Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Construction Engineering and Management Stream

INVESTIGATION OF COST IMPACT OF CONSTRUCTION MATERIALS WASTAGES ON SITE DURING OPERATION. A CASE STUDY OF ADDIS ABABA CITY ADMINSTRATION SAVING HOUSES DEVELOPMENT ENTERPRISE.

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Engineering and Management)

BY: KUMSHEL GENETI ALLE

October 2016

Jimma, Ethiopia

Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Construction Engineering and Management Stream

INVESTIGATION OF COST IMPACT OF CONSTRUCTION MATERIALS WASTAGES ON SITE DURING OPERATION. A CASE STUDY OF ADDIS ABABA CITY ADMINSTRATION SAVING HOUSES DEVELOPMENT ENTERPRISE.

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Engineering and Management)

By: Kumshel Geneti

Advisor: Engr. Emer T. Quezon. (Associate professor)

Co-Advisor: Engr. Alemu Mosisa. (M.Sc.)

October 2016

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled "**Investigation of Cost impact of Construction materials wastages on site during operation. A case study on Addis Ababa City Administration Saving Houses Development Enterprise..**" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for this thesis have been dually acknowledged.

Candidate:

Mr. Kumshel Geneti

Signature: _______________

As Master research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Mr. Kumshel Geneti Alle entitled: **Investigation of Cost impact of Construction materials wastages on site during operation. A case study on Addis Ababa City Administration Saving Houses Development Enterprise.**

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Engr. Emer T. Quezon. (Associate professor)	___________	____________
Advisor	Signature	Date
Engr. Alemu Mosisa (M.Sc.)	____________	____________
Co-Advisor	Signature	Date

ACKNOWLEDGEMENT

First of all I would like to give thanks to Almighty God who gave me the commitment and tolerance to pass various obstacles and come up to the accomplishment of this thesis. I am also deepest thanks for the Jimma University, Institute of Technology and the Ethiopian Roads Authority for giving a chance and making all the necessary arrangements throughout my study.

I would like to express deepest appreciation to my advisor Prof, Emer T.Quezon and my Co-advisor Engr.Alemu Mosisa Jimma University Technology Institute, school of Civil and Environmental Engineering for their valuable advice, continuous encouragement and professional support and guidance.

I want to appreciate Addis Ababa City Administration Saving Houses Enterprise site coordinators, Consulting firms and contractors for their helpful collaboration in completing the questionnaires used in this study and providing valuable data's during data collection process. I want to acknowledge Ato Hailu Kenea Addis Ababa City Administration Saving Houses Enterprise manager, Ato Tisasu Ayele Weyessa branch office contract administrator for their great support in material and successful accomplishment of this research work. Finally, I would like to express my sincere appreciation for my friend Ato Tesfaye Belyneh and his family for their constant source of support in my life.

I also give deepest thanks to my wife Meseret Kibret and My children Yonatan Kumshel and Telile Kumshel for their all-round support.

ABSTRACT

The building construction industry in Ethiopia in general has been found to be among the main consumers of resources and energy. Moreover, the materials wasted on construction site during operation exceed the allowance level considered during design stage. This materials waste is shooting up the cost of the house, which is challenging for the government who constructs the house and transfer to the registered house seeker. Due to this, the house seekers failed to afford the cost of final project and the contractor's profit was minimized.

The objectives of the research were to investigate how much construction materials wastage was costing housing project budgets in Addis Ababa city administration saving houses development enterprise. The study identify the mostly wasted construction materials during operation, the major cause of construction materials wastage, and suggesting some frame work to mitigate the effect of construction materials wastage on housing project cost.

The main tools for the collection of data include questionnaires, interviews, site visit and observation that used to identify the mostly wasted materials, cause of construction materials wastage during operation and to what extent materials wastage was costing housing project.

The findings of this research indicate that the first five mostly wasted construction materials on housing construction sites are Concrete hollow block, Timber formwork, Cement, Reinforcement bar and Tiles. It is also concluded that the three most important factors contributory to construction material waste generation on building sites are materials handling and storage, design change and revisions and operation.

The study revealed that the cost of waste incurred, on average in these four sites is 7.6 % of the total cost, ranging from 5.2 % to 9.5 %. This indicates that minimization of material waste in the housing construction projects would therefore lead to substantial saving on the purchasing cost of building materials, in addition to savings on dumping costs. 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:* Housing project, Materials wastage and project cost**.

TABLE OF CONTENTS

CONTENTS PAGE

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

BC	Building contractors
C&D	Construction and Demolition
CEN	Capital Ethiopia Newspaper
CS	Central Statistics
ECIP	Ethiopian Construction Industry Policy
EPD	Environmental Protection Department
ETB	Ethiopian Currency(Birr)
GC	General Contractors
GRD	Great Renaissance Dam
HCB	Hollow Concrete Block
IHDP	Integrated Housing Development Project
Kg	Kilogram
MSE	Micro and Small Scale Enterprise
MUDHC	Ministry of Urban Development, Housing and Construction
OPC	Ordinary Portland Cement
Pcs	Pieces
Qtl	Quintal
RII	Relative Importance Index
ROEE	Report On Ethiopian Economy
SHDE	Saving Houses Development Houses
SWMP	Site Waste Management Plan
UAE	United Arab Emirates

CHAPTER ONE
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 and energy related construction works, water supply & sewerage civil works etc. are some of the major projects (program) in the construction industry.

It plays a vital role in meeting the needs of society and enhancing the quality of life and its importance emanates largely from the direct and indirect impact it has on all economic activities (Shen et al., 2000). The fundamental economic sector which permeates most of the other sectors as it transforms various resources into constructed physical economic and social infrastructure necessary for socio-economic development (ECIP, 2012). The contribution of the industry to the national output and stimulates the growth of other sectors through a complex /system of linkages (ROEE, 2007).

The construction industry contributes to employment and creates income for the population and has multiplier effects on the economy. However 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, cited in Seyoum A.2015).

