during designing, coordinating dimensions between materials and the design, and planning ahead to minimize design changes are sensible mechanisms.
- The consultant need to be sure the quality of materials delivered on the site is as stated in the specification and construction supervisors and contractors on the site shall start refusing to accept substandard material.
- Material ordering practice needs to be improved in order to reduce waste comes from excessive quantity of material used that could be addressed by introducing just in time material delivery system, especially for hollow concrete block.
- Storage facility on the sites needs to be improved by planning the details of material delivery and their storage space on site. Besides, all workers shall practice careful handling and usage of tools in all courses of the construction process.
- Contractors need to develop waste management plans and to hire site waste manger to address material wastage problem and to enjoy the likely benefit. In addition, they shall start providing short term and long-term trainings and workshops for the workers.

- Devise good site controlling strategy to ensure adequate material planning and ordering, on-site material handling and storage which are helpful for controlling excessive material wastage. In order to facilitate this, supervisors should also give emphasis to different parameters of these building projects in allocating the site supervisors so as to make easy the site controlling and supervision work.
- Another useful measure is strengthening the enforcement of existing relevant laws. Strengthening the enforcement of laws such as the solid waste proclamation which imposes penalty in cases of violation should be considered. The public body should strengthen supervision to make sure contractors live up to their contractual obligation. As an implementing governmental body, it has the obligation to enforce constitutional provisions pertaining to environmental protection as well as other relevant laws. Its responsibility entails to make sure that entities responsible for waste disposal discharge their obligations in relation to environmental protection. It should carry out supervision to make sure dumping of waste from site is done in a manner not harmful to health and environment.

5.4.1 Recommendations for further study areas

This study with its limitation has investigated the assessment material wastage in building construction projects in Addis Ababa in selected contractor's level. Nevertheless, the following issues are identified and suggested for future studies.

- ❖ This study was carried out in the building contracting companies of one, two and three so further studies should be made on the rest of the construction companies to identify additional root causes of construction material wastage. Besides, further studies should include the perspective of consultants and clients in this area.
- ❖ It is required study Practices of Construction Materials Management in Ethiopian Construction Industry.
- ❖ It is necessary to repeat this research every three years to observe the new trends of contractors.
- ❖ It required the research of new technology of recycling waste and managing mechanism for applying to construction companies in Ethiopia, especially in Addis Ababa.

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APPENDIX A

Questionnaire

Project Management Department

M.A thesis on Project Management

Dear Respondent,

I am kindly requesting your willingness to participate in this research "**Assessment of Construction Material Waste in Addis Ababa: The Case of Selected Building Construction Projects**" by filling this questionnaire. Any information you are willing to provide will be greatly appreciated.

The objective of this research is to assess the contributing factors of construction Material waste, to identify the major factors of waste in the main construction materials during construction operations and to examine the measures taken for minimizing construction material wastage.

All the data collected will only be used for academic purpose. If you have any inquiry, please feel free to contact me through the provided addresses.

Thank you for giving 15 minutes of your time and your kind cooperation for the research.

Contact Address

Selam Hailemariam

E-mail: selina.hailee@gmail.com

Phone No: 0920201867

- ❖ **Please note that it is very important that each question is read carefully and answered consciously.**

Please tick or write in words as required on the space provided at your convenience to respond the questions.

SECTION A : RESPONDENT'S IDENTIFICATION

1. Category of your firm: Level

[1] BC1 ☐
[2] BC2 ☐
[3] BC3 ☐

2. Your position in the company

[1] Project Manager ☐
[2] Site Engineer ☐
[3] Office Engineer ☐
[4] Forman ☐
[5] Other please specify ---------------------------------

3. For how long have you been working on the construction industry?

[1] 1-5 years ☐
[2] 6-10 years ☐
[3] 11-15 years ☐
[4] >15 years ☐

SECTION B: Wastage Factors

1. The following are selected factors that cause for construction material waste in Addis Ababa building construction projects. Please indicate the level of influence on the following statements regarding to your project. Please note that: 1= Very low influence; 2= Low influence; 3 = Moderate influence; 4 = High influence; and 5 = Very high influence

No.	A. Design and Documentation	Very low influence [1]	Low influence [2]	Moderate influence [3]	High influence [4]	Very high Influence [5]
1.	Error in contract documents					
2.	Complexity and error of drawing details					
3.	Frequent design changes at construction stage					
4.	Blueprint error					
5.	Design changes and revisions					
6.	Designs which do not consider modulization					
7.	Lack of information in the drawings					
	B. Material Procurement and handling	**Very low influence**	**Low influence**	**Moderate influence**	**High influence**	**Very high influence**
1.	Ordering error, over ordering, under ordering					
2.	Suppliers error					

