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"Managing and Minimizing Wastage of Construction Materials on Selected Public Building Projects in Addis Ababa"

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DECLARATION

This thesis is my original and has not been presented for a degree in any other university, and that all sources of materials used for the thesis have been duly acknowledged.

Name Kalid Abdu Ali

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Place St. Mary's University

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Date of submission June 14, 2021

DEDICATION

I would like to dedicate this work to my family and my friends for their sacrifice and endless support.

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LIST OF ABBREVIATIONS

BC = Building Contractors

EPD = Environmental Protection Department

GC = General Contractors

GNP = Gross National Product

HCB = Hollow Concrete Block

MoWUD = Ministry of Works and Urban Development

RC = Road Contractors

RII = Relative Importance Index

SC = Specialized Contractors

SPSS = Statistical Package for Social Science

Contents

List of tables

List of figures

List of charts

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. Specifically in our country Ethiopia, it covers 58% of the annual budget. The successful execution of construction projects within given cost, time and quality, good handling of construction materials on construction site requires systematic planning and controlling of the construction works. The type of materials produced to serve the industry range from raw goods such as sand, aggregates, soil and water to manufactured goods such as bricks, cement, plasterboard, metals (steel and iron), timber, concrete, cement, and plaster. Because of a high rate of consumption of these materials, waste is generated in large quantities, which can have significant impact on the environment. Therefore, this research was attempt to assess the current situation of managing and minimizing wastage of construction materials in the Addis Ababa on selected public building construction projects and formulates and gives recommendations with respect to handling of construction materials in accordance with the outcome of the paper. The main tools for the collection of data included questionnaires, interviews and site visit were used 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. 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 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 results of this 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.

Key words: - **Construction, Construction materials, Waste management & Waste minimizing**

CHAPTER ONE

1. INTRODUCTION

1.1.Background

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 and sewerage civil works etc. are some of the major projects (program) in the construction industry. Material management is defined as the process to provide right material at right place at right time in right quantity to minimize the cost of project. Material management is concerned with the planning, identification, procuring, storage, receiving and distribution of material (Pataskar, 2013). If we didn't manage properly waste can occur in the project. 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 (Mahesh, 2011).

From 2003 to 2004, the global construction industry grew by 6.6%. In 2003 the largest global construction firms were Vinci of France ($12 Billion (B) domestic/$8B international revenue), and Skanska of Sweden ($3B domestic/$14B international). The largest international construction market is Europe. The second largest international construction market is Asia/Australia with China being the single fastest growing market. Transportation is the largest sector in the international construction market (27.5%), followed by general building (25.4%) and petroleum infrastructure (18.7%) (Conway, 2005).

The important of material management is to ensure that the materials are available at their point of use when needed, contractor to consider that there may be significant difference in the date that the material was requested or date when the purchase order was made, and to minimize wastage of construction material. Minimizing waste can be important for environment like less use of natural resources, lower CO_2 emissions also it important for construction stake holders like client by minimizing the cost of material and also time.

Construction is not only one of the major sectors of an economy but it is also 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 in our country Ethiopia, it covers 58% of the annual budget (Semere, 2006) but the construction industry in developing countries failed to meet expectations of governments, clients and society as a whole (Yimam, 2011).

One of the failed areas is material waste, material waste is a major problem in the Ethiopian construction industry that has important implications both for the efficiency industry and for the environmental impact of construction projects due to lack of effective management and planning. The type of materials produced to serve the industry range from raw goods such as sand, aggregates, soil and water to manufactured goods such as bricks, cement, plasterboard, metals (steel and iron), timber, concrete, cement, and plaster. Because of a high rate of consumption of these materials, waste is generated in large quantities, which can have significant impact on the environment (Bell L., 1987).

The materials management in Ethiopian construction industry, especially on public building construction project in Addis Ababa is done usually by experience and using traditional methods. It is also viable that lack of proper construction materials management system in the country contributes to the high construction cost and poor quality of construction products in Ethiopia. Therefore, the mentioned issues indicate that need to develop an effective constructions materials management system in Ethiopia construction projects, in general and handling construction materials will need attention for result of a completed project with good quality and within the schedule.

The Purpose of this study is too engaged in the construction industry how they can managing and minimize wastage of construction materials while they produce, transport and stored at construction site. In addition, this study intends to provide some framework for the development of policies and rules in the management of construction waste.

1.2.Statement of the problem

Construction is not only one of the major sectors of an economy but it is also 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 in our country Ethiopia, it covers 58% of the annual budget (Semere, 2006). Waste in the construction industry is important not only from the respective of efficiency, but also concern has been growing in recent years about the adverse effect of the waste of building materials on the environment. This kind of waste typically accounts for between 15 and 30% of urban waste. A wide range of measures have been used for monitoring waste, such as excess consumption of materials, quality failure, costs and maintenance and repair costs, accidents, and nonproductive time (Carlos Torres Formoso, 2002) Generally, the construction industry in developing countries failed to meet expectations of governments, clients and society as a whole (Yimam, 2011).

The type of materials produced to serve the industry range from raw goods such as sand, aggregates, soil and water to manufactured goods such as bricks, cement, plasterboard, metals (steel and iron), timber, concrete, cement, and plaster. Because of a high rate of consumption of these materials, waste is generated in large quantities, which can have significant impact on the environment (Bell L., 1987).

The lack of data about managing and minimizing construction materials waste composition and quantities is a major gap, which has inhibited the development of waste management in Ethiopia. Construction managers often fail to identify and control waste in the construction process, because the absence of appropriate tools to measure waste. The amount of construction waste on site cannot be overlooked. Waste quantification at the job sites is crucial as a waste evaluation in waste minimization. To benchmark the construction waste management practices, whether standard, good or best practices, the construction waste quantity may act as an indicator. (Hassan, 2018)

Therefore, this research was determining the current situation with regard to managing and minimizing construction materials waste in Ethiopia, especially in Addis Ababa and assess the effectiveness of the waste control measures with a view to seeking for ways to minimize construction materials waste in future construction projects.

1.3.Research Questions

To achieve the objectives this Research, the following questions was asked

1. What is the major wastage source of construction materials on building construction sites?
2. What is the existing rate of construction waste (quantitative) generating in selected public construction project?
3. Which construction parties benefit by minimizing wastage of construction materials on building construction? And how?
4. What are the views of professionals on construction materials waste minimization?

1.4.Research Objectives

1.4.1. General Objective

The main objective of this study is to assess managing and minimizing wastage of construction materials on selected public building construction projects in Addis Ababa

1.4.2. Specific Objectives

1. To identify the causes of construction materials wastage on selected public building construction projects at Addis Ababa.
2. To investigate the level of construction materials wastage on public building construction project in Addis Ababa and to suggest appropriate forms to calculate percentage of waste in construction projects.
3. To assess mitigation measure managing and minimizing construction materials wastage at selected public building construction project in Addis Ababa.
4. To identify impacts of construction materials wastage on building construction.

1.5.Significance of the Research

This research is significant in that it may help the people engaged in the construction industry how they can manage and minimize wastage of construction materials while they produce, transport and stored at construction site. In addition, this study intends to provide some framework for the development of policies and rules in the management of construction waste.

1.6 Scope of the study

The case studies spent time (5 months) on five (5) building construction sites and observed the flow activities of materials (handling and storage).Both primary and secondary data were used. The primary data for the study were obtained through questionnaires as well as direct personal interviews with people involved in the project as well as the construction industry. In order to develop the questionnaire for the research, a review of textbooks and journals were used to identify the various efforts that have been made in the past to evaluate and examine the causes and impacts of concrete and concrete making materials waste on building construction project. Simple statistical analysis involving tables and percentages were used in analyzing the results from the questionnaire. Secondary sources of data were obtained from relevant literature that covered research and publication on the subject matter. Finally, the data were analyzed, discussed and conclusions and recommendations were drawn.

1.7 Limitation of the Study

This research was limited and focuses on selected public building construction projects in Addis Ababa which has project cost more than 120 million birr with managing the flow activities of materials (storage and handling) and minimizing wastage of construction materials problems in 6+which most of them are under construction. Surveys in the forms of questionnaires, site visit and personal interviews were conducted with the proponents who were undertaking referenced projects.

1.8 Organization of the study

The Organization of the study is divided in different chapters, as follows:

Chapter 1. Introduction: This section provides a background of the topic researched in this study. The main idea of this chapter is to explain the background of the problem, the objectives and the contribution made by this project.

Chapter 2. Literature Review: This chapter were provides information about the main subjects of this thesis; causes and sources of construction materials waste on building construction project and to Providing the practical suggestions and recommendations to upgrade the knowledge of managing and minimize the construction materials waste on public building in Addis Ababa. In addition, this chapter will be provides a theoretical foundation with the formulation of some propositions, which are the basis for the methodology research.

Chapter 3. Methodology:- This chapter provides the plan of the research. In other words, this section explains the research paradigm, approaches, strategies and data collection methods. In this project, a case study strategy is used to confirm or reject the propositions.

Chapter 4. Case Study Analysis and Discussions:- this section were provides the results from the case studies and analysis to makes a comparison with the existing literature. In addition, these results are used in this section to see the way in which they help confirm or reject the hypotheses. On the other hand, this chapter also provides a critical evaluation of this work including the limitations of the research.

Chapter 5. Conclusions and Recommendations: This section will be summarizes the main issues of this dissertation and it provides an overview of the main findings. It also concludes if the project met the proposed objectives and the way in which this dissertation was useful to confirm or reject the hypothesis.

CHAPTER TWO

2. LITERATURE REVIEW

2.1.Theoretical literature

Ethiopia has a rich history of magnificent construction endeavors. The obelisks of Axum the rock-hewn churches of Lalibela and the castles of Gondar are a few examples of this expertise. With the advent of modern civilization, particularly during the reign of Emperor Menelik, there have been some significant developments in this regard. The Addis-Djibouti railway line is one example where such a venture has been successfully carried out. During the Italian occupation of the 1930‟s there were some construction activities, particularly in the development of long trunk roads. After the Italian occupation and before the 1960‟s, expatriate contractors generally dominated most of the medium and small civil and building projects (Kahssay, 2003).

Waste generated because of design & 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 offsite 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 (www.wrap.org.uk/construction).

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 don't 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 etc.)

2.1.1. Estimation and auditing of waste

The estimation of waste provides information on the quantities of the different types of waste that will be generated from projects. The first step in implementing a waste minimization program is to estimate the quantity of construction waste that will be generated from projects. The waste at work places can be estimated and audited as follows (Al-Moghany, 2006)

Concrete waste

The amount of concrete waste can be estimated if the material wastage level of concrete is known. Recent research indicated that the average wastage level is about 4%, which is considered the norm for the concreting trade in this guideline. However, it could be reduced to 3% if careful material ordering and handling is applied. The amount of waste can be estimated according to: Quantity of concrete works (m3) x Material wastage (%)

Waste from block work and brickwork

Inert granular waste generated by block work and brickwork is estimated to be 10% of the quantity of this work required in the building project. The estimate can be calculated as the following: Amount of waste = Quantity of work done (m2) x thickness (m) x Material wastage (%)

Waste from screeding and plastering

A higher wastage of 15% is given as the norm since these trades are difficult to control. The estimate can be calculated according to: Amount of waste = Quantity of work done (m2) x thickness (m) x Material wastage (%)

Waste from timber formwork

Timber formwork is assumed to have been used at least 12 times before being discarded. The timber waste can be estimated according to: Amount of waste = Quantity of formwork (m2) x thickness (m) ÷ 12 (number of uses).

2.1.2. Wastage of key construction materials on projects sites

A lot of studies have been undertaken concerning the wastage of materials on construction sites. Some of the materials that are wasted on the construction sites include steel reinforcement, concrete, formwork, blocks, cement, mortar, tiles, pipe, aggregate as follows.

Steel reinforcement

Steel reinforcement bars are common materials used in building (Shen, 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 (Formoso, 2002). The main causes of wastage of steel are as a result of cutting, damages during storage and rusting (Shen, 2002). According to (Formoso, 2002), there are three main reasons that can be pointed out 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.
- Structural design that is poor in terms of standardization and detailing, causing waste due to non-optimized cutting of bars.

Concrete and concrete making materials

There are two types of mixed concrete, concrete ready mixed (premixed concrete) and concrete site mixed (Formoso, 2002). Concrete is the most widely used material both for substructure and for superstructure of buildings. The wastage mainly results from the mismatch between the quantity of concrete ordered and that required in the case of ready mixed concrete supply. The contractor may not know the exact quantity because of imperfect planning, leading to over-ordering. Concrete wastes also result from project delays and unnecessary waste handling processes (Shen, 2002)

In a survey 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 (Poon, 2001). According to (Bossink, 1996), the building contractor may not know the necessary quantity because of imperfect planning. This leads to over- ordering and overfilling of the means of transport and formwork. If the formwork is overfilled, skimming becomes necessary, i.e., leveling off the concrete poured into the formwork.

A. Cement

Analyzing the waste of cement is relatively complex due to the fact that this material is used as a component of mortar and cast in-place concrete in several different processes, such as brick work, plastering, and floor screed.