Similar to the case with other developing countries, the Ethiopian construction industry shares many of the problems and challenges the industry is facing in other developing countries, perhaps with greater severity. Given the critical role, the construction industry plays in Ethiopia and other developing countries, and the poor level of performance of the industry in those countries, improving the performance of the industry ought to be a priority action.

As contractors are one of the key players in the industry and the makers of the final product, any development and improvement initiatives in the industry have to consider ways of improving the capacity and capability of the contractors (Yimam, 2011). However, 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 construction industry has been found to be a major generation of waste. The generation of construction waste also contributes to the depletion of raw materials used in the construction industry (Al-Moghany, 2006).Waste in the construction industry has been the subject of several research projects around the world in recent years. Many of them have focused on the environmental damage coming from materials waste in the process of construction.

On the other hand, there have been some studies concerned with the economic aspect of waste in the construction industry. In 1996, Bossink and Brouwers carried out an intense study in the Netherlands; with a concern of the measurement and prevention of construction waste, based on sustainability requirements stated by Dutch environmental policies. Accordingly, they estimated 1–10% by weight of the purchased construction materials leave the sites of residential projects as waste in Dutch (Bossink and Brouwers, 1996).

Similarly, based on a study of 86 housing projects in the Gaza strip, AlMoghany came up with an estimation of the material loss resulting from direct and indirect wastes were about 3.6–11%, which were significantly higher than the values that were normally allowed (AlMoghany, 2006).

Skoyles undertook one of the most extensive studies regarding economic aspect of material waste. He monitored materials waste on 114 building sites, concluding that a considerable amount of waste can be reduced by adopting relatively simple prevention procedures. Storage and handling were identified as major causes of waste (Skoyles, 1987).

Most problems of materials wastage appeared at building sites are associated with flaws in the management system and very little with the lack of qualified workers (Skoyles, 1987).Since some degrees of waste materials are inevitable in the construction process, all estimators allow wastage factors in pricing a bill of quantities.

Over the years, experience has shown, however, that unless controlling measures are implemented, wastage may frequently exceed often by a larger margin than the figure allowed in the tender document (Al-Moghany, 2006; Bossink and Brouwers, 1996).In our country, there were thesis studies undertaken at undergraduate and postgraduate level on the material waste control. A research conducted by (Getachew Araya, 2009, cited in Girma E. 2016) for his Master's thesis on wastage of materials in building construction sites of Addis Ababa, is amongst these academic works.

In his survey; questionnaires were spread to 72 respondents and the result showed that 100 % of the respondents strongly agreed upon the existence of material wastage. According to his study, the top three sources of material wastage in building construction are operational, material handling and design respectively (Getachew A., 2009, cited in Girma E, 2016).

In addition, other study at undergraduate level also pointed out the existence of wastage at the construction site of condominiums and different building projects (Mulualem et al., 2012). But these studies do not exhaustively worked out to identify mostly wasted construction materials, the effect of wastages on project cost and minimization techniques of materials wastage on condominium sites.

In 2005, the government of Ethiopia considering provision of houses as one of the major developmental tasks to reducing poverty and improving the livelihoods of slum dwellers; and thereby bringing sustainable socio-economic development, established a National Integrated Housing Development Program under the then Ministry of Works and Urban Development (MWUD) later renamed as the Ministry of Urban Development, Housing and Construction, (MUDHC, 2005 E.C).

The Integrated Housing Development Program (IHDP) is a government-led and financed housing provision program for low-and middle-income households in Ethiopia. Achieving the IHDP objective i.e. construction of Condominium housing for low and middle income group requires huge resources investment.

There is a pressing need for more cost efficient alternative materials, as the current cost of construction materials is a high proportion of total construction cost, typically around 70 per cent (IHDP technical manual, VolI).TeklewoldAtnafu, Governor of the National Bank of Ethiopia (NBE) in his statement on the (CEN, 2013 cited in Merkebu K.,2014), over the recently conducted registration of Addis Ababa City Dwellers for condominium houses mentioned that "the government needs 67 billion Birr to construct the condominium houses for all registrants (i.e. 858,000 registrants).

This makes the condominium construction project as one of the biggest projects that the country is currently undertaking [in terms of financial magnitude].In fact the condominium construction is second to the Great Renaissance Dam (GRD) which consumes USD 4.2 billion, roughly 80 billion birr." This implies that stronger resource (financial, Materials and labour) management is required to ensure that every cent of public money is spent on the intended purposes (Merkebu K. 2014).

These resources should be properly managed so that the government intention of availing affordable housing to the poor, one of the poverty reduction strategy is achieved. However, to solve the housing problem, which is one of the major problems in Addis Ababa; the city administration has been working on affordable housing projects for the last ten years and starting from 2013 new affordable housing scheme by all levels of the city dwellers launched.

The successful execution of housing projects within given cost, time and quality, requires systematic planning and controlling of the construction works through good handling of construction materials on construction site throughout the life of the project from inception to completion. In the present situation, the contractors and the designers are mainly concerned on how to control cost without any emphasis on waste control measures (Seyoum A., 2015).

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. This waste generation activities consume time and effort without adding values to the client thus resulting losses in material. Therefore to avoid overrun the cost of the project it is necessary to avoid the waste generation and proper waste management.

1.2 Statement of the Problem

Material waste has been recognized as a major problem in the construction industry that has important implications both for the efficiency of the industry and for the environmental impact of construction projects. Nowadays the increased economic as well as urbanization all over the world have lead into extensive construction activities that generate large amount of waste material in construction projects resulted into environmentally unfriendly and costly to project budgets.

Waste which has negative impact on the environment, cost, productivity, time, social and economy. Production of construction waste in huge amount due to increasing demand of infrastructure; commercial buildings and housing development projects which has generated large amount of construction waste.

In 1996, Bossink and Brouwers carried out an intense study in the Netherlands; with a concern of the measurement and prevention of construction waste, based on sustainability requirements stated by Dutch environmental policies. Accordingly, Bossink and Brouwers estimated 1–10% by weight of the purchased construction materials leave the sites of residential projects as waste in Dutch (Bossink and Brouwers, 1996).