3.	Purchased materials that don’t comply with specification					
4.	Lack of possibilities to order small quantities					
5.	Changes in material prices					
6.	Poor quality of materials					
7.	Inappropriate storage leading to damage or deterioration					
8.	Inadequate stacking and insufficient storage on site					
9.	Wrong storage of materials					
10.	Lack of material storage space near to the construction site					
11.	Damage during transport and delivery					
12.	Theft and vandalism					
	C. Operation and workmanship	**Very low influence**	**Low influence**	**Moderate influence**	**High influence**	**Very high influence**
1.	Use of incorrect materials, thus requiring replacement					
2.	Choice of wrong construction method					
3.	Equipment malfunction					
4.	Required quantity of					

	products unknown due to imperfect planning					
5.	Information about types and sizes of products that arrives too late at the contractor					
6.	Rework due to workers mistakes					
7.	Poor workmanship					
8.	Using untrained labors					
9.	Lack of coordination among crews					
10.	Unfriendly attitudes of project team and laborers					
11.	Lack of communication between the contractors and sub-contractors					
	D. External factors	**Very low influence**	**Low influence**	**Moderate influence**	**High influence**	**Very high influence**
1.	Accidents					
2.	Inclement weather Conditions					
3.	vandalism					
	E. Site Supervision and Management	**Very low influence**	**Low influence**	**Moderate influence**	**High influence**	**Very high influence**
1.	Shortage of technical					

	professionals in the contractor’s organization					
2.	Poor site layout					
3.	Poor qualification of contractor’s technical staff assigned to the project					
4.	Ineffective control of the project progress by the contractor					
5.	Lack of strategy to material waste minimization					
6.	Owner’s poor communication with the construction parties and government authorities					
7.	Ineffective planning and scheduling of the Project by the contractor					
8.	Poor coordination and communication by the contractor with the parties involved in the project					
9.	Suspension of work by the owner					
10.	Change orders by the client					
11.	Lack of good site supervision					

SECTION C: Major factors of waste in the main construction materials during construction operations

2. Please indicate your level of agreement on the wastage level of the following construction materials on the building projects of Ethiopia. Please indicate their level on the appropriate box.

No.	Factors	Very low influence **(1)**	Low influence **(2)**	Moderate influence **(3)**	High influence **(4)**	Very high influence (5)
1. Concrete						
1	Some suppliers often deliver quantities of material smaller than what are paid for					
2	Inadequate use of vibration which leads to Honey combing					
3	Flaws in the framework assembling process					
4	Excessive dimensions of concrete structure					
5	Use of inadequate tools and equipment's					
6	Far distance between place of mixing and casting					
7	Lack of proper maintained					

	pathways					
8	Poor performance leading to rework					
9	Ordering an additional allowance of Concrete					
	2. Steel reinforcement					
1	Using longer bars than what are required					
2	Short unusable pieces are produced when bars are cut					
3	Unnecessary replacement of some bars by others of large diameter					
4	Poor handling because its cumbersome to handle due to weight and shape					
5	Nonoptimized cutting of bars					
6	Structure design was poor in terms of standardization and detailing					
7	Damage during storage and rusting					
	3. Timber Formwork					
1	Nonoptimized cutting of timber boards					
2	Cutting the longer timber although the required are found					

3	Cutting for internal finishing and fittings					
4	Wrong storage					
5	Using for other purposes					
6	Deterioration resulting from unpainted before use and unclean after use					
7	Breaking of timber boards during the removal of the frames					
8	Use of low-quality timber					
	4. Cement					
1	Loading the cement manually in the mixer using inadequate equipment's and tools					
2	Excessive quantities during mixing more than the required					
3	Wrong storage					
4	Inappropriate way of transportation					
5	Multiple handling of the same batch of mortar					
6	Excessive consumption of mortar in joints					
7	Mixing of quantities more than the required					

8	Damage resulting from severe weather conditions					
9	Mixing in unsuitable places					
10	Damage the external plaster due to rainfall					
11	Excessive thickness of plaster					
12	Poor performance causing redoing					
13	Damage the fall mortar during plastering					
14	Excessive thickness for concrete floor screed					
	5. Sand					
1	Poor storage					
2	Excessive consumption of sand					
3	Damage the remained quantities in the place work					
4	Weather condition					
	6. Aggregate					
1	Excessive quantities during mixing					
2	Mixing quantities greater than the required					

3	Wrong handling					
4	Far distance between place of mixing and casting					
5	Poor distribution of material in site					
6	Losing the aggregate during passing the equipment's on it					
7	Neglecting the aggregate remainder					
	7. Tiles					
1	Unpacked supply (fragile)					
2	Damage during finishing					
3	Excessive quantities of tiles on site					
4	Poor distribution of tiles in site					
5	Damage during transportation					
6	Damaging the tile during the necessary cutting process					
7	Inadequate workers					
8	Manufacturing defects					
9	Cutting the tiles in great quantities					
10	Damage of the remains left on site					
11	Rework because of executive mistakes					

8. Block						
1	Excessive cutting of blocks					
2	Block damage during the process of cutting					
3	Damage the blocks during unloading and transportation operation					
4	Damage of the unused quantities left on site					
5	Manufacturing defects					
6	Lack of halves and quarters of blocks					

SECTION D: Measures Taken for Minimizing Construction Material Wastage

1. Is there any kind of techniques used to minimize this material wastage in your site?

☐ Yes ☐ No

If your answer is yes, please list some of them

----

2. What are your recommendations to minimize material wastage in Ethiopian building projects?

APPENDIX B

Key informant Interview Questions

1. What are the external factors which leads to construction material wastage?
2. Do you have any waste minimization techniques?
   If yes, what kind of techniques do you use for construction material waste minimization?
3. Do you have any recommendation to minimize construction material waste in Ethiopian building projects?