1. **Plastering: -** was usually done by applying cement and sand mortar onto a wall and then troweling it smooth. This was especially essential for concrete components that were cast by the in-site concreting method. The production of plastering waste was primarily due to excessive mixing/left over of mixed plaster, lost during applying and poor storage. Other sources of plastering waste included off-cuts, residues remained in spoiled bags and packaging (AlMoghany, 2006).

2. **Mortar:** - is used to set blocks and bricks as well as finish off the facings of the buildings. The main causes of waste here is the scraping out of mortar from the spaces between the facing bricks. Other causes of waste are mixing too much mortar and spilling during its transport around the building site. Too much mortar being mixed creates residues in tubes, wheelbarrows, and mixer. The supplier is partly to blame, as contractors are usually faced with a minimum-order obligation and therefore usually receive too much mortar (Al-Moghany, 2006).

B. Sand, Lime, and Premixed Mortar

The main causes of cement waste can also explain most of the problems related to sand, lime, and premixed lime and sand mortar. 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 (Sagoe, 2011). According to (Formoso, 2002), Some companies in Brazil have started using packed ready-to-use mortar mix, which tends to eliminate many of the problems related to delivery control, handling, and transportation. 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.

Timber formwork

In Hong-Kong, timber for formwork is a major contributor to construction waste accounting for 30% of all wastes identified on construction sites. Timber possesses a number of advantages that makes it a popular construction material. It is relatively inexpensive, light in weight and with a high load bearing capacity. It is also pliable and can be readily cut that it can be shaped for producing any distinct forms of concrete elements (Agyerum, 2012). However, its relatively low durability and reusability makes it a material of high wastage. The main causes of wastage are the natural deterioration that results from usage and cutting waste. Both are difficult to avoid. Another major material used for formwork is timber board.

The main causes of wastage are those that result from usage and cutting waste, both of which are difficult to avoid (Shen, 2002). A study undertaken on construction sites in Hong-Kong showed that the majority of timber waste was generated from formwork with a smaller quantity resulting from cutting timber 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 (Agyerum, 2012)

Brick and block

In most poorly performing sites, a combination of causes was related to the waste of bricks and blocks. At several sites, there were problems related to the delivery of materials, such as the lack of control in the amount of bricks or blocks actually delivered and the damage of bricks or blocks during the unloading operation. In both studies, poor handling and transportation were the major sources of waste for bricks and blocks. As in the case of mortar, multiple handling of the same batch of bricks, due to intermediate stocks along the process flow, was observed at many sites. Insufficient planning of the site layout, lack of properly maintained pathways, and the use of inadequate equipment were among the main causes of waste. It seems that most of the problems related to delivery, handling, and transportation could be eliminated by supplying bricks and blocks on pallets (Sagoe, 2011).

Another source of waste was the need to cut blocks and bricks, due to the lack of modular coordination in design. Indeed, the percentage of cut pieces at some sites was relatively high considering a sample of 40 sites, the percentage of cut ceramic blocks in relation to the total number of blocks was, on average, nearly 18%. In this context, the waste tends to be higher if the cutting operation is not planned and needs to be executed at the installation locale (Sagoe, 2011)

Ceramic tiles

Lack of modular coordination and flaws in the integration between architectural and structural design were the main causes of the ceramic tiles waste in building construction site. At some of the sites, the lack of planning in the distribution of materials contributed to increased waste of ceramic tiles. In contrast, a few companies adopt the strategy of sending to the work face the exact number of tiles in a kit, including all necessary precut pieces. This allows the operation of cutting tiles to be centralized and thereby optimized and avoids unnecessary handling of wasted parts (Formoso, 2002).

Pipes and wires

Keeping track of the causes of waste of electrical pipes, electrical wires, and hydraulic and sewage pipes is a fairly complex task. Both electrical and plumbing services are usually subcontracted, and the materials are sometimes provided by the specialist subcontractor. As this activity tends to be very fragmented on site, such materials are often moved into and out of the site.

2.2.Conceptual Literature Review

Construction as defined by the United Nations Statistics Division is “an economic activity directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature, and other such engineering constructions as roads, bridges, dams and so forth”. It is a process that consists of the building or assembling of infrastructure in the fields of architecture and civil engineering. It comprises the building of new structures, including site preparation, as well as additions and modifications to existing ones. It also incorporates maintenance, repair, and improvements on these structures. It is the process of adding structure to real property (Centeral Statistical, 2008/09)

Control of material is relatively a new practice in the construction industry. In the present situation, the contractors and the designers are mainly concerned on how to control cost without any emphasis on waste control measures. Generally, it is accepted that cost of materials accounted for a great percentage of the total cost of construction projects. Therefore, a critical control of materials on site together with good construction management is expected to decrease the cost of construction projects.

The construction industry includes all companies primarily engaged in construction such as general contractors, heavy construction (airports, highways, and utility systems), and construction by specialist trades. Also included are companies that engage in the preparation of sites for new construction and in subdividing land for building sites. Construction work may include new work, additions, alterations, or maintenance and repairs.

Materials management in construction projects is a key function that significantly contributes to the success of a project. The management of materials in construction projects is made challenging by materials shortages, delays in supply, price fluctuations, damage and wastage, and lack of storage space. Materials management is a vital function for improving productivity in construction projects.

The management of materials should consider at all the phases of the construction process and throughout the construction and production periods. This is because poor materials management can often affect the overall construction time, quality and budget. The important for planning and controlling of materials to ensure that the right quality and quantity of materials and installed equipment are appropriately specified in a timely manner, obtained at a reasonable cost, and are available when needed. Many construction projects apply manual methods, not only for the tracking of materials, but also for materials management as a whole and this involves paper-based techniques and is problematic with many human errors (Narimah Kasim, 2013)

2.2.1. Definition of waste

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 (Mahesh, 2011)

Waste has been considered as a major problem in the construction industry. Waste in construction is not only focused on the quantity of waste of materials on site, but also related to time waste. Waste in the construction industry has been the subject of several research projects around the world in recent years. Some of them have focused on the environmental damage those results from the generation of material waste. On the other hand, there have been a number of studies mostly concerned with the economic aspect of waste in the construction industry (Agyerum, 2012).

All those activities that produce costs, direct or indirect, and take time, resources or require storage but do not add value or progress to the product can be called non-value – adding activities or waste (Al-Moghany, 2006). Waste in construction is not only focused on the quantity of waste of materials on-site, but also related to several activities such as overproduction, waiting time, material handling, processing, inventories and movement of workers (Agyerum, 2012). Construction site waste can be described as the non-hazardous by-product resulting from activities during new construction and renovation. It is generated during the construction process because of factors such as site preparation, material use, material damage, material non-use, excess procurement and human error (Macozoma, 2002)

Waste in construction can be classified into two main types; waste of materials and waste of time (Agyerum, 2012). However, this research focuses on materials waste.

Material waste

Construction material wastes refer to materials from construction sites that are unusable for the purpose of construction and have to be discarded for whatever reason. Construction material waste is defined as any material apart from earth materials, which needs to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process (Agyerum, 2012).

Generally, wastages of building materials can be divided into two types. One is direct waste and the other is indirect waste. Direct waste is 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.

2.2.2. Materials Management Issues in construction projects

The construction industry is the most significant industry in the economy and the successful measure with completion within time, budget, accordance with specification and satisfaction of stakeholders. Construction is the process of physically erecting the project and putting construction equipment, materials, supplies, supervision, and management necessary to accomplish the work. Construction projects are complex, with many organizations involved such as clients or owners, architects, engineers, contractors, suppliers and vendors (seller). This includes the heterogeneous and often complex process of producing unique, large and immovable products with a supply of the resources (money, equipment, material, and labour).

As projects grow in scale, complexity, materials management becomes more difficult, frequently requiring the use of appropriate tools, and techniques to ensure, amongst other things, that materials are delivered on time, stock levels are well managed, the construction schedule is not compromised, and that wastage is minimized. Materials management is especially problematic for large and complex projects, where sophisticated tools and techniques are necessary. The management of materials in complex construction projects needs adequate consideration due to the various elements involved and the importance of the project. The improper handling and management of materials on construction sites has the potential to severely buildup project performance. The result of improper handling and managing materials on site during construction process will influence the total project cost, time and the quality (Kasim, 2013).

2.2.3. Sources of materials waste

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

Natural Waste

Natural waste is the wastage that costs more than what is saved if tried to prevent. There is a certain limit up to which, waste of materials can be prevented. Beyond that limit, any action taken to prevent 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 vary from one situation to another and so do the natural waste. For instance, cost of preventing 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 acceptable level of natural waste in the former situation will be lesser than the later (Carlos Torres Formoso, 2002)

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 (Carlos Torres Formoso, 2002).

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).

2.3.Empirical literature

From 2003 to 2004, the global construction industry grew by 6.6%. In 2003 the largest global construction firms were Vinci of France ($12 Billion (B) domestic/$8B international revenue), and Skanska of Sweden ($3B domestic/$14B international). The largest international construction market is Europe. The second largest international construction market is Asia/Australia with China being the single fastest growing market. Transportation is the largest sector in the international construction market (27.5%), followed by general building (25.4%) and petroleum infrastructure (18.7%) (Conway, 2005).

According to (MoWUD, 2013) the local construction firms are broadly classified based on trend of work as follows: General Contractors, GC; Building Contractors, BC; Road Contractors, RC; Specialized Contractors, SC. The first three categories are again divided into ten grades based on equipment, man-power and turnover requirement. However, it is common to come across selfdeclared contractors without any professional competence and license registration in many construction sites. The self-building sector is characterized by an informal sector, consisting of informal groups that supply materials and labor. These informal groups are not licensed or registered. However, they employ a great number of people. Now a day according (MoWUD, 2014) there are over 4034 contracting companies registered under G1 up to G10 in Ethiopia.

2.3.1. Magnitude of Materials waste in building construction

The magnitude of waste at construction sites is considerable. Studies showed that the waste rate was different between developed countries and developing countries as follows

Magnitude of Construction Materials waste in developed countries

According to (Bossink & Brouwers, 1996) a research conducted in the Netherlands that was concerned with the measurement and prevention of construction waste with regard to meeting sustainability requirements stated by Dutch environmental policies. Waste from seven materials was monitored in five house-building projects between April 1993 and June 1994. During the study, all material waste was sorted and weighed. The amount of direct waste by weight ranged between 1 and 10% in weight of the purchased number of materials. Further, it was concluded that an average 9% (by weight) of the total purchased construction materials end up as site waste in the Netherlands.

A study in Malaysia shows, composition and percentage of material wastes: Soil 27%, wood 5%, brick and blocks 1.16%, metal product 1%, roofing material 0.20%, plastic and packaging materials 0.05%, concrete and aggregate 6.58% (Begum, 2006). (Jones and Greenwood, 2003) Obtained percentage of waste in ten materials as plasterboard 36%, packaging 23%, cardboard 20%, insulation 10%, timber 4%, chipboard 2%, plastic 1%, electric cable 1%, and rubber 1%

A study carried out by (Rameezden, 2004) in Sri Lanka identified the main materials wastages as Sand (25%), Lime (20%), Cement (14%), Bricks (14%), Ceramic Tiles (10%), Timber (10%), Rubble (7%), Steel (7%), Cement Blocks (6%), Paint (5%) and Asbestos Sheets (3%). Research in Hong Kong indicates that about 5-10% of building materials end up as waste on building sites. There are many contributory factors to this figure, human, mechanical and others (Poon, 2004)

Magnitude of Construction Materials waste in developing countries

In developing countries (Tanzania, Zambia, Zimbabwe and Botswana) the followings are estimated; 40% of construction is rework, 30 to 40% labor potential is used, 8% of total project costs account for accidents and 20 to 25% of materials are wasted (Datta, 2004)

Research in Nigerian construction sites, indicated four major types of construction materials waste. These include cutting waste, transit waste, theft and vandalism waste, and application waste. The studies concluded that the identified construction materials under cutting waste indicated that reinforcement bars had highest percentage of wastages of 19.03%, followed by wires and cables with wastage of 17.26%, roofing sheets and pipes both have 15.70% wastage. Moreover, the identified construction materials under transit waste indicated that tiles had highest percentage of wastages of 21.38%, followed by window glazing and ceramic sanitary appliances with percentage wastages of 14.73% and 14.72% respectively

(Babatunde, 2012). In addition, the studies in Nigeria identified construction materials under theft and vandalism waste revealed that reinforcement bars, timber (hardwood and softwood) and cement had the highest percentage of wastages of 18.64%, 18.64% and 18.44% respectively

Furthermore, the identified construction materials under application waste showed that POP (Plaster of Paris) ceiling had the highest percentage of wastage of 15.70%, followed by mortar (through screeding) with wastage of 14.91% and concrete (through columns, beams, lintels and walls) had percentage wastages of 14.13%. Moreover, the study concluded that theft and vandalism waste had the highest average level of 16.58% followed by cutting waste with 15.44%. Application waste and transit waste had the least overall average wastage of 14.16 % and 14.89% respectively. The study finally concluded that construction materials wastage accounted for an average of 15.32% in the Nigerian construction sites. Therefore, the study recommended 15-20% allowance for construction materials waste in Nigeria (Babatunde, 2012)

According to (Mahesh, 2011) in some Brazilian building sites the sources of waste were organized into

- Overproduction; - Related to the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man-hours or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar that cannot be used on time.
- Substitution: - Related to the substitution of a material by a more expensive one (with an unnecessary better performance); the execution of simple tasks by an over-qualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough.
- Waiting time: - Related to the idle time caused by lack of synchronization and leveling of material flows, and pace of work by different groups or equipments. One example is the idle time caused by the lack of material or by lack of work place available for a gang.
- Transportation: - Concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways can cause this kind of waste. It is usually related to poor layout, and the lack of planning of material flows. Its main consequences are: waste of man hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.
- Processing - Related to the nature of the processing (conversion) activity, which could only be avoided by changing the construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered.
- Inventories: - Related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, vandalism), and monetary losses due to the capital that is tied up. It might be a result of lack of resource planning or uncertainty on the estimation of quantities.