Similarly, based on a study of 86 housing projects in the Gaza strip, AlMoghany came up with an estimation of the material loss resulting from direct and indirect wastes were about 3.6–11%, which were significantly higher than the values that were normally allowed (AlMoghany, 2006).

The building construction industry in Ethiopia in general has been found to be among the main consumers of resources and energy. Moreover, this sector is reported to be generating unacceptable levels of material and manpower waste. Over the years' experience has shown that unless site management control is tight, wastage can frequently exceed often by a large margin than the figure allowed in the tender document. In order to achieve minimum cost in construction, the Ethiopian building industry must appreciate the difference between waste and value and how to minimize waste in the projects which are carried out.

Since the cost of materials account a great percentage of the total cost of construction projects, construction materials waste has an impact in the overall project cost. More over the materials wasted on construction site during operation exceed the allowance level considered during design stage. This materials waste is shooting up the cost of the houses which is challenging for the government who construct and transfer to the registered house seeker and reduce contractor's profit. Past researchers study on existence of construction materials wastages, professionals view on wastages and materials waste level for selected construction materials but they didn't show that to what extent construction materials wastages costing the project budget.

To sum up, wastage reduction needs serious consideration and due attention since the construction industry consumes large amount of raw materials. Addis Ababa city administration is now investing huge amount of money to build large amount of condominium houses. Therefore, this research aimed to provide ways to manage waste and cost at construction sites of Addis Ababa housing project.

1.3 Research Questions

To achieve the objectives of this Research, the following questions were asked

1. Which construction materials are mostly wasted at construction site that would greatly affect the project cost?
2. What are the major causes of construction materials wastage on building construction sites?
3. What the extents are of wasted of construction materials and costs of housing projects?
4. What are the measures to be undertaken to manage and minimize construction materials wastage on site?

1.4 Objectives

1.4.1 General objective

The general objective of the study was to investigate ways of managing and minimizing construction materials wastage and project cost related to wastages in Addis Ababa Saving Hosing Development Projects.

1.4.2 Specific Objectives

1. To identify the mostly wasted construction materials that would greatly affect the project cost.
2. To investigate the major causes of construction materials wastage on housing project.
3. To determine and analyze the extent of construction materials wastages and costs of housing projects.

4. To suggest some framework and strategy to mitigate the effect of construction materials wastage on housing project cost.

1.5 Scope and Limitation of Study

This study focused on building construction materials wastage in Addis Ababa housing project. Although the housing project under study would be covered, most of the districts in the city, eight (8) sites for only finished houses focused on and only Saving Houses Development projects were considered. The study is constrained by the Cost that limited how widespread our data can be collected, as more data would have been necessary to have a better assessment of the issues.

Significance of the Study

This research is significant because it may help the people engaged in the housing construction industry how they can manage and minimize wastage of construction materials while they produce, transport, and store and operation construction site. In addition, this study intends to provide some framework for the development of policies and rules in the management of construction waste for housing projects and other researchers will also use this research paper for further study on this issue.

CHAPTER TWO

LITERATURE REVIEW

Nowadays building construction industries are boosting globally and consuming huge amounts of resources. Responsibly managing waste on a building construction project is a vital component of optimum use of the limited resources we have that sustain the ongoing development. In the present situation, the contractors and the designers are mainly concerned on how to control cost without any emphasis on waste control measures (Seyoum A., 2015).

2.1 Definition and Concept of Construction waste

Various researchers and experts define waste in different ways. Waste could be any losses produced by activities that generate direct or indirect costs but do not add value to the product from the point of view of the client (Formoso et al. 2002). According to the new production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labor, or capital in larger quantities than those considered as necessary in the production process (Koskela, 1992).

Furthermore, he describes waste includes both the incidence of material losses and the execution of unnecessary work, which generates additional costs but do not add value to the product. In other words, 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.

Researchers describe waste as a loss created through activities, but do not add value to the construction progress rather adds cost (Formoso et al. 2002, Koskela, 1992). So drawing from the views expressed above, the definition of construction waste to be used in this study is any losses in material, time and monetary result of activities but do not add value or progress to the construction.

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, cited in

Seyoum A.,2015). Waste defined as comprising of unwanted materials generated during construction, including rejected structures and materials which have been over ordered or are surplus to requirements, and materials which have been used and discarded (EPD, 2000).The issue of material waste is not a new concept. Previous studies suggest that construction is a major contributor to the generation of waste all over the world (Craven et al., 1994; Kartam et al., 2004; Begum et al., 2006; Tam et al., 2007 and Jaillon et al., 2009).

However, the figures appear not to be consistent from country to country, but it is clear that the waste in construction is substantial compared to other industries. Over 2 billion tons of waste was generated in the European Union every year, approximately half of which is produced by the construction industry (Ferguson et al., 1995). Globally data shows that approximately 40% of waste generated originates from the construction industry. (Nitivattananon and Borongan, 2007, BERR, 2007) highlights that in the UK alone, construction produces more than 100 million tons of waste a year, representing more than 50% of the total waste production of the country. This makes the construction industry the largest generator of controlled waste going to landfill (NCE, 2007).

2.2 Classification of material wastage in building construction

Regarding the possibility to control the incidence of waste, study admits that there is an acceptable level of waste, which can only be reduced through a significant change in the level of technological development. Thus, waste can be classified in unavoidable waste (or natural waste), in which the investment necessary to its reduction is higher than the economy produced, and avoidable waste, when the cost of waste is significantly higher than the cost to prevent it.

The percentage of unavoidable waste in each process depends on the company and on the particular site, since it is related to the level of technological development (Formoso, 2002).Besides a clear understanding of the general concept of waste; it is helpful to use a classification of waste in different categories.

(Skoyles, 1987:18-24), categories waste into four principal types, namely “natural, direct, indirect and consequential” waste. (Babatunde, et al., 2012) identified four major types of construction materials waste in the Nigerian construction sites. These include cutting waste, transit waste, theft and vandalism waste, and application waste. Construction waste falls into different categories. According to (CasteloBranco, 2007), construction waste can be categorized into physical and financial waste.