APPENDIX C

Overall Results of Wastage Factors

Construction Material Wastage factors	Category	Mean	SD	RII	Overall Rank
Frequent design changes at construction stage	Design and Documentation	4.31	0.882	0.86	1st
Rework due to workers mistakes	Operation and workmanship	4.11	1.022	0.82	2nd
Poor quality of materials	Material Procurement and handling	4.07	1.026	0.81	3rd
Change orders by the client	Site Supervision and Management	4.04	0.982	0.81	4th
Ordering error, over ordering, under ordering	Material Procurement and handling	4.02	0.983	0.8	5th
Use of incorrect materials, thus requiring replacement	Operation and workmanship	4.02	0.971	0.8	5th
Owner's poor communication with the construction parties and government authorities	Site Supervision and Management	3.97	1.022	0.79	7th
Lack of strategy to material waste minimization	Site Supervision and Management	3.96	1.005	0.79	8th
Inappropriate storage leading to damage or deterioration	Material Procurement and handling	3.94	0.998	0.79	9th
Lack of coordination among crews	Operation and workmanship	3.94	1.01	0.79	9th
Lack of good site supervision	Site Supervision and Management	3.94	1.01	0.79	9th
Damage during transport and delivery	Material Procurement and handling	3.93	0.992	0.79	12th

Lack of material storage space near to the construction site	Material Procurement and handling	3.91	1.002	0.78	13th
Wrong storage of materials	Material Procurement and handling	3.9	0.984	0.78	14th
Poor coordination and communication by the contractor with the parties involved in	Site Supervision and Management	3.9	1.061	0.78	14th
Theft and vandalism	Material Procurement and handling	3.89	1.011	0.78	16th
Suspension of work by the owner	Site Supervision and Management	3.88	1.037	0.78	17th
Lack of communication between the contractors and sub- contractors	Operation and workmanship	3.87	1.008	0.77	18th
Unfriendly attitudes of project team and labors	Operation and workmanship	3.82	0.978	0.76	19th
Ineffective control of the project progress by the contractor	Site Supervision and Management	3.76	0.987	0.75	20th
Lack of information in the drawings	Design and Documentation	3.63	0.756	0.8	21st
Error in contract documents	Design and Documentation	3.51	0.723	0.7	22nd
Complexity and error of drawing details	Design and Documentation	3.51	0.723	0.7	22nd
Design changes and revisions	Design and Documentation	3.47	0.737	0.69	24th
Inclement weather Conditions	External factor	3.39	1.296	0.68	25th
Ineffective planning and scheduling of the Project by the contractor	Site Supervision and Management	3.38	1.214	0.68	26th
Designs which do not consider modulization	Design and Documentation	3.37	0.71	0.67	27th

Inadequate stacking and insufficient storage on site	Material Procurement and handling	3.3	0.694	0.66	28th
Blueprint error	Design and Documentation	3.27	0.897	0.65	29th
vandalism	External factor	3.18	1.337	0.64	30th
Poor qualification of contractor's technical staff assigned to the project	Site Supervision and Management	3.14	0.894	0.63	31st
Purchased materials that don't comply with specification	Material Procurement and handling	3.09	0.907	0.62	32nd
Required quantity of products unknown due to imperfect planning	Operation and workmanship	3.08	0.864	0.62	33rd
Shortage of technical professionals in the contractor's organization	Site Supervision and Management	3.03	0.814	0.61	34th
Using untrained labors	Operation and workmanship	2.98	0.936	0.6	35th
Poor site layout	Site Supervision and Management	2.98	0.912	0.6	35th
Choice of wrong construction method	Operation and workmanship	2.93	0.859	0.59	37th
Poor workmanship	Operation and workmanship	2.84	0.873	0.57	38th
Suppliers error	Material Procurement and handling	2.77	0.849	0.55	39th
Equipment malfunction	Operation and workmanship	2.77	0.862	0.55	39th
Information about types and sizes of products that arrives too late at the contractor	Operation and workmanship	2.76	0.903	0.55	41st
Accidents	External factor	2.69	0.967	0.54	42nd

Lack of possibilities to order small quantities	Material Procurement and handling	2.41	0.579	0.48	43rd
Changes in material prices	Material Procurement and handling	2.34	0.564	0.47	44th