- ❄ Movement: - Concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.
- ❄ Production of defective products: - It occurs when the final or intermediate product does not fit the quality of specifications. This may lead to rework or to the incorporation of unnecessary materials to the building (indirect waste), such as the excessive thickness of plastering. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification of the team work, lack of integration between design and production, etc.
- ❄ Others: - Waste of any nature different from the previous ones, such as burglary, vandalism, inclement weather, accidents, etc.

Research in Indian construction industry indicates the following causes of material waste at construction site (Mansi, 2012).

- ❄ Lack of Awareness in the Industry: The major barrier in the industry is the lack of awareness among local contractors, construction labor and architects about waste management techniques and approach. Usually most of the waste that is produced during the construction process is the result of poor handling and techniques.
- ❄ Lack of interest from clients: Another main reason for an ignorant industry is lack of importance given by clients in imposing waste reduction and management practices into the projects. Clients do not support those activities, which do not offer tangible benefits to them. Potential of significant cost saving is not yet voluntarily implemented in projects and timing is given major preference.
- ❄ Lack of proper training and education: Lack of contractor‟s federations and professional institutes in the country which could significantly raise awareness among the clients and contractors about the possible economic benefits and its social consequences.
- ❄ Lack of skilled labor: Major portion of construction labor in the industry is unskilled. Due to which proper waste handling methods are not adopted. Thus, it is very important that contractors and sub-contractors should develop awareness and skills in labor which is mostly illiterate.
- ❄ Lack of market competition: The above-mentioned barriers make the industry as a whole to be fragmented and fail to extract benefits from the much evident aspects. This leads to lack of competition among contractors, for e.g., if one contractor makes good cost savings from a project and increases their profit margins. Eventually this should then incentivize other contractors to get involved with waste minimization and management techniques. But mostly from a contractor‟s viewpoint, taking up waste minimization and management is more of ex ante issue where risks are associated with the contractor to bear the cost implications. This will become widespread only after taking project initiative and then benefiting from them.
- ❄ Lack of Government Interventions: Government regional, national policies and regulations are limited and are not implemented appropriately. Regulations like

landfill tax or tax incentives to incorporate this approach in the project might enforce industry to explore cost savings seriously.

- Lack of waste reduction approach by architects: Usually architects do not give preference to waste minimization approach during design and planning stage. Designing as per standard minimum sizes will eliminate wastage on sites.

2.4.Synthesis

2.4.1. Materials Control on Site

Control of the materials used start from the time which the contractor is handed over the site. All materials delivered to site must compared with the relevant standards. Moreover, the general waste of Construction materials on site, there is a lot of damage, and this is often due to poor management by contractors and lack of proper supervision. Responsibility for materials must begin with the person handling them. Many foremen and supervisors see their main function as that of materials supplier to the group they are responsible for, ignoring materials handling. If a materials controller is appointed to anticipate materials requirement and distribute supplies, trades foremen will have enough time to do their job properly. Site management is ultimately responsible for materials use and handling (Agyerum, 2012). Materials may be kept on site over long or short period of time until they are needed. Storage also means expenditure of capital, and money and contractors are reluctant to purchase materials in advance, except for those needed almost immediately (Addise, 2005)

According to (Agyerum, 2012) the activities of materials control fall into four basic categories.

- Materials Planning
- Material Availability
- Material Movement
- Material Feedback

2.4.2. Construction materials Waste in handling

On the most of sites it would be difficult to decide which materials were worst affected, bricks, blocks, concrete or mortar, although the waste from bagged plaster and cement has always been exceptionally high. Whenever concrete is used in large quantities it is wasted and one reason for that is the quantities required have been miscalculated (Addise, 2005). The construction industry has changed considerably in recent years, influencing production rates, construction techniques and the total quantity of materials each year. The increase in the total quantity of materials used has in turn led to an increase in the amount of waste. Materials waste can be classified as loss through poor site security, inefficient handling, inadequate storage, and misuse in construction or manufacture, or all of which point to poor management

2.4.3. Managing and Minimizing Wastage of materials on construction projects

Construction Material wastage has been recognized as a major problem in the construction industry that has important implications both for the efficiency industry and for the environmental impact of construction projects. Moreover, waste measurement plays an important role in the management of production systems since it is an effective way to assess their performance, allowing areas of potential improvement to be pointed out (Carlos Torres Formoso, 2002).

Waste management for construction activities has been promoted with the aim of protecting the environment and the recognition that wastes from construction and demolition works contribute significantly to the polluted environment. The construction industry plays a vital role in meeting the needs of society and enhancing the quality of life. However, the responsibility for ensuring the construction activities and products in consistent with environmental policies needs to be defined and good environmental practices through reduction of wastes need to be improved. Normally, the best way to deal with material wastes is not to create it in the first place (Shen, 2002).

CHAPTER THREE

3. RESRARCH METHODOLOGY

3.1.Research approach

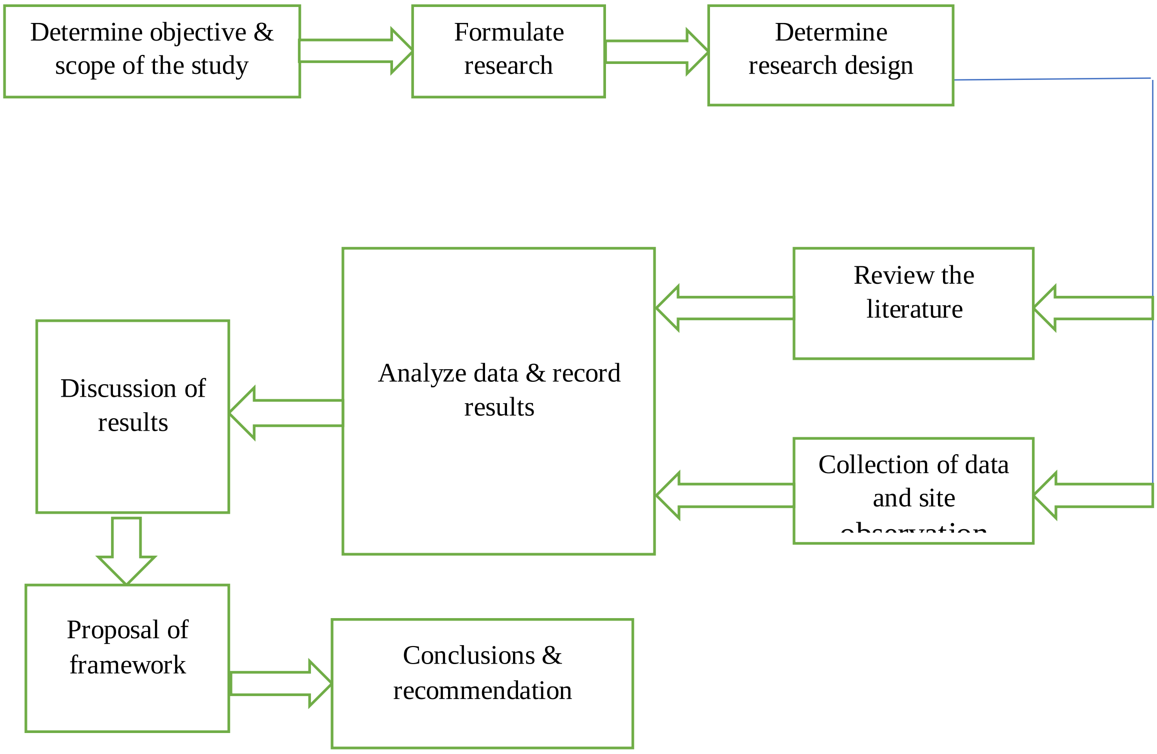
In a quantitative study, the steps involved in conducting an investigation are fairly standard (AlMoghany, 2006). In this study, interviews, structured questionnaire and site visits were used in the gathering of data. The interviews were adapted to collect detailed information about respondent's experiences and impressions about Construction materials wastage on projects. It also uses to collect preliminary information to help in structuring the questionnaires. The questionnaire survey also adapts to get feedback on opinions of respondents about wastage of building materials in Addis Ababa construction industry.

The site visits involved observations where the researcher sought to find out how materials were store and handled and also to provide a compendium on high waste generating building materials used in the construction industry. The researcher spent time (5 months) on five (5) building construction sites and observed the flow activities of materials (handling and storage).

3.2.Research Design

Research design is the overall plan for obtaining answers to the questions being studied and for handling some of the difficulties encountered during the research process. Research design is an action plan for getting from here to there where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions. Between here and there are a number of major steps, including the collection and analysis of relevant data (AlMoghany, 2006). The structured questionnaire is probably the most widely used data collection technique for conducting surveys to find out facts, opinions and views. Interviews can be classified according to the degree to which they are structured. In an unstructured or nondirective type of interview the interviewer asks questions as they come to mind. On the other hand, in the structured or directive interview the questions are specified in advance (Agyerum, 2012). The figure 3.1 shows that process of this research paper.

***Figure: - 3.1**. The Research Process*



3.3 Sampling techniques, sample size and Target Population

The term population refers to the aggregate or totality of all the objects, subjects, or members that conform to a set of specifications. In quantitative studies, the researcher identifies the population to be studied during the planning phase. A smaller population can be studied more extensively at a fixed cost than a larger population, so it is important to decide what population is really of critical importance.

The population of this research include contracting companies, consultants and public owners' sectors, the contractor's companies had valid registration according to Ministry of Urban Development and Construction (MoWUD) and a randomly selected Consultants companies and Owners, which participated on public building projects

According to (MoWUD, 2013) the local construction firms are broadly classified based on trend of work as follows: General Contractors, GC; Building Contractors, BC; Road Contractors, RC; Specialized Contractors, SC. The first three categories are again divided into ten grades based on equipment, man power and turnover requirement. There are over 4034 contracting companies registered under G1 up to G10 in Ethiopia (MoWUD C., 2014).

Therefore, the populations this research were, includes General contractors classified as (GC1-GC3), G1Consultant Company and public owners that by reconnaissance survey in Addis Ababa and have a valid registration by MoWUD. Because those selected categories are having experience, efficiency and managerial and financial capability.

Sampling is the process of selecting representative units of a construction parties for the study in research investigation. The advantage of using a sample is that it is more practical and less costly than collecting data from the construction parties. The risk is that the selected sample might not adequately reflect the behaviors, traits, symptoms, or beliefs of the participate (Al-Moghany, 2006).

In order to evaluate and assess the current situation of managing and minimizing wastage of construction materials on selected public building projects in Addis Ababa, a wide range of Construction parties involved in construction of projects were targeted.

In this research, the population includes contracting companies of first, second, third category Contractors and G1Consultants companies that have a valid registration by Ministry of Urban Development and Construction (MoWUD) in Addis Ababa. Because those selected population, will have a sufficient experience in construction, managerial capability and has more than one hundred twenty million Birr contracting amount capacity.

There are 70 total numbers of GC1, GC2 and GC3 contractors and there are 80 G1 Consultant companies registered in Addis Ababa (MoWUD C. , 2014). The sample population were distributing between contracting companies: 46 of GC1 contractors, 10 GC2 contractors, 14 GC3 contractors, 80 G1Consultant companies.

To Sample public owners in building construction sites in Addis Ababa, reconnaissance survey was made and nine (9) public owners were identified as project owners with project cost more than one hundred twenty million (120) birr during this research. Therefore, this research paper considers these owners as sample representative.

Therefore, the following equation is used to determine the sample size (Al-Moghany, 2006

{Equation 3.1} $$Ss = \frac{Z * P * (1-P)}{C}$$

Where SS = Sample size

Z = Z value (e.g., 1.96 for 95% confidence level)

P = percentage picking a choice, expressed as a decimal (0.50 used for sample size needed).

C = margin of error (9%)

So Ss = 119

Correction for Finite Sample: -

{Equation 3.2} $$Ss\ new = \frac{Ss}{1 + Ss-1}$$

poP

Where: Total sampled of construction parties = 159 match the proposed contracting companies

Ss new =68.3 ≈68

To ensure good representation of each stratum, the following was done:

GC1 contractors = 46

Ss new GC1 contractors = 20 GC1 contractors

GC2 contractors = 10

Ss new GC2 contractors = 4 GC2 contractors

GC3 contractors = 14

Ss new GC3 contractors = 6 GC3 contractors

G1Consultants = 80

Ss new Consultants = 34 consultants

Owners = 9

Ss new owners =4 owners

3.4 Data sources and data collection techniques

A. Sources of data

The studies were depended on both primary and secondary data. Primary data made up of first-hand data collected by the candidate through the use of questionnaires, interviews and site visits (observation). The secondary sources of data were obtained using relevant books, journals, magazines and research papers.