2.3 Magnitude of Construction Materials waste

The amount of direct waste by weight ranged between 1 and 10% in weight of the purchased amount 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. (Bossink and Brouwers, 1996 cited in Seyoum A., 2015)

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).Researchers estimated that; 40% of construction is rework, 30 to 40% lab or potential is used, 8% of total project costs account for accidents and 20 to 25% of materials are wasted (Datta, 2004).

2.4 Material Usage Standard in Building Construction Project

Generally, the materials cost of a project is conceptualized during the inception stage by using past experience while contracting the quantities of work involved in a project are detailed in the contract bill of quantities. These are derived from the design and drawings. But there is inherent material wastage associated with all types of materials. For example the actual requirements of concrete for the floor slab of a building may be 2% more than the theoretical quantities measured from the drawing, as certain wastage does occur while placing concrete especially, due to inaccuracies in levelling of formwork. This waste factor is used to increase material quantity to ensure that enough material is procured to realistically complete the work and allow bulk discount purchase.

This wastage of materials is generally expressed as a percentage of the materials calculated theoretically from the quantities of work involved, and are termed as "standard wastage". The total quantity of materials to be provisioned should cater for the standard wastage by increasing the theoretical quantity, proportionately (Chitkara, 2004).
Actually needed quantity=theoretical quantity*(100+standard wastages %..)… [eq.2.1]

It may be noted here that standard wastage caters for wastage during utilization only for causes considered beyond control at the site. This standard wastage of construction materials depends upon many variables such as the nature of work, method of application and type of materials used.

However, such allowances are often traditionally assigning and their accuracy or base rarely challenged. Rather, the standard wastage best be specified from the experience of contractors and its value is different for different materials. Good record keeping on previous work performance and by systematically comparing the current situation with similar performance in the past, a probable outcome can be predicted (Chitkara, 2004).

2.5 Measuring of Construction Material Waste

Waste quantification is a primary requirement for the waste minimization process. In addition to the fact that recording and measuring waste is a prerequisite to its management, knowing how much waste generated can also be used as a benchmarking tool against other projects cost estimation and cost overrun control. Since the quantities produced are difficult to estimate and variable in composition, distinct measurement procedures are necessary for each of them.

Some studies have been conducted indifferent countries to gain insight in the percentage of generated waste during construction operation for specific materials. According to (Bossink and Brouwers, 1996) a research conducted in the Netherlands that was concerned with the measurement and prevention of construction waste, materials waste in construction studied in building projects in three views:

1. Construction waste of a specific material as percentage of total construction waste,

2. Construction waste of a specific material as percentage of its total amount,

3. Cost of construction waste of a specific material as percentage of total waste costs.

These methods are all illustrative of the level of waste generated and they can be used Simultaneously. Amount of material waste generated in the projects found out by calculating the difference between the final estimated quantities and actual consumption.

Wastage quantity (%) = ((Mp-Mu) x100%)/Mp……………………….. [Eq.2.2]

Where: Mp is the purchased material; and

Mu is actual needed material

2.6 Causes of material wastage in building construction

Among the total project cost around 67% is covered by the material cost from the building project. As in the work of (Skoyles, 1976 and cited by Formoso), most causes of waste are related to flaws in the management system, and have very little to do with the lack of qualification and motivation of workers. Also, waste is usually the result of a combination of factors, rather than originated by an isolated incident.

Many factors contribute to construction waste generation at site. Waste may occur due to one or a combination of many causes. Gavilan and Bernold organized the sources of construction waste under six categories: In his research, the factors which cause waste on site were identified after a review of the literature, and placed in four major sources as Design, Operational, Material handling, Procurement, mainly for the practical purpose(Gavilan and Bernold ,1994).

Al-Moghany, identified the source materials wastage in his thesis work were reworks that don't comply with drawing and specifications, rework due to worker's mistakes, cutting uneconomical shapes, ordering of materials that don't fulfil project requirements defined on design documents, and inappropriate storage leading to damage or deterioration are the most five signifying sources of construction waste during the construction process (Al-Moghany, 2006).

From previous work in this area, it was identified that construction waste could be divided into two main categories: waste generated due to design and specification, and waste generated by construction activities. Waste production on construction sites is often down to poor storage and protection, poor or multiple handling, inaccurate or over-ordering of materials and damage to materials during deliveries or by poor co-ordination with other trades (DETR, 2000a cited by Jonathan et al.,2010).

Although waste percentage values displayed differences among materials, design-related aspects, skill level and attitude of labour, incorrect calculation of material quantities, contractual clauses and material defects were the most effective reasons for waste within the projects analysed (Mehmet, 2007). According to (Poon et al., 2001), recent research in Hong Kong indicates there are many contributory factors to wastage, both human and mechanical. (Lee et al., 1999) organized the sources of waste during the construction process as: rework/repair, defect, and material waste, delays, waiting time, poor material allocation, unnecessary material handling and material waste. In Singapore, (Ekanayake and Ofori, 2000) organized the sources of construction waste under four categories: (1) design; (2) operational; (3) material handling; (4) procurement

To be able to reduce the amount of construction waste, the question occurs as to what the main causes of the generation. By identifying the main causes, construction industry players can avoid excessive waste generated. Construction waste originates from various sources in the whole process of implementing a construction project due to one or a combination of many causes.

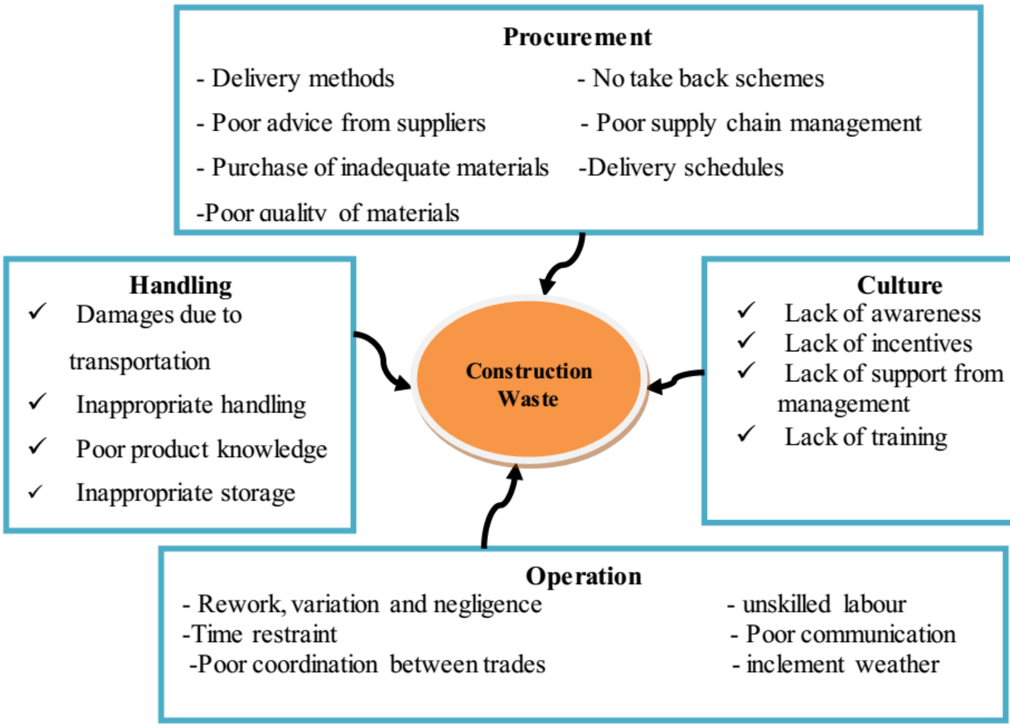

Figure 2.1 Origins of construction waste [source (Al-Hajj &Hamani, 2011)]

Material waste can be categorized according to its source; namely the stage in which the root causes of waste occurs. Different studies in different countries identify these sources which cause building material waste. (Bossink and Brouwers, 1996) organized the sources of waste during the construction process as: design, procurement, materials handling, operation and residual.

Further, the most common causes of construction waste were identified from past researches by (SasitharanNagapan, 2011). His study, conducted on causative factors of construction waste existing in construction field activities. The causes of construction waste are matrix and found that 63 waste factors existed in construction activities. The waste causes were grouped into seven categories: Design, Handling, Worker, Management, Site condition, Procurement and External. In this research the sources which cause waste on site were identified after a review of the literature, and placed in seven major categories.

It is assumed that the importance of these categories will vary not only from project situation to project situation but also from material to material. For example, it is more likely that concrete waste rather than dimensional lumber waste will be created by design error. However, those wastes that are created can usually be attributed to short comings in one of the following areas:

2.6.1 Design and Documentation

- Lack of attention paid to dimensional coordination of products
- Design changes and revision
- Ambiguities,
- Mistakes and inconsistencies in drawings and specification

The best opportunities for improving materials resource efficiency in construction projects occur during the design stage. Inadequacy of design and specification and lack of standard manufactured sizes are just some of the waste contributory factors. Design changes are common as a result of owner demands or requests to meet changing requirements and preferences.

Changes in design decisions while construction is in progress can result in demolition, surplus and redundant materials, demoralization of lab or force and reduction of quality of products and in extreme cases, turnover of construction personnel. Besides, considerable waste is often incurred as a result of design information being incomplete when construction is to begin. There are always cases that the design specifications do not agree with the practical material dimensions causing large amounts of material wastage during construction. If detailed technical information about the construction materials or construction process can be taken into account by the designers, a significant amount of waste can be avoided (Asmi et al., 2012)

2.6.2 Procurement

- Poor quality of materials
- Poor schedule to procurement
- Mistakes on quantity surveys
- Purchased materials that do not comply with the specification

Errors in ordering and shipping can cause materials wastes in the building construction projects. Procurement mistakes can result in one of three material conditions: over shipment, under shipment, or miss-shipment. They are usually caused by miscommunication either within the builder's organization or between the builder and the vendor (Bossink and Brouwers, 1996). An enormous amount of waste stems from procurement errors. Ordering errors like ordering significantly more or less will interrupt the pre-planned flow of materials, thus causing deliveries made to redundant and result in additional handling with all its related costs (Sagoe, 2011)

.

2.6.3 Handling and Storage

- Improper handling of materials
- Double handling of materials
- Overloading of transport equipment (beyond its capacity)
- Improper storage of materials on site

Wrong materials storage and poor handling are key factor for physical waste generation in the building projects. Improper handling, may occur at the work site, or before the material arrives at the site. That is, the material may be damaged during fabrication, packaging, loading, or delivery. At the site, construction materials may be damaged due to unnecessary handling or improper storage without appropriate protection.

For example, many construction materials are subject to deterioration and bio-degradation due to environmental impacts. Besides, excessive stocks are subject to damage, deterioration, theft and vandalism (Al-Moghany, 2006).Proper handling of materials is dependent on planning, particularly on clear and uninterrupted access from the place of storage to the place of usage, inclusive of provision of temporary roads and appropriate equipment (Asmi, 2012).

2.6.4 Operation

- Rework (chiselling, complete removal and rework…etc.)
- Using an excessive quantity of materials than required
- Using an incorrect type of material
- Damage to work done by other trade (like electrical & sanitary installation)
- Poor workmanship

Operation is one of the major causes for waste generation accepted by many researches.

Improper operation procedures are often resulting in high materials wastage. But, raw materials should be fully utilized avoiding wastage. Operational errors like rework, damage to work done by other trade, poor workmanship, using excessive quantity of materials than required are all due to negligence and carelessness or incapability of operatives (Asmi, 2012).