Sources and causes of materials waste

Sources and causes of materials waste as well as twenty-four (24) waste minimization measures which have been extensively studied were extracting from the literature. The sources and causes of materials waste gathered from literature were pre-tested through interviews of ten selected construction practitioners to evaluate their applicability to the current study

Research Instrument

The research data collect mainly through interviews and questionnaires. Field observations through site visits also employed to gather data on high waste generating building materials.

Questionnaire Design

The questionnaire design undertakes to determine the opinion of contractors, consultants and client regarding the causes of material waste in selected public building construction projects in Addis Ababa. The questionnaire consists of three major sets of closed-ended and one open question on the sources and causes of materials waste and waste minimization measures, the questionnaire further sought to obtain information on the level of knowledge of construction professionals on the concept of managing and minimizing wastage of construction materials in the Ethiopian building industry. Interviews and site visit also use to obtain specific information about construction materials waste on building projects.

Structure of questionnaire

The questions were constructed using the Likert scale. The respondents were asked to rank on a scale of 0%-100% factors that cause materials waste on construction sites where E.S. = extremely significant [100%], V.S. = very significant [75%], M.S. = moderately significant [50%], S.S. = slightly significant [25%] and N.S. = not significant [0%].

Selected Sample construction parties

Based on the sampling method and criteria cited above, the researcher were selected sixty-eight (68) construction parties which participate on public building projects in Addis Ababa.

Research location

Addis Ababa is the location of this study and this research is carried out a randomly selected of five (5) public building construction projects in Addis Ababa, which their project costs are more than 120 million birr.

B. Data collection techniques and procedures

Data collection

In this research, methods of data collection include questionnaire with personal interview and site visits. The site visits involved observations where the researcher sought to find out how materials were stored and handled; and to provide a compendium on high waste generating building materials used on those selected public building construction projects.

The case studies spent time (5 months) on five (5) building construction sites and observed the flow activities of materials (handling and storage). The Photographs is taking to document how these materials were stored and handle on site.

The questionnaire survey consists 5 groups which address causes of construction materials wastage on construction project, these groups are Design and documentation, Materials handling and storage, Operation, Site management and practices and Site management and practices (The questionnaire is included in appendixes)

3.5 Data analysis techniques

The sample for this study is relatively small. As a result, the analysis has combined all groups of respondents (clients, consultants, contractors) in order to obtain significant results. Data were analyzed by calculating frequencies and Relative Importance Index (RII). The Relative Importance Index (RII) is calculated as follows (Aibinu and Jagboro, 2002).

$$RII = \frac{4n1+3n2+2n3+1n4+0n5}{4N} \quad \text{\{Equation 3.3\}}$$

Where: N = Total number of respondents

ni = the variable expressing the frequency of the ith response.

n1= Number of frequency 'extremely significant' response,

n2= Number of frequency 'very significant' response

n3 = Number of frequency 'moderately significant' response

n4 = Number of frequency 'slightly significant' response.

n5 = Number of frequency 'not significant' response

The levels of response are:

E.S. = extremely significant [100%]

V.S. = very significant [75%]

M.S. = moderately significant [50%]

S.S. = slightly significant [25%]

N.S. = not significant [0%]

CHAPTER FOUR

4 DATA ANALYSIS, RESULTS AND DISCUSSION

This chapter reports and discusses the survey findings. After the questionnaire survey was carried out, statistical analyses were undertaken on the responses using various methods described in the research methodology.

This chapter describes the results that have been obtained from processing of sixty-eight (68) questionnaires using Excel and statistical package for social sciences (SPSS). The results are prepared to present the information about the sample size, response rate and contracting companies‟ characteristics in Ethiopia especially; in Addis Ababa. It also includes the ranking of factors affecting the waste on construction projects based on their relative mean ranks, in addition to the causes of waste in some important materials, magnitude of waste, waste minimization strategies and the relative significant of construction waste sources.

4.1. Response rate

Out of the 68 questionnaires distributed on the contracting companies, 42 responses were received with 61.76 % return rate in this study. The other 26 questionnaires as follows: 16 (23.53%) have not been received, 6(8.82 %) are uncompleted and 4 (5.88 %) are illogical or incorrect responses, see chart 4.1.

***Chart: - 4.1** Questionnaires general response rate*

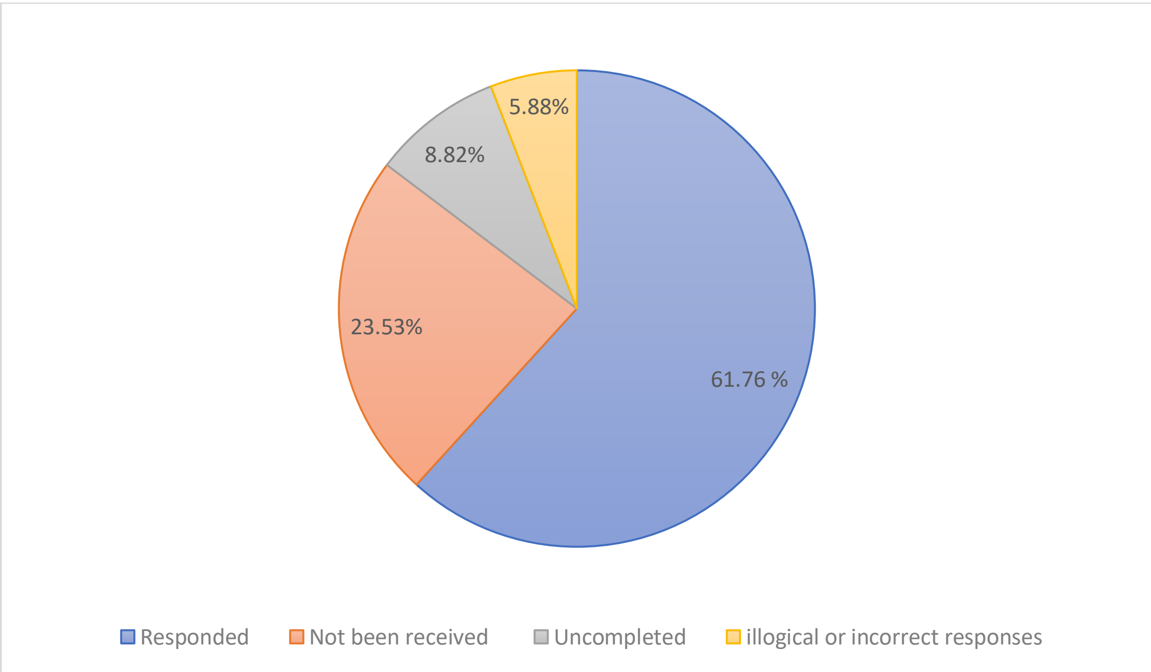


Table 4.1 represents the response rates among the groups of contracting companies, these rates are 75.00% GC1-contractors, 75.00% GC2-Contractors, 83.33% GC3-Contractors, 55.88% Consultants and 100.00% for Clients.

***Table: - 4.1** Response rates among the groups of construction parties*

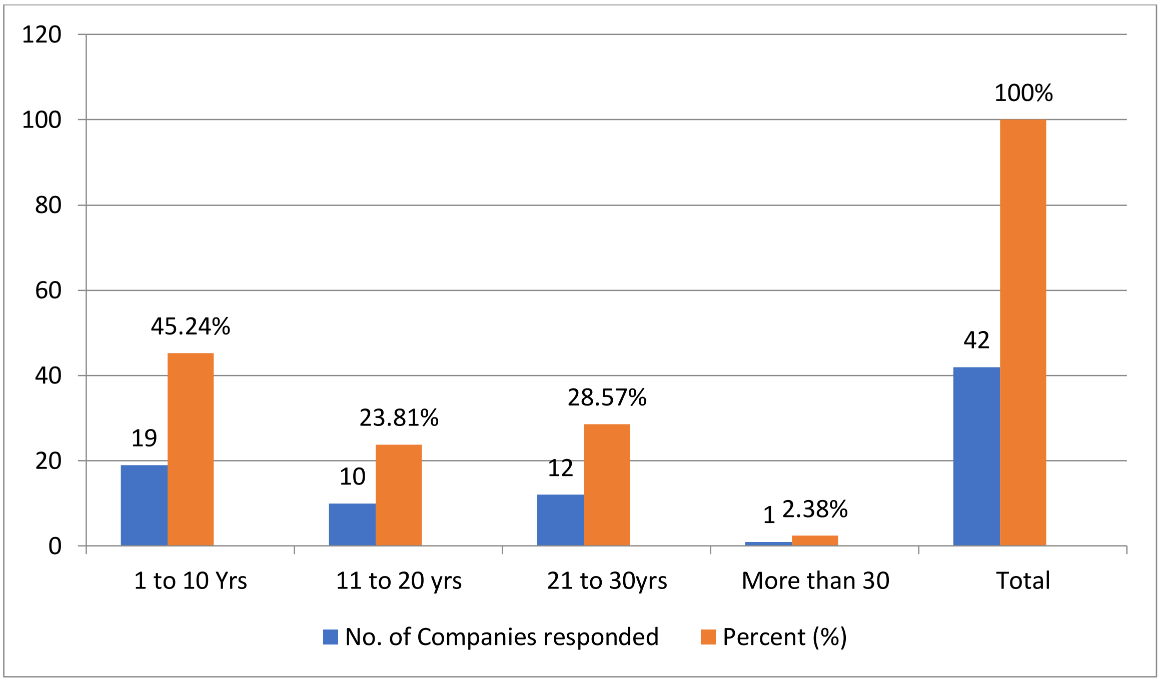
Companies' classification	*No. of Selected company sample*	*No. Relevant Responded*	*Not been received*	*uncompleted responses*	*incorrect responses*
GC-1Contractors	20	11	6	2	1
GC-2Contractors	4	3		1	
GC-3Contractors	6	5			1
Consultants	34	19	10	3	2
Clients	4	4			
Total	68	42	16	6	4

Source: own Survey (2021)

4.1.1. Respondent's experience

Chart 4.1 shows the years of experience for the surveyed contracting companies in Addis Ababa. About 45.24% of contracting companies have 1-10 years of experience and 23.81 % of them have 11- 20 years of experience and while 28.57 % of them have 21-30 and the last 2.38% of contracting companies have more than 30 years of experience.

***Chart: - 4.2** Respondent's experience on selected construction companies in Addis Ababa*

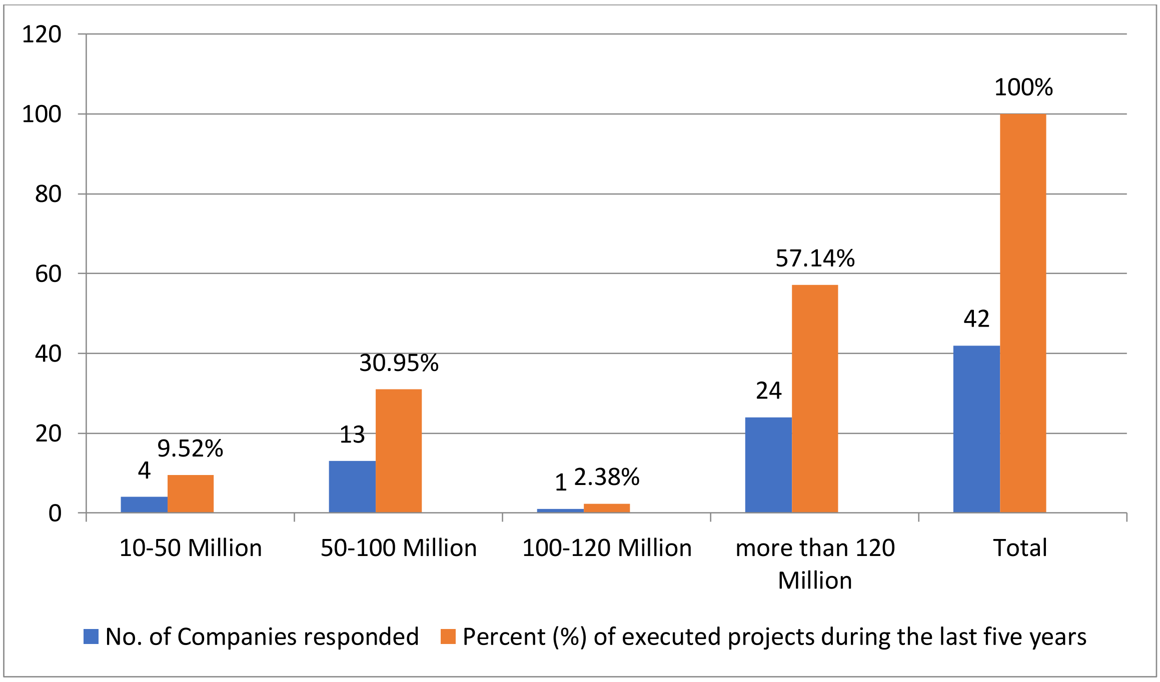


Source : Own Survey (2021)

4.1.2. Executed projects and their value during the last five years

The value of the executed projects during the last five years is illustrated in chart 4.4 (9.52%) the executed projects up to 50 million ETB, (30.95 %) of the executed projects up to 100 million ETB, (2.38%) executed projects up to 120 million ETB and while (57.14 %) of them with more than 120 million ETB.