2.6.5 Site management

- Poor qualification of subcontractors
- Scarcity of Equipment
- Untidy construction site

Construction management is about planning, coordinating and controlling everything involved in the construction project. Poor planning which is due to lack of planning skills of the management staff lead to the generation of physical waste in building projects. Furthermore, incorrect planning and selection of equipment also cause the work to stop. Thus, proper planning and controlling is the key function that should be used effectively in eliminating material wastage (Asmi, 2012).

2.6.6 Site Supervision

- Poor qualification of consultant engineer's staff assigned on the site
- Delay in performing inspection and testing by the consultant Engineer
- Poor coordination and communication between the consultant engineer, contactor
- Client slow response from the consultant engineer to contractor inquiries.

Professional construction supervision specifically tailored to safeguard the successful completion of a construction project. Construction site supervision services can be complemented by compressive quality control services. This guarantees the materials used all equipment's and systems are of good quality, function well and confirm to the standard. Checking and approving all these helps to reduce material wastage on the site (Al-Moghany, 2006).

2.6.7 Others

- Weather condition
- Theft

These wastes may result from a wide variety of sources. This can be due to weather conditions, theft and accident. To reduce material wastage from such causes avoids placing washable materials at sleep slope or near drain and providing security guard at the construction site are advisable (Asmi, 2012).

2.7 Cost Effect of wastage on construction industry

The economic and environmental benefits to be gained from waste minimization and recycling are enormous (Gutherie, 1999 cited by Jain, 2012), since it will benefit both the environment and the construction industry in terms of cost savings.

2.7.1 Impact of Material Wastage on Building Construction Project Performance

Construction waste management and minimization has great potential to contribute to construction industry performance improvement in addition to waste management problem caused by the construction sector. Wastage of materials in construction projects has an impact on quality of works, project cost, working time, safety and health of the workers (Sagoe, 2011). These impacts of material wastage described in detail below.

2.7.2 Effect on Quality of Work

Quality is one of the critical factors in the success of construction projects. Quality problems are considerable in all phases of construction. Achieving good waste minimization on construction projects helps to reduce the quantities of construction waste sent to landfill. Since most of the causes of material wastage are the causes for quality problem in construction projects, minimizing material wastage has a role in the improvement of quality of work. For example, the problem related to labor such as lack of skilled labor, a mistake by the workers, rework, etc. are the causes for material wastage and poor quality of work. Consequently, resolving these causes of materials wastage result also in achieving good quality of work (Sagoe, 2011).

2.7.3 Effect on Cost of Project

Construction material wastage significantly affects the total cost of a project. The true cost of material waste consists of direct and indirect costs. Direct cost consists of the purchase price of the material that ended up as waste and indirect costs consist of:

(i) Cost of transporting the waste off-site

(ii) Missed opportunity of not reclaiming reusable and recyclable material.

(iii) Lost time in terms of labor and management time.

(iv) Loss of ability to win contracts based on bad waste history

A construction company can thus be profitable by reducing the amount of waste it needs to dispose of. Due to this the construction materials wastage has significant influence on the overall project cost (Sagoe, 2011).

2.7.4 Effect on Work Time

The total time of construction project is usually specified prior to the commencement of construction. However, construction projects are known to experience time delays due to various reasons. Material waste has a direct impact on the productivity and completion time of project, which results in loss of a significant amount of revenue (Sagoe, 2011).

The occurrence of material wastage in construction projects results in an unnecessary works like waste handling processes, which are non-value adding activities to the project. These non-value adding activities consume a high percentage of overall working time and effort without adding value thus resulting in delay. Therefore, effective minimization of material wastage in construction project results in the avoidance of unnecessary works (Bo Terji, 2010).

2.7.5 Effect on Safety of Workers of a Project

Another material wastage effect on the building project is lack of safety and health on the workers. Decreasing the amount of waste on site and managing more effectively what remains will lead to cleaner and safer sites. For instance, high winds might lift unclear debris such as iron sheeting into the air, which could be a potential threat to people (Al-Moghany, 2006).

Good waste management on site, which includes, for example, encouraging your workers to think about where they place their waste, will also result in a better site image. More importantly, it could also lead to improved health and safety, as there are likely to be fewer accidents if material waste is minimized. This can be achieved by providing:

- Safe access to people and vehicles on site that they can reach the allotted workplace Walkway which are free from obstructions of waste materials
- Tidy sites and storing materials in safe places and ensuring that all projecting nails are hammered down flat or removed completely
- Proper arrangement for gathering and disposing off waste materials

Indirect costs consist of: (i) Purchase price of the material that ended up as waste. (ii) Cost of transportation from suppliers to the site of material that ends up as waste. (iii) Missed opportunity of not reclaiming reusable and recyclable material. (iv)Lost in terms of labor and management time. (iv)Loss of ability to win contracts based on bad waste history. According to (Osmani et al., 2006), construction projects usually allow 4% as an allowance for waste, and savings of 1% can be achieved through a waste minimization program.

Hauling and disposal costs, the value of recovered materials, and labor costs contribute to whether materials recovery is more or less cost-effective than disposing of materials. Recovery of low value materials may be cost-effective if disposal costs are high and removal and sorting are not labor-intensive. The added labor necessary to remove items for reuse may be offset by savings from both the avoided costs of purchasing new materials and avoided disposal costs (Al-Moghany, 2006)

2.8 Construction waste management and minimization measures

2.8.1 The concept of waste management

The business of keeping our environment free from the contaminating effects of waste materials is generally termed waste management. (Gbekor, 2003), for instance, has referred to waste management as involving "the collection, transport, treatment and disposal of waste including after care of disposal sites". Similarly, (Gilpin, 1996) has defined waste management as "purposeful, systematic control of the generation, storage, collection, transportation, separation, processing, recycling, recovery and disposal of solid waste in a sanitary, aesthetically acceptable and economical manner".

It can be deduced from these definitions that waste management is the practice of protecting the environment from the polluting effects of waste materials in order to protect public health and the natural environment. Thus, the priority of a waste management system must always be the provision of a cleansing service, which helps to maintain the health and safety of citizens and their environment (Cooper, 1999). Further, (Gilpin, 1996) regards the business of waste management as a professional practice, which goes beyond the physical aspects of handling waste.