***Chart: - 4.3** value of the executed projects during the last five years construction companies in Addis Ababa*



4.2. Background characteristics of study respondents / construction projects

4.2.1 Case study

This study covered selected Five (5) public building construction projects in Addis Ababa which Constructed and supervised by different contractors and consultant and has project costs more than 120 million birr. In this part, the respondents were asked to identify the main causes of material waste. Therefore, 30 contractors, 34 Consultant Company and 4 clients are participating to response the questionnaires.

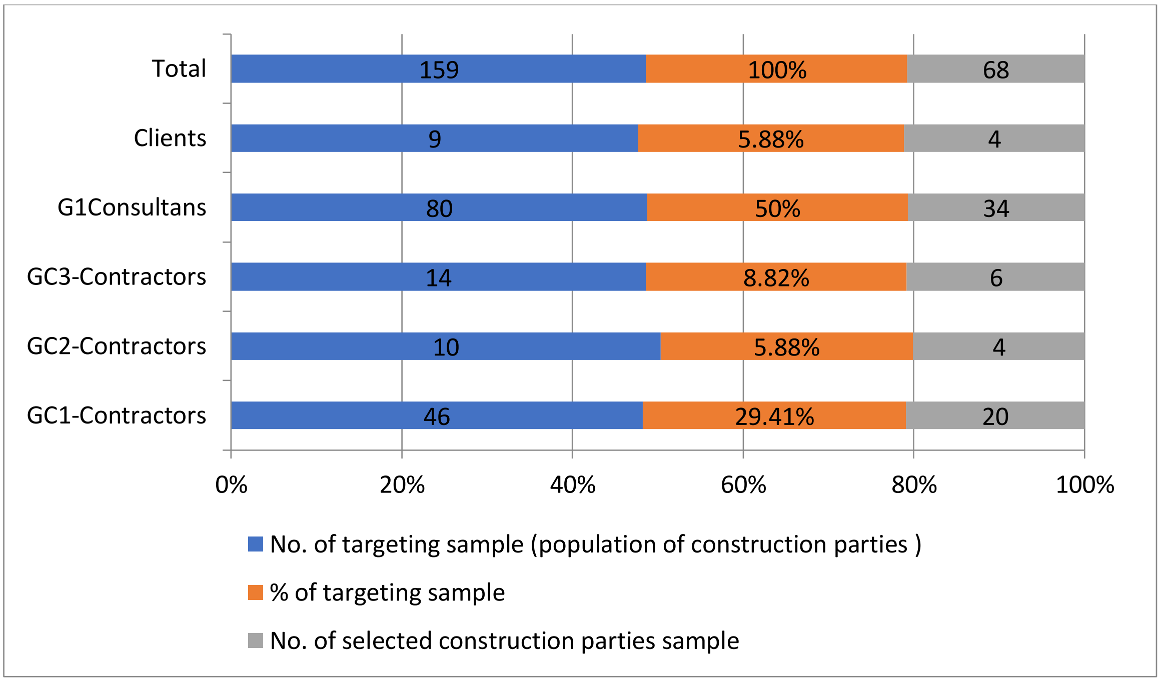
Table: - 4.2 case study information

No.	Project Name	Project Location	Project duration	Project cost (ETB)	Current status
1	The Adwa Zero Kilometer Museum project	Addis Ababa/Piassa	2 years	4.6 billion	Under Construction
2	Meskel Square project	Addis Ababa/Meskel square	10 months	500 million	Completed
3	CBE Headquarter building project	Addis Ababa/Beherawi	5 Years	5.3 billion	Under Construction
4	Addis Ababa City Public Library project	Addis Ababa/ near to Parliament	3 years	1.1 billion	Under Construction
5	Nefase Selk Lafto kfle ketema Project	Addis Ababa/garment	3 years	130 million	Under Construction

4.2.2. Classification of sample size

Chart 4.3 shows the characteristics of the sample size for the contracting companies. The sample consists of GC1-contactors (29.41 %), GC2-contactors (5.88 %), GC3-contactors (8.82 %), consultants (50 %) and client (5.88 %).

***Chart: - 4.4** Classification of sample size construction parties in Addis Ababa*



4.3. Sources and causes of construction materials waste on construction projects

There are many factors, which contribute to construction materials waste generation on site. Waste may occur due to one or combination of many causes. As discuss in literature review parts the sources of waste classified under five categories: those are design and documentation, site management and practices, Materials handling and storage, operation and site supervision.

Group 1. Design and documentation factors

Respondents were asked to score which factors are considered to be major causes of waste arising from design and documentation.

Table 4.3 shows that the Relative Importance Index of all the 13 causes of waste evaluated for the respondents (contractors, client and consultants). This means that all the thirteen factors are considered as causes of waste arising from design and documentation.

Table: - 4.3 *Ranks of construction materials wastage due to Design and Documentation factors*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Lack of knowledge about construction techniques during design activities	0.73	2	0.72	3	0.87	1	0.77	1
Rework that doesn't comply with drawings and specifications	0.79	1	0.67	4	0.62	4	0.69	2
Selecting the lowest bidder contractors and subcontractor	0.62	7	0.80	2	0.56	5	0.66	3
Design changes and revisions	0.63	6	0.53	8	0.81	2	0.65	4
Lack of attention paid to standard sizes available on the market	0.60	8	0.64	5	0.69	3	0.64	5
Ambiguities, mistakes, and changes in specifications	0.60	8	0.53	8	0.81	2	0.64	5
Poor/ wrong specifications	0.65	5	0.72	3	0.56	5	0.64	5
Selection of low-quality products	0.69	3	0.61	6	0.62	4	0.64	5
Designer's inexperience in method and sequence of construction	0.62	7	0.81	1	0.44	6	0.62	6
Poor site layout	0.66	4	0.55	7	0.62	4	0.61	7
Ambiguities, mistakes, and inconsistencies in drawings	0.56	10	0.64	5	0.62	4	0.60	8
Poor communication leading to mistakes and errors	0.62	7	0.64	5	0.56	5	0.60	8
Lack of information in the drawings	0.57	9	0.47	9	0.37	7	0.47	9

Group 2. Materials handling and storage factors

The respondents were asked to evaluate causes of construction materials waste arising from materials storage and handling. Table4.4 shows that the Relative Importance Index of all the 13 causes of waste evaluated for the respondents (contractors, client and consultants).

Table: - 4.4 *Ranks of construction materials wastage due to Materials handling and storage factors*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Wrong handling of materials	0.84	1	0.72	3	0.69	3	0.75	1
Poorly schedule to procurement the materials	0.57	10	0.75	2	0.81	1	0.71	2
Using excessive quantities of materials more than the required	0.69	6	0.64	5	0.81	1	0.71	2
Poor quality of materials	0.79	2	0.64	5	0.69	3	0.70	3
Lack of onsite materials control	0.70	5	0.78	1	0.62	4	0.70	3
Poor storage of materials	0.65	7	0.78	1	0.69	3	0.70	3
Purchased materials that don't comply with specification	0.70	5	0.67	4	0.69	3	0.68	4
Conversion waste from cutting uneconomical shapes	0.72	4	0.58	7	0.75	2	0.68	4
Insufficient instructions about storage and stacking	0.62	8	0.78	1	0.56	5	0.65	5
Overproduction/Production of a quantity greater than required or earlier than necessary	0.73	3	0.58	7	0.50	6	0.60	6
Lack storage of materials near of construction site	0.59	9	0.61	6	0.62	4	0.60	6
Damage during transportation	0.69	6	0.64	5	0.44	7	0.59	7
Over ordering or under ordering due to mistake in quantity surveys	0.57	10	0.58	7	0.44	7	0.53	8

Group 3. Operation (On site, Equipment) factors

The Relative Importance Index each of the sub-factors of the operation/on site group, which causes of construction material waste, is presented in Table 4.5 in a descending order

Table: - 4.5 *Ranks of construction materials wastage due to operation/ on site factors*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Poor workmanship	0.69	5	0.75	1	0.87	1	0.77	1
Choice of wrong construction method	0.72	3	0.72	2	0.81	2	0.75	2
Using untrained labors	0.70	4	0.75	1	0.81	2	0.75	2
Lack of workers or tradesmen or subcontractors" skill	0.75	1	0.72	2	0.75	3	0.74	3
Rework due to workers mistakes	0.72	3	0.66	4	0.81	2	0.73	4
Shortage of manpower (skilled, semiskilled, unskilled labor)	0.68	6	0.72	2	0.75	3	0.71	5
Lack of coordination among crews	0.62	7	0.67	3	0.81	2	0.70	6
Poor technology of equipment	0.68	6	0.75	1	0.62	5	0.68	7
Shortage of tools and equipment's required	0.69	5	0.66	4	0.69	4	0.68	7
Use of incorrect material, thus requiring replacement	0.68	6	0.53	6	0.75	3	0.65	8
Problems between the contractor and his subcontractors	0.68	6	0.67	3	0.56	6	0.63	9
Equipment frequently breakdown	0.73	2	0.56	5	0.44	7	0.57	10

Group 4. Site management and practices factors

The Relative Importance Index each of the sub-factors of the site management and practices group, which causes construction material waste, is presented in Table 4.6 in a descending order.

Table: -4.6 *Ranks of construction materials wastage due to site management and practices factors*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Lack of strategy to waste minimization	0.78	3	0.86	1	0.87	1	0.83	1
Poor project management	0.85	1	0.80	3	0.75	3	0.80	2
Lack of a quality management system aimed at waste minimization	0.82	2	0.80	3	0.68	5	0.76	3

Poor qualification of the contractor's technical staff assigned to the project	0.72	6	0.78	4	0.75	3	0.75	4
Ineffective planning and scheduling of the project by the contractor	0.69	7	0.78	4	0.75	3	0.74	5
Lack of proper waste management plan and control	0.75	5	0.83	2	0.62	6	0.73	6
Shortage of technical professionals in the contractor's organization	0.66	8	0.72	5	0.81	2	0.73	6
Poor management and distribution of labors, materials and equipment's	0.66	8	0.78	4	0.69	4	0.71	7
Poor provision of information to project participants	0.65	9	0.78	4	0.62	6	0.68	8
Poor coordination and communication between parties involved in the project	0.66	8	0.78	4	0.62	6	0.68	8
Lack of team work	0.76	4	0.72	5	0.56	7	0.68	8
Poor site layout	0.65	9	0.61	6	0.62	6	0.62	9

Group 5. Site supervision factors

The Relative Importance Index of each of the sub-factors of the site supervisor group, which causes construction material waste, is presented in Table 4.7 in a descending order.

Table: - 4.7 *Ranks of construction materials wastage due to Site supervisor factors*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Lack of supervision and delay of Inspections	0.69	2	0.78	1	0.81	2	0.76	1
Change orders by owner	0.70	1	0.64	4	0.94	1	0.76	1
Poor qualification of consultant engineer's staff assigned to the project	0.65	3	0.75	2	0.69	4	0.69	2
Poor coordination and communication between the consultant engineer, contactor and client	0.70	1	0.53	5	0.75	3	0.66	3
Slow response from the consultant engineer to contractor inquiries	0.60	4	0.72	3	0.62	5	0.64	4

4.3.1. Summary Sources and causes of construction materials waste on construction project

The questionnaire of this study considered 81 factors which cause material waste in construction, and those factors were distributed into five groups as mentioned before, namely, Design and documentation; Materials handling and storage; Operation; Site management and practices; Site supervision. Table 4.8 gives the result of a collected data in the second section of the questionnaire, namely, causes of construction materials waste and illustrates the mean and ranking of each group.

Table: -4.8 *Weighted average and ranking over-all causes of construction materials wastage*

Group No.	*Main groups*	*Weighted average (all groups)*	*Rank*
Group 4	Site management and practices factors	0.72	1
Group 5	Site supervision factors	0.70	2
Group 3	Operations factors	0.69	3
Group 2	Materials handling and storage factors	0.66	4
Group 1	Design and documentation factors	0.63	5

4.3.2. Causes of key construction material wastage on building sites

The results showing that the key materials, which are wasted on construction sites, are concrete, reinforcement steel, Cement, Sand, Coarse Aggregate, hollow blocks, bricks, formworks, ceramic tiles and concrete pipes. Thus, the respondents agree that formwork, cement/mortar, concrete, hollow blocks, reinforcement steel, sand, coarse aggregate, ceramic tiles and concrete pipes are all contribute to the generation of waste on building construction sites.

Concrete

Concreting is a major building material. Site managers often repine about the difficulty of controlling the number of concrete deliveries. The Relative Importance and rank of each factor of the concrete waste are presented in Table 4.9 in a descending order.