It also "involves preparing policies, determining the environmental standards, fixing emission rates, enforcing regulations, monitoring air, water and soil quality and offering advice to government, industry and land developers, planners and the public" (Gilpin, 1996). Waste management, therefore, involves a wide range of stakeholders who perform various functions to help maintain a clean, safe and pleasant physical environment in human settlements in order to protect the health and well-being of the population and the environment. Effective waste management is, however, a growing challenge to all municipal governments, especially in developing countries.

2.8.2 The principles of waste management

The principles of waste management, as identified by (Schubeller et al., 1996), are "to minimize waste generation, maximize waste recycling and reuse, and ensure the safe and environmentally sound disposal of waste". This means that waste management should be approached from the perspective of the entire cycle of material use, which includes production, distribution and consumption as well as waste collection and disposal. While immediate priority must be given to effective collection and disposal, waste reduction and recycling should be pursued as equally important longer-term objectives (Schubeller et al., 1996).

2.8.3 Strategies for waste reduction

Environmental stresses are escalating due to the consumer culture that relies heavily on resource extraction, production, consumption and disposal (Barr, 2004; Entwistle, 1999; Pongracz Phojola, 2004). Sources of production are often distant from places of consumption and disposal, making the interconnectedness of resource cycling difficult to ascertain. It must be emphasized how the conditions experienced by one group of people can undermine the existence of another (Hartwick, 2000). To link the spaces of production to the places of consumption and disposal, one must "follow the path of a commodity back from the point of consumption, marketing, distribution, and processing, along the transport network, to the point of production, and beyond" (Hartwick, 2000).

It is also important to follow the commodity forward through consumption, second handedness, deconstruction, transformation, or disposal. (Hernandez and Martin-Cejas, 2005) reinforce that "the integral management of solid waste requires a global perspective of the flow of materials circulating in the ecosystem." Taking account of the full environmental, social and economic costs of products and waste management policies is a step towards regarding the future consequences of today's actions (Craighill et al., 1996).

These costs must be considered in a long-term context as sustainable waste management "raises concerns not only about the intra generational but also the inter-generational implications of cradle-to-grave control where the potential environmental impacts may last hundreds of years" (Petts, 2005). Recent investigations into waste management strategies are challenging the idea that production consumption-disposal follow an inevitable sequence from cradle to grave. Production and consumption processes can be imagined as being part of a cycle, referred to as a 'cradle-to cradle' model by (McDonough and Braungart,2002), where materials are continuously utilized throughout multiple lifecycles, never being downgraded to lesser products.

The emphasis is on durable, long-lived products over single-use items, thereby minimizing waste, conserving raw resources, reducing pollution and offering the consumer a sustainable option. Consumer waste is highly variable, typically unsorted, and contains multiple materials from an array of production sources. The true economic costs of solid waste management are far removed from consumers' decisions thus violating the 'polluter pays' principle (Michaelis, 1995). Waste management on a global scale should enforce the notion that individuals, governments and industry have a role in reducing and reusing materials. Individuals have a responsibility to reduce environmental impacts from waste through participation in environmentally conscious consumer practices; governments have a responsibility to monitor and enforce best practices for waste reduction, including the implementation of policies and incentive programs; and industry has a responsibility for reducing energy and resource consumption by producing packaging that is recyclable or reusable.

2.8.4 Evaluating the concept of waste minimization

According to (Crittenden and Kolaczkowski, 1992) waste minimization is "any technique, process or activity which avoids, eliminates or reduces waste at its source or allows reuse or recycling of the waste". Waste minimization, prevention and management are sometimes used interchangeably. (Jacobsen and Kristofferson, 2002) in their report on waste minimization practices in Europe gave a clear distinction between the three concepts and defined waste minimization as a set of three options prioritized according to the waste hierarchy. The first priority is waste prevention; the second is waste re-use while the third priority is waste recycle.

Studies undertaken in different countries (e.g. Poon et al., 2004; Shen and Tam, 2002; Mcdonald and Smithers, 1998) have proven the effectiveness of the SWMP approach as an important measure in reducing waste generation on construction sites. This analysis shows that there is a poor implementation of the technique on construction sites in the UAE. An increase in the use of SWMP in UAE projects will have an immediate impact in the level of material waste generated on site.

The analysis shows that the top three measures of waste minimization fall within the first level, which is waste prevention. These measures are (i) adequate storage of material, (ii) ordering just what is needed and (iii) staff training and awareness. The three measures that the analysis shows to be less frequently implemented in the industry are namely (i) recycling on-site, (ii) recycling off-site and (iii) appointment of waste manager on site. The current practices implemented by contractors to minimize material waste on construction sites are: adequate storage, staff training and awareness, and 'just- in time' delivery (A.Al-Hajj, 2011).

The aim of construction C&D waste management is based on waste minimization and appropriate disposal, which both two help to reduce negative environmental impacts. The specifications of European Union can be evaluated under three principles of waste management: Waste Prevention**,** Recovery and proper storage**.** Purchase and storage conditions should be carefully controlled during the construction stage in order to minimize wastage of surplus raw material and to provide financial savings Waste management in Turkey (Arslan et al., 2012).

Construction waste can be control by various ways such as practicing attitude towards Zero wastage, proper decisions at design stage, site management, proper standardization of construction materials, and Codification of the same. Construction waste can also be reduced by using waste management system on project. The project activities are to be planned at every stage by every construction personnel, who are involved in minimizing the overall waste generation at project.

Concept of 3R and 4R can be also beneficial to reduce the wastage of construction materials, which includes reduce, reuse, recycle, and recovery. The context of production and consumption is very well known. Recycled material can be used in actual practice and can be reduce the use of resources and energy. This can be used during from starting point of construction of project like products and starting from design and extraction of raw material to transport, manufacture, use, dismantling and disposal.