***Table: - 4.9** Relative Importance Index and ranking of concrete wastage on building construction site*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Poor performance leading to rework	0.74	2	0.53	2	0.75	1	0.67	1
Inadequate use of vibration which leads to problems in concrete	0.75	1	0.47	4	0.69	2	0.63	2
Poor performance mixing and transport	0.62	5	0.50	3	0.62	3	0.58	3
Far distance between place of mixing and casting	0.50	6	0.50	3	0.75	1	0.58	3
Excessive dimensions of concrete structure	0.70	3	0.44	5	0.62	3	0.58	3
Use of inadequate tools and equipment's	0.70	3	0.58	1	0.44	4	0.57	4
Flaws in the framework assembling process	0.69	4	0.53	2	0.44	4	0.55	5

The main causes of this material were: - Poor performance leading to rework and redoing due to poor concrete placement quality; site managers often order an additional allowance of concrete in order to avoid interruptions in the concrete-pouring process, sometimes this results in a surplus of concrete that is not used. Inadequate use of vibration leads to problems in concrete such as honeycomb, which leads to redoing.

Excessive dimensions of concrete structural elements (foundations, columns, beams, and slabs) the excessive thickness of slabs seems to be the most serious problem due to relatively high percentage of this element in the volume of the whole structure. This section looks at the manufacturing, control and storage and handling of the key concrete and concrete making materials identified as constituting to high wastage on building construction site.

Cement

Analyzing the waste of cement is relatively complex because this material is used as a component of mortar and wet trades which include block walling, plastering, floor screeds, internal and external finishing. The Relative Importance index and rank of each factor of the cement waste are presented in Table4.10 in a descending order.

Table: - 4.10 *Relative Importance Index and ranking of cement wastage on building construction sites*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Damage the fall mortar during plastering	0.72	2	0.53	4	0.75	1	0.66	1
Poor performance causing re-plaster	0.76	1	0.55	3	0.69	2	0.66	1
Mixing of quantities greater than the required	0.72	2	0.55	3	0.69	2	0.65	2
Excessive thickness for concrete floor screed	0.63	7	0.58	2	0.75	1	0.65	2
Loading the cement manually in the mixer using inadequate equipment's and tools	0.70	3	0.61	1	0.62	3	0.64	3
Excessive consumption of mortar in joints	0.68	5	0.47	6	0.69	2	0.61	4
Excessive quantities during mixing more than the required	0.66	6	0.50	5	0.62	3	0.59	5
Mixing in unsuitable places	0.69	4	0.58	2	0.50	5	0.59	5
Inappropriate way of transportation	0.69	4	0.55	3	0.50	5	0.58	6
Damage the external plaster due to rainfall	0.66	6	0.44	7	0.56	4	0.55	7
Wrong storage	0.72	2	0.55	3	0.62	3	0.52	8

Sand

The relative importance Index and rank of each factor of the sand waste are presented in Table 4.11 in a descending order. The major cause can be pointed out for sand waste was excessive consumption of sand, that's result from insufficient information about the used quantities and poor supervision.

Table: - 4.11 *Relative Importance Index and ranking of sand wastage on building construction sites*

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Poor storage	0.73	1	0.83	1	0.44	1	0.66	1
Damage the remained quantities in the place work	0.63	3	0.72	2	0.44	1	0.59	2
Excessive consumption of sand	0.66	2	0.67	3	0.31	3	0.54	3
Theft of sand	0.60	4	0.53	4	0.37	2	0.50	4

Coarse Aggregate

The mean and rank of each factor of the coarse aggregate waste are presented in Table 4.12 in a descending order.

Table: -4.12 *Relative Importance Index and ranking of course aggregate wastage on building construction sites.*

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Far distance between place of mixing and casting	0.73	1	0.61	3	0.62	1	0.65	1
Excessive quantities during mixing	0.65	4	0.58	4	0.62	1	0.61	2
Mixing quantities greater than the required	0.66	3	0.53	5	0.62	1	0.60	3
Wrong handling	0.65	4	0.72	1	0.44	2	0.60	3
Losing the aggregate during passing the equipment's on it	0.70	2	0.64	2	0.25	3	0.53	4

Steel Reinforcement

Dominating the use of steel reinforcement in construction sites is relatively difficult because it is cumbersome to handle due to its weight and shape (Carlos T. Formoso, 2002), but this reason has one of the lowest waste indices among all factors, which cause the waste of steel reinforcement.

Most companies in Ethiopia use a table to calculate the weights of required bars. However, most construction companies do not have a table to calculate the weight of surplus bars and short unusable pieces. The mean and rank of each factor of the steel reinforcement waste are presented in Table 4.13 in a descending order.

Table: - 4.13 *Relative importance Index and ranking of steel reinforcement wastage on building construction sites.*

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
No optimized cutting of bars	0.68	2	0.64	1	0.87	1	0.73	1
Structure design was poor in terms of standardization and detailing	0.73	1	0.58	3	0.75	2	0.68	2
Damage during storage and rusting	0.57	4	0.61	2	0.69	3	0.62	3
Unnecessary replacement of some bars by others of large diameter	0.68	2	0.36	5	0.75	2	0.59	4
Poor handling because its cumbersome to handle due to weight and shape	0.65	3	0.42	4	0.62	4	0.56	5

Timber formwork

Timber possesses a number of advantages, it is relatively inexpensive comparing to other materials, light in weight and easy to handle, it can be shaped for producing any distinct forms of concrete elements. However, its relatively low durability and reusability make it a material of high wastage. The mean and rank of each factor of the timber formwork waste are presented in Table 4.14 in a descending order.

Table: - 4.14 *Relative Importance Index and ranking of Timber formwork wastage on building construction sites*

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Breaking of timber boards during the removal of the frames	0.70	1	0.69	2	0.75	1	0.71	1
Non optimized cutting of timber boards	0.68	2	0.72	1	0.69	2	0.69	2
Deterioration resulting from un paint before use and unclean after use	0.65	4	0.61	4	0.69	2	0.65	3
Cutting the longer timber although the required are found	0.65	4	0.72	1	0.50	4	0.62	4
Use of low-quality timber	0.70	1	0.67	3	0.50	4	0.62	4
Wrong storage	0.66	3	0.55	5	0.62	3	0.61	5

Tile

The five main causes of tile waste were

- Rework because of executive mistakes, this problem results from inadequate supervision and using materials don't comply with specifications.
- Manufacturing defects such as deviations in the dimension of tile change in the color and cracks.
- Cutting the tiles in great quantities, that 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
- Damaging the tile during the necessary cutting process such waste was mostly related to inadequate tools and equipment's used for cut, and inadequate training of labor.
- Finally, leaving excessive quantities of tile on site due to lack of planning. These remainder quantities and pieces are left as waste when the crew moves to the next work.

The mean and rank of each factor of the tile waste are presented in Table 4.15 in a descending order.

Table: - 4.15 *Relative Importance Index and ranking of Tile wastage on building construction sites*

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Damage during transportation	0.72	2	0.78	1	0.75	2	0.75	1
Damaging the tile during the necessary cutting process	0.72	2	0.74	2	0.75	2	0.73	2
Cutting the tiles in great quantities	0.68	5	0.66	4	0.81	1	0.71	3
Damage of the remains left on site	0.75	1	0.67	3	0.62	3	0.68	4
Excessive quantities of tiles on site	0.70	3	0.64	5	0.62	3	0.65	5
Inadequate workers	0.68	5	0.64	5	0.62	3	0.64	6
Poor distribution of tiles in site	0.66	6	0.64	5	0.56	4	0.62	7
Unpacked supply (fragile)	0.69	4	0.67	3	0.37	6	0.57	8
Rework as a result of executive mistakes	0.63	7	0.50	6	0.56	4	0.56	9
Damage during finishing	0.50	8	0.50	6	0.50	5	0.50	10
Manufacturing defects	0.72	2	0.47	7	0.25	7	0.48	11

Block (HCB)

Blocks are the most common walling material. The three main causes of block waste were: Manufacturing defects, such as deviations in the dimension of block and cracks. Lack of halves and quarters of blocks were the second source of waste for blocks. The third source of waste was cutting blocks due to the lack of modular coordination in design. The mean and rank of each factor of the block (HCB) waste are presented in Table 4.16 in a descending order

Table 4.16. *Relative importance Index and ranking of block (HCB) wastage on building construction sites.*

Factors	*Contractors*		*consultants*		*clients*		*Weighted average (all groups)*	
	RII	R	RII	R	RII	R	RII	R
Lack of halves and quarters of blocks	0.69	4	0.89	1	0.87	1	0.81	1
Damage the blocks during unloading and transportation operation	0.72	3	0.69	2	0.69	2	0.70	2
Excessive cutting of blocks	0.78	1	0.58	4	0.69	2	0.68	3
Block damage during the process of cutting	0.72	3	0.67	3	0.62	3	0.67	4
Damage of the unused quantities left on site	0.73	2	0.67	3	0.44	4	0.61	5
Manufacturing defects	0.68	5	0.55	5	0.62	3	0.61	5

4.4. Assessment of key construction materials waste arising through storage and handling on building construction sites

In this part, respondents were asked to assess materials waste in construction projects. The results exposed that the key materials, which are wasted most on construction sites, are concrete, cement, coarse aggregate, sand reinforcement steel, formwork, bricks and HCB (blocks). Blocks are most commonly used as walling materials on building construction sites.

4.4.1. Storage and handling of blocks on construction sites

Figure: - 4.1 *Wastage of HCB on building construction sites due to poor handling*

Figure: - 4.2 *Wastage of HCB on building construction sites due to change orders*

4.4.2. Recommended ways of storing and handling blocks on construction sites

To avoid wasting a lot of blocks on construction sites, it is advisable to take into consideration its storage and handling operations on site.

- The blocks should be stacked on pallets or on level grounds
- It should be stored in a container or a covered place
- It should not be stored in a walk way where people will always step on it.

Fig: - 4.3 *properly packed HCB on building construction site*

Steel reinforcement

Steel reinforcement bars are common materials used in building. Controlling the use of steel reinforcement in building sites is relatively difficult because it is cumbersome to handle due to its weight and shape. The main causes of wastage of steel are as a result of cutting, damages during storage and design change.

Figure: - 4.4 *wastage of steel reinforcement bar due to non-optimized cutting of bars and design change*

Figure: - 4.5 *Poor handling of steel reinforcement bar on building construction site*

4.5. Handling and storage of Concrete making materials on site

The storage of concrete making materials on construction sites is a major problem. Some of these materials are not stored appropriately resulting in the severe wastage of materials on site. Coarse and fine aggregates and cement should be properly stored, batched, and handled to maintain the quality of the resulting concrete.

This section presents photographs of how key materials are wasted on construction sites as a result of storage and recommends appropriate ways of storing these materials to reduce their levels of wastage on construction sites.

4.5.1. Wastage of Sand through storage and handling

Fig: - 4.6 *Poor handling of sand onsite*

4.5.2. Wastage of aggregates through storage and handling

If the aggregate that are not properly stored, it will limit the strength of the concrete work on a building project, it could also affect the durability and structural performance of the building. Aggregates should be stored where it will not have direct contact with the lateritic soil, which may reduce the quality of the concrete or cause void on the surface of the concrete.

4.5.3. Common problems in storing aggregates

- Segregation of aggregate (example: large particles of aggregate roll down the side of a tall cone pile)
- Degradation of aggregate (example: end loaders or trucks on pile crush the aggregate)
- Contamination of materials by deleterious substances (example: trucks track clay and mud onto aggregate)
- incompatible or undesirable moisture content (example: materials are not wetted or allowed to drain properly)

Fig: - 4.7 *Poor handling of Coarse aggregate onsite*

4.5.4. Recommended ways of storing aggregates on site

To minimize the wastage of aggregates through storage and handling, the following recommendations should be adhered to.

- Store aggregates in separate bunkers when many gradations and types of aggregate are required in small quantities for relatively low-production operations.
- Otherwise, store aggregate in open stockpiles.

Fig: - 4.8 *Good handling of sand and coarse aggregate on building site*

4.5.5. Wastage arising from batching and measurement of concrete making materials that leads to materials wastage

The batching and measurement of concrete making materials (coarse and fine aggregates and cement) most of the times lead to wastage of these materials on construction sites.

Some of the wastages from batching involve

- ❄ Aggregate segregation
- ❄ Varying moisture content
- ❄ Addition of too much water, resulting in reduced concrete strength and increased shrinkage

4.5.6. Recommended ways of batching concrete making materials

To avoid wasting the aggregates (coarse and fine), proper equipment should be used.

To assist in minimizing the wastage of concrete making materials resulting from batching, it is recommended that the following procedures be adhered.

- ❄ Use separate aggregate basket for each size of coarse aggregate. Bins should be capable of shutting off material with precision.
- ❄ Maintain mixer blades. Watch for wear and coating.
- ❄ Do not load mixer above rated capacity.
- ❄ Operate mixer at manufacturer-recommended speed.
- ❄ Mix all concrete thoroughly until it is uniform in appearance, with all ingredients evenly distributed.
- ❄ Take samples from different portions of a batch to ensure that the whole batch has the same air content, slump, unit weight, and aggregate proportions

4.5.7. Wastage arising from mixing and transportation of concrete on site

Thorough mixing is essential for the production of uniform quality concrete. Therefore, equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce uniform mixtures of the lowest slump practical for the work.

Transportation

The method used to transport concrete depends on which one is the lowest in cost and easiest for the job size. Some ways to transport concrete include a concrete truck, a concrete pump, a crane and bucket, a chute, a conveyor or a hoist. On small jobs, a wheelbarrow is the easiest way to transport concrete. Always transport concrete as little as possible to reduce problems of segregation and wastage.

Fig: - 4.9 *Wastage of concrete due to poor transport*

4.5.8. Recommended methods of transporting concrete to avoid wastage

Concrete should be transported from the mixer to the place of casting as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients and maintaining the required workability.

During hot or cold weather, concrete should be transported in deep containers, other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted

4.5.9. Wastage of cement through storage and handling

The effective storage of cement on building projects reduces wastes, project delay and helps to keep the quality of cement in good shape before usage. Analyzing the waste of cement is relatively complex due to the fact that this material is used as a component of mortar and cast-in-place concrete in several different processes, such as brickwork, plastering and floor screed. The effects of poor storage of cement and handling results in cracks and spilling of concrete, which the damage usually starts at the edges and corners of concrete, reduction in quality of concrete and caking of cement.

__Fig: - 4.10__ Wastage of cement due to poor handling lack of control and poor storage

__Fig 4.11__ Due to mixing in unsuitable place

Fig 4.12 *Mixing of mortar greater than the required*

Fig: - 4.13 *Wastage of cement mortar due to chiseling and design change on building sites*

4.5.10. Recommended ways of storing cement to minimize wastage

Portland cement that is kept dry retains its quality indefinitely. Portland cement stored in contact with moisture sets more slowly and has less strength than dry Portland cement. A warehouse or shed used to store cement should be as air-dry as possible. All cracks and openings should be closed. Cement bags should not be stored on damp floors. Bags should be stacked close together to reduce air circulation, but they should not be stacked against outside walls. Bags to be stored for long periods should be covered with tarpaulins or other waterproof covering.

Standard strength tests or loss on ignition tests should be made whenever the quality of the cement is doubtful. Bulk cement is usually stored in waterproof bins. Ordinarily, it does not remain in storage very long but it can be stored for a relatively long time without deterioration.

Fig: - 4.14 *Recommended ways of storing cement on building site*

4.6. Impacts of Material Wastage on Building Construction sites and Environment

Construction waste becomes a global issue facing by practitioners and researchers around the world. Waste can affect success of construction project significantly. More specifically, it has major impact on construction cost, construction time, and productivity and sustainability aspects. Currently in Addis Ababa in every corner, various constructions are under way specially, building construction.

The highest environmental impact of construction materials waste is believed in terms of contamination. Although, construction activities also pollute the soil, the main areas of concern are air, water and noise pollution. Construction activities that contribute to air pollution include land clearing, operation of diesel engines, demolition, burning and working with toxic materials. Construction sites are generating high level of dust (typically from concrete, cement, wood, stone, silica) and this can carry a large distance over a long period. Sources of water pollution on building sites include diesel and oils; paints, solvents, cleaners and other harmful chemicals; and construction garbage and dust.

4.7. Auditing wastage of key construction materials on selected public building projects in Addis Ababa

Five public building sites were randomly selected in Addis Ababa, for periods of six months. Most of those sites were under construction. The results indicated that the level of construction wastages on selected public building construction projects in Addis Ababa like cement (13.64%); reinforcement steel (10.64%); sand (14.26%); Coarse aggregate (10.55%) and HCB (11.64%) as show in Appendix C because of reworks that don't comply with drawing and specifications; rework due to worker's mistakes; cutting uneconomical shapes; ordering of materials that don't fulfill project requirements defined on design documents; and inappropriate storage leading to damage or deterioration.

4.8. A future Framework for Minimizing Materials Wastage on Construction Sites

The framework proposed is emphasizes how principles could be applied to minimize materials wastage on construction sites. The objectives of the framework are to help construction parties to:

Identify what could be done to tackle or counter-balance these challenges (what to do),

Identify how to address these challenges (how to do it) and

Realize the possible outcome (results), which is minimizing materials wastage Based on the questioner survey, the respondent identifies the major causes of materials waste and its future framework to minimizing materials wastage on construction sites in the table 4.17.

Table: - 4.17 *A framework for minimizing materials waste*

Challenges or major causes of construction materials wastage	*What to do to minimize wastage of construction materials*	*How to do it*	*Result*
Lack of proper waste management plan and control	Prepare effective waste management planning and control	Prevent detective production Timely delivery of materials Understand client needs and expectation Government should be embarking on applicable polices	Construction materials waste minimi

Lack of teamwork	Prepare good teamwork	Managers should be committed to change Be able to work in team Change organization cultures Empower members in decision making	zation
Poor project management	Prepare good project management	Deals with uncertainties & fears Train employers on lean concept	
Lack of technical capabilities	Enhancement of technical capabilities	Promote standard construction elements	
Poor communication between parties	Prepare good communication between parties	Improve communication among players	

A successful project requires careful planning, organization and control throughout the project to achieve the correct result for the client. For the contractor, good planning, organization and control are essential in order to achieve a timely and satisfactory outcome for the client, and to ensure a financial profit. To ensure the successful implementation of construction projects there should be an effective teamwork between all parties. To ensure proper teamwork on construction sites, managers should be committed to change, workers should be able to work in teams, companies should be more client focused, firms should be willing to change organizational cultures that do not promote lean construction, partnering to maximize team building and team members should be empowered in decision-making to make partnerships meaningful.

Managing a construction project is depends on how parties in a construction project interpret the construction process. Main strategies such as training of employees on lean concepts and dealing with uncertainties and fears that cause organizations to conceal information instead of sharing it should be employed to enhance the implementation of main principles. The enhancement of technical capabilities is very important in order to effectively implement the managing materials on construction sites. To ensure that technical capabilities are enhanced, the managers should understand and use standards to define normal and abnormal conditions and develop clear, user friendly, visual controls at all levels to help monitor and improve standards.

The lack of standardization can be viewed as one of the reasons for the inefficiency of the construction sector. There is also the need for managers to maintain personal discipline, direct and coach others to keep within standards and procedures and always react to off standard and off target situations with immediate investigation. In addition, standardized construction elements should be promoted to reduce the number of materials wasted on construction sites. In an organization, communication is carried out in several ways including verbal and signs. Authority, control and motivation are the functioning of an organization. Worker’s communication needs to be effective for coordinate efforts, leading to improvement in quality of the works. Communication quality which has characteristics of being timely, accurate and useful and complete enhances productivity and quality of work. Communication should be improved among players to enhance the successful implementation of lean strategies.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

This chapter includes the conclusion and the practical recommendations that may minimize or prevent waste in building construction projects in Addis Ababa.

The major finding from our respondents weighted average and ranking over-all causes of construction materials wastage is

Group No.	Main groups	Weighted average (all groups)	Rank
Group 4	Site management and practices factors	0.72	1
Group 5	Site supervision factors	0.70	2
Group 3	Operations factors	0.69	3
Group 2	Materials handling and storage factors	0.66	4
Group 1	Design and documentation factors	0.63	5

Table: - 5.1 Weighted average and ranking over-all causes of construction materials wastage

And the other major finding indicated that the level of construction wastages on selected public building construction projects in Addis Ababa like cement (13.64%); reinforcement steel (10.64%); sand (14.26%); Coarse aggregate (10.55%) and HCB (11.64%)

Materials	Sum of Qty Waste (%)	Average Waste (%)
Cement	40.92	13.64
Reinforced steel	31.92	10.64
Sand	42.77	14.26
Coarse aggregate	31.66	10.55
HCB	34.93	11.64

Table: - 5.2 Level of construction wastages on selected public building construction projects in Addis Ababa

5.1.Conclusion

This study is focused on Managing and Minimizing wastage of construction materials on selected public building projects in Addis Ababa and it also identified the major causes of waste in construction and presented a comprehensive analysis of these causes. The questionnaire of this study considered 81 factors which cause material waste in construction, and those factors were distributed into five groups namely, Design and documentation, Materials handling and storage, Operation, Site management and practices and Site supervision.

Therefore, 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.

A. Site supervision factors

The findings showing that in the first ranks the site supervision factor as causes of materials wastage on building construction site by contractors, consultants and owners due to Change orders by owner, Poor qualification of consultant engineer’s staff assigned to the project, Lack of supervision and delay of inspections, slow response from the consultant engineer to contractor inquiries, Poor coordination and communication between the consultant engineer, contactor and client `

B. Materials storage and handling factors

The findings showing that in the second ranks Materials storage and handling factors as causes of materials wastage on building construction site by contractors, consultants and owners due to Lack of onsite materials control, Poor handling of materials, Lack storage of materials near of construction site, insufficient instructions about handling & Wrong handling of materials, Using excessive quantities of materials more than the required & Purchased materials that don't comply with specification. The results further revealed that Overproduction/Production of a quantity greater than required or earlier than necessary, Conversion waste from cutting uneconomical shapes, Poor quality of materials, over ordering or under ordering due to mistake in quantity surveys, Damage during transportation & Poorly schedule to procurement the materials are other important causes of materials waste arising from storage and handling.

C. Design and documentation factors

The findings showing that in the third ranks Design and documentation factors as causes of materials wastage on building construction site by contractors, consultants and owners due to Design changes and revisions, Designer's inexperience in method and sequence of construction, Poor communication leading to mistakes and errors & Lack of knowledge about construction techniques during design activities are the first five major causes of materials waste. The other causes of waste include Poor/ wrong specifications, Rework that don't comply with drawings and specifications, Selection of low-quality products, Lack of information in the drawings, Selecting the lowest bidder contractors and subcontractor, Poor site layout, Ambiguities, mistakes, and changes in specifications, Ambiguities, mistakes, and inconsistencies in drawings & Lack of attention paid to standard sizes available on the market.

D. Site management and practices factors

The findings showing that in the fourth ranks Site management and practices factors as causes of materials wastage on building construction site by contractors, consultants and owners due to Ineffective planning and scheduling of the project by the contractor, Poor project management, Poor qualification of the contractor's technical staff assigned to the project, Lack of proper waste management plan and control & Shortage of technical professionals in the contractor's organization

E. Operational factors

The findings showing that in the fifth ranks Site management and practices factors as causes of materials wastage on building construction site by contractors, consultants and owners due to Lack of workers or tradesmen or subcontractors‟ skill, Choice of wrong construction method, Shortage of manpower (skilled, semiskilled, unskilled labor), Poor workmanship & Rework due to workers‟ mistakes

The results indicated that the level of construction wastages on sampled public building construction projects in Addis Ababa, Cement (13.64%), Reinforcement steel (10.64%), sand (14.26%), Coarse aggregate (10.55%) and HCB (11.64%) Appendix C. The main causes are reworks that don't comply with drawing and specifications, rework due to worker's mistakes, cutting uneconomical shapes, ordering of materials that don't fulfill project requirements defined on design documents, and inappropriate storage leading to damage or deterioration.

The highest environmental impact of construction materials waste is believed in terms of contamination. Although, construction activities also pollute the soil, the main areas of concern are air, water and noise pollution. Construction sites are generating high level of dust (typically from concrete, cement, wood, stone, silica) and this can carry a large distance over a long period. Sources of water pollution on building sites include diesel and oils; paints, solvents, cleaners and other harmful chemicals; and construction garbage and dust.

The mitigation measures practiced for reducing construction materials in constructing industry are, Training of construction personnel, changing attitude of workers towards the handling of materials by proper training, improving supervision, good coordination between store and construction personnel to avoid over-ordering and proper storage and handling of materials on site.

5.2.Recommendations

The following recommendations have been made to improve the application of principles to minimize construction materials wastage at Addis Ababa public building construction site.

5.2.1. Owners

- ❄ Should asking contractors to prepare and submit an acceptable waste management plan matching with the nature of the project.
- ❄ Should take the waste management history of the contractors as a criterion in awarding contracts.
- ❄ Should visits to construction site at all critical stages.

5.2.2. Consultants

- ❄ Should give attention to avoid design and planning errors at the design and planning stages.
- ❄ Should optimize the use of resources during design.
- ❄ Should review the specifications, design, detailing drawing or other errors at the construction stage.
- ❄ Should assigned qualified consultant engineer's staff to the project.
- ❄ Should give daily inspections to contractor.

5.2.3. Contractors

- ❄ Should assign qualified staff and workforce in construction projects.
- ❄ Should Preparing waste management plan to minimize the waste.
- ❄ Should prepare good handling and storing materials on site.
- ❄ Should Provide waste reduction training to site staff to raise their environmental awareness and improve working procedures to reduce waste generation in construction projects.
- ❄ Should proper site and waste management techniques, and preparation of accurate specification for materials to adopt in the quest to minimize materials waste in construction.

Recommendation for future studies

- ❄ It is needed to develop a study concerning cost minimization alternatives base on managing and minimizing construction waste and improving an efficient management practice in Ethiopian Construction Industry.
- ❄ 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 Survey for Thesis paper on

Managing and Minimizing Wastage of construction Materials on selected public building projects in Addis Ababa

ST. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF BUSINESS, MA in Project Management

Questionnaire Survey for Thesis paper on

Managing and Minimizing Wastage of construction Materials on selected public

Building projects in Addis Ababa

I am presently pursing a Master of Art Degree in Business under Project Management at St. Mary's University, School of Graduate Studies.

The aim of this questionnaire is to study Managing and Minimizing Wastage of Materials on selected public building construction projects in Addis Ababa and the causes of materials waste on building construction sites. Please answer all questions where possible. All the information gathered will be kept strictly confidential and will be used only for academic research and analysis without mentioning the names of individuals companies involved.

Thank you in advancing for your time and kind cooperation

Yours Faithfully

Kalid Abdu Ali

(Mobile. +251945946411)

Supervised by

Chalachew Getahun (phD)

Part 1: General Organization Information

Please add (☐) as appropriate:

1. Type of Organization (Respondents designation)

☐ Owner	☐ Consultant	☐ Contractor

2. Relevant working experience (Years):

☐ 1-10	☐ 11-20
☐ 21-30	☐ More than 30

3. Value of executed projects executed in the last five years: (in ETB)

☐ 10-50 Million	☐ 50-100 Million
☐ 100-120 Million	☐ More than 120 Million

Part 2: Sources and Causes of Construction Materials Waste on Construction Project.

The given below are numbers of Sources and causes of construction materials waste on building construction sites in Addis Ababa. Please indicate the significance of each factor by ticking the appropriate boxes. Add any remarks relating to each factor on the last column e.g. as to the reasons, the critical factors or the solutions.

E.S. = extremely significant [100%] V.S. = very significant [75%]

M.S. = moderately significant [50%] S.S. = slightly significant [25%]

N.S. = not significant [0%]

Causes of construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remarks**
Group 1. Design and documentation						
Design changes and revisions						
Designer's inexperience in method and sequence of construction						
Lack of attention paid to standard sizes available on the market						
Lack of information in the drawings						
Ambiguities, mistakes, and changes in specifications						
Ambiguities, mistakes, and inconsistencies in drawings						
Poor/ wrong specifications						
Selecting the lowest bidder contractors and subcontractor						
Rework that don't comply with drawings and specifications						
Lack of knowledge about construction techniques during design activities						
Poor communication leading to mistakes and errors						
Poor/ wrong specifications						
Selection of low quality products						
Poor site layout						

Causes of construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remark**
Group 2. Materials						
(A): Procurement						
Poorly schedule to procurement the materials						
Over ordering or under ordering due to mistake in quantity surveys						
Purchased materials that don't comply with specification						
(B): On site						
Damage materials on site						
Conversion waste from cutting uneconomical shapes						
Overproduction/Production of a quantity greater than required or earlier than necessary						
Poor quality of materials						
Lack of onsite materials control						
Poor storage of materials						
Using excessive quantities of materials more than the required						
(C): Handling						
Wrong handling of materials						
Unnecessary material handling						
Insufficient instructions about handling						
(D): Storage						
Wrong storage of materials						
Inadequate stacking and insufficient storage on site						
Insufficient instructions about storage and stacking						
Inappropriate storage leading to damage or deterioration						
(E): Transportation						
Damage during transportation						
Lack storage of materials near of construction site						

Causes of construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remark**
Group 3. Operation						
(A): On site						
Rework due to workers‟ mistakes						
Damage to work done caused by subsequent trades						
Use of incorrect material, thus requiring replacement						
Poor workmanship						
Lack of workers or tradesmen or subcontractors‟ skill						
Choice of wrong construction method						
Accidents due to negligence						
Shortage of manpower (skilled, semiskilled, unskilled labor)						
Using untrained labors						
Lack of coordination among crews						
Problems between the contractor and his subcontractors						
(B): Equipment						
Equipment frequently breakdown						
Poor technology of equipment						
Shortage of tools and equipment’s required						

Causes of construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remark**

Group 4. Site management and practices						
Lack of proper waste management plan and control						
Poor project management						
Lack of a quality management system aimed at waste minimization						
Lack of strategy to waste minimization						
Lack of team work						
Poor site layout						
Poor qualification of the contractor's technical staff assigned to the project						
Poor provision of information to project participants						
Ineffective control of the project progress by the contractor						
Shortage of technical professionals in the contractor's organization						
Ineffective planning and scheduling of the project by the contractor						
Poor coordination and communication between parties involved in the project						
Poor management and distribution of labors, materials and equipment's						
Group 5. Site supervisor						
Lack of supervision and delay of Inspections						
Poor qualification of consultant engineer's staff assigned to the project						
Slow response from the consultant engineer to contractor inquiries						
Poor coordination and communication between the consultant engineer, contactor and client						

Change orders by owner						

Part 3: Causes of key material wastage on building construction sites.

Please indicate the significance of each factor by ticking the appropriate boxes. Add any remarks relating to each factor on the last column e.g. as to the reasons, the critical factors or the solutions.

E.S. = extremely significant [100%] V.S. = very significant [75%]

M.S. = moderately significant [50%] S.S. = slightly significant [25%]

N.S. = not significant [0%]

Causes of key construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remark**
1. Concrete						
Flaws in the framework assembling process						
Excessive dimensions of concrete structure						
Use of inadequate tools and equipment's						
Poor performance mixing and transport						
Far distance between place of mixing and casting						
Poor performance leading to rework						
Inadequate use of vibration which leads to problems in concrete						
2. Steel reinforcement						
Unnecessary replacement of some bars by others of large diameter						
Poor handling because its cumbersome to handle due to weight and shape						
No optimized cutting of bars						
Structure design was poor in terms of standardization and detailing						
Damage during storage and						

rusting						

Causes of key construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remark**
3. Cement						
Loading the cement manually in the mixer using inadequate equipment's and tools						
Excessive quantities during mixing more than the required						
Wrong storage						
Damage the fall mortar during plastering						
Poor performance causing re-plaster						
Inappropriate way of transportation						
Excessive consumption of mortar in joints						
Mixing of quantities greater than the required						
Mixing in unsuitable places						
Damage the external plaster due to rainfall						
Excessive thickness for concrete floor screed						
4. Aggregate						
Excessive quantities during mixing						
Mixing quantities greater than the required						
Wrong handling						
Far distance between place of mixing and casting						
Losing the aggregate during passing the equipment's on it						
5. Sand						
Poor storage						
Excessive consumption of sand						
Damage the remained quantities in the place work						

Theft of sand						

Causes of key construction materials waste	E.S 100%	V.S 75%	M.S 50%	S.S 25%	N.S 0%	**Remark**
6. Block						
Excessive cutting of blocks						
Block damage during the process of cutting						
Damage the blocks during unloading and transportation operation						
Damage of the unused quantities left on site						
Manufacturing defects						
Lack of halves and quarters of blocks						
7. Tile						
Cutting the tiles in great quantities						
Damaging the tile during the necessary cutting process						
Excessive quantities of tiles on site						
Poor distribution of tiles in site						
Damage during transportation						
Damage of the remains left on site						
Inadequate workers						
Manufacturing defects						
Unpacked supply (fragile)						
Damage during finishing						
Rework as a result of executive mistakes						
8. Timber Formwork						
Non optimized cutting of timber boards						
Cutting the longer timber although the required are found						
Cutting for internal finishing and fittings						
Wrong storage						
Using for other purposes						

Deterioration resulting from un paint before use and unclean after use						
Breaking of timber boards during the removal of the frames						
Use of low-quality timber						

Part 4: Open Questioners

1. What are the major impacts of construction materials waste on building construction and environment?

2. Which construction parties beneficial by managing and minimizing wastage of construction materials on building construction? And how?

3. Who should take action to reduce construction materials waste?

4. What are futures Framework for Minimizing Materials Wastage on Construction Sites?

THANK YOU!!

APPENDIX -B

A suggested form for estimating waste of construction Materials generated on building Construction projects

A suggested form for estimating waste of construction Materials generated on Building Construction projects

(Daily Report)

Company name:-____

Project:-______________________________Location of project:-____________________

Duration:-______________________Total contract sum:-___________________________

Type of Work	**Material**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
		Unit	**Prrice/ unit (birr)**	**Qty Purchased**	**Qty existing in stock**	**Qty Designd (actual)**	**Qty waste**	**Waste (%)**	**Cost of waste (birr)**
		Qty					**(C-D)-(E)**	**/(F)(E) /*100%**	**(F)*(B)**
Block Work	HCB								
	Bricks								
	Cement								
	Sand								
Plastering	Cement								
	Sand								
Tiles	Cement								
	Sand								
	Ceramics								
Concrete	Steel								
	Cement								
	coarse aggregate								
	sand								
Total cost of waste									

The highest percentage of waste:_______________________%, for(material):______ _______________________

The main causes of waste:____

____

____

____

A suggested form for estimating waste of construction Materials generated on Building Construction projects

(Monthly Report)

Company name:-____

Project:-________________________Location of project:-__________________________

Duration:-_____________________Total contract sum:-___________________________

Type of Work	**Material**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
		Unit	**Prrice/ unit (birr)**	**Qty Purchased**	**Qty existing in stock**	**Qty Designd (actual)**	**Qty waste**	**Waste (%)**	**Cost of waste (birr)**
		Qty					**(C-D)-(E)**	**/(F)(E) /*100%**	**(F)*(B)**
Block Work	HCB								
	Bricks								
	Cement								
	Sand								
Plastering	Cement								
	Sand								
Tiles	Cement								
	Sand								
	Ceramics								
Concrete	Steel								
	Cement								
	coarse aggregate								
	sand								
Total cost of waste									

The highest percentage of waste:_______________________%, for(material):______ _______________________
The main causes of waste:____
____
____
____

APPENDIX -C

Auditing wastage of key construction materials on selected public building Projects in Addis Ababa

Auditing wastage of key construction materials on selected public building Projects in Addis Ababa

Table 1:- The Adwa Zero Kilometer Museum project

Material	A	B	C	D	E	F	G	H
	Unit	**Price/unit (birr)**	**Qty purchased**	**Qty existing in stock**	**Qty Designed (actual)**	**Qty waste**	**Waste (%)**	**Cost of Waste (birr)**
						(C-D)-(E)	**[(F)/(E)]* 100%**	**(F)*(B)**
Cement	Qtl	410.00	406,712.00	3,034.50	338,926.73	64,750.77	19.10	26,547,815.70
Reinforced Steel	Kg	43.00	3,363,415.30	147,149.42	2,802,846.08	413,419.80	14.75	17,777,051.40
Sand	M3	440.00	61,768.62	2,427.22	48,544.40	10,797.00	17.48	4,750,680
Coarse Aggregate	M3	380.00	83,523.02	755.76	75,602.11	7,165.15	9.48	2,722,757
HCB	Pcs	16.00	75,088.81	5,256.22	60,208.38	9,624.22	12.82	153,987.52

Table 2:- Meskel Square project

Material	A	B	C	D	E	F	G	H
	Unit	**Price/unit (birr)**	**Qty purchased**	**Qty existing in stock**	**Qty Designed (actual)**	**Qty waste**	**Waste (%)**	**Cost of Waste (birr)**
						(C-D)-(E)	**[(F)/(E)]* 100%**	**(F)*(B)**
Cement	Qtl	410.00	4,227.00	86.00	3,802.05	338.95	8.91	138,969.50
Reinforced Steel	Kg	43.00	26,439.15	987.54	23,972.59	1,479.02	6.17	63,597.86
Sand	M3	440.00	775.00	18.00	680.09	76.91	9.92	33,840.40
Coarse Aggregate	M3	380.00	558.70	18.00	492.67	48.03	9.75	18251.40
HCB	Pcs	16.00	4,703.00	1,150.00	3,125.00	428.00	9.10	6,848

Table 3:- CBE Headquarter building project

Material	A	B	C	D	E	F	G	H
	Unit	**Price/unit (birr)**	**Qty purchased**	**Qty existing in stock**	**Qty Designed (actual)**	**Qty waste**	**Waste (%)**	**Cost of Waste (birr)**
						(C-D)-(E)	**[(F)/(E)]* 100%**	**(F)*(B)**
Cement	Qtl	410.00	15,833.00	6,656.50	8,128.00	1,048.50	12.90	429,885
Reinforced Steel	Kg	43.00	224,696.09	30,985.15	174,516.84	19,194.10	11.00	825,346.30
Sand	M3	440.00	3,350.57	579.43	2,401.97	369.17	15.37	162,434.80
Coarse Aggregate	M3	380.00	74,560.35	256.06	66,088.64	8,215.65	12.43	3,121,947
HCB	Pcs	16.00	78,483.00	1,344.00	68,258.32	8,880.68	13.01	142090.88

Table4:-Level of construction wastages on selected public building construction projects in Addis Ababa

Materials	Sum of Qty Waste (%)	Average Waste (%)
Cement	40.92	13.64
Reinforced steel	31.92	10.64
Sand	42.77	14.26
Coarse aggregate	31.66	10.55
HCB	34.93	11.64