To help reduce amount of construction waste by designing to dimension available in the market that will eliminate cutting and shaping steel frame, plywood and drywall. Significant amount of waste can be eliminated by using smart engineering, standard dimensions, recycled material, metal formwork instead of wooden formwork for concrete works. Providing the proper training to the individuals that are performing work on site is definitely additional cost to the project but it will save huge amount of money at the end.

Providing different containers and smaller bins for all possible kinds of waste marked clearly and properly to indicate that the type of waste that will contain. Scheduled waste disposal and replacement of waste containers will be part of the subcontractor's responsibility. Various strategies for Construction and Demolition waste reduction also include standardization of design, stock control for minimization of over ordering, environmental education to workforce etc. Government's interventions like Landfill tax, higher tax for using virgin construction materials, tax credits for recycling etc. can be used on construction site for waste minimization.

2.8.5 Construction Materials Waste Minimization

Waste minimization is one of the most effective approaches to respond to the waste problem in the construction industry. The (EPA, 2000), defines waste minimization as "any method that reduces the volume or toxicity of a waste that requires disposal". (Poon and Jaillon ,2004) also studied how to reduce building waste at construction sites in Hong Kong, and defined waste minimization as "any technique, process or activity which avoids, eliminates or reduces waste at its source or allows re-use or recycling of the waste". In both sense waste minimization is a method that reduces the amount of waste generated on site.

2.8.6 Benefits of Construction Materials Waste Minimization

The consideration of waste minimization on the construction projects can create mainly financial and environmental benefits.

2.8.6.1 Financial benefit

For economic reasons people in the construction industry need to have an insight into the financial consequences of construction waste. Substantial savings could be obtained by reducing the amount of construction waste (Begum et al., 2006). The financial benefit gained by waste minimization appreciated over a short term or long-term period. This financial benefit comes from:

- Reduced purchase quantity of raw materials by waste minimization
- Reduced transportation costs for waste materials (less transportation because of less material wasted)
- Reduced disposal costs of waste materials. Less waste generated means less waste taken
  to landfill, which will reduce landfill fees for disposal.
- Long term benefits through reduction of the occurrence of delay, poor quality, and health and safety problem on the building sites. Due to this the company will get higher profit.

According to (Al-Moghany, 2006), sending building materials to landfill is like throwing money away. This is because it is already paid for the material, paid someone to deliver it and then paid someone to collect it and throw it away. However, this argument could be necessarily true when the cost of waste is significantly higher than the cost to prevent it.

2.8.6.2 Environmental benefit

The large volume of waste in the construction industry contributes to the rapid depletion of natural resources and production of high volumes of air pollution (Formoso et al., 1999). The Environmental benefit is crucial because of its role in the improvement of the planet's atmosphere; taking into consideration the next generation's environment. Waste minimization can provide environmental benefits, which are important to be considered due to the alarming situation of materials waste on construction sites. The environmental benefit comes from (Sagoe, 2011):

- Minimized amounts of waste disposed of at landfills, which therefore extend the life span of landfills and reduced environmental effects as a result of disposal, e.g. noise, pollution.
- Reduces the production of greenhouse gas emissions and other pollutants by reducing the need to extract raw materials and ship new materials long distances.
- When material ends up as waste it has the potential to be reused thereby minimizing its impact on the environment through less processing.

2.8.6.3 Increased image of the company

The ability to demonstrate good waste management could differentiate one contractor from the competitors. A clear waste management policy, which includes effective recovery and recycling of resources, could enhance the reputation of a contractor and give the superiority when tendering for new projects (Narimah, 2008).

2.8.6.4 Other benefits

- Increased site safety
- Increased work efficiency
- Creates employment opportunities and economic activities in recycling industries

2.8.7 Construction Materials Wastage Minimization Hierarchy

Three main waste minimization strategies used in construction projects. These are reduction reuse and recycling collectively called the "3Rs" (Adinyira et al., 2007).

2.8.7.1 Reduction

Reduction is defined as any activity that reduces or eliminates the generation of waste at the source, usually within the process. Therefore, Waste reduction or source reduction, means preventing the creation of the waste in the first place (Begum et al., 2006). The biggest opportunity to impact on waste generation through prevention principles is at (Dennis, 2002):

Design: - through design for waste reduction, i.e. the design stage will provide plans and specify materials that are prefabricated, recyclable and low waste building technologies. **Operations:-**This is through clear communication of the designer to the project team to avoid unnecessary waste through errors and redo.

Procurement: - through the engagement of suppliers in delivering quality materials and through take back agreements for unused materials. Reduction is at the highest preference on the construction waste minimization hierarchy; it has the most positive environmental impact due to the action having a direct effect. Many design and job site practices can significantly reduce waste and cost of materials while requiring only slight modifications of procedures.

2.8.7.2 Reuse

Reuse means to utilize articles from the waste stream again for a similar or different purpose without changing the form or properties of the article. This includes scrap generated on site and used materials. Reuse extends resource supplies and reduces energy and pollution even more than recycling (Begum et al., 2006). When reusing materials, the contractor should ensure that the material is of suitable quality and fit for the intended use.

2.8.7.3 Recycling

Recycling is a process where the separation of a waste from a waste stream for further use and the processing of that separated material as a product or a raw material. According to (Ekanayake and Ofori, 2000), recycling waste materials is a very important environmental management tool for achieving sustainable development. Recycling, as a minimization strategy generally, requires more technological innovation than those of reduction and reuse, as the process typically requires the modification of materials through remanufacture. On the other hand, recycling waste without properly based scientific research and development can result in environmental problems greater than the waste itself (Begum et al., 2006). Recycling is actually the last option after rethinking to reduce the amount of waste produced and reusing waste that are produced. Minimization of waste at source should be given the highest priority when developing strategies for waste minimization. This is because, conceptually, it makes more sense to avoid or minimize the generation of waste than to develop extensive schemes for treating waste. Reusing and recycling do not avoid the generation of waste rather reduce the volume of waste material to be disposed of and discharged into the environment, thereby allowing waste materials to be put to beneficial use. However, the successful development of new materials or components using waste as raw material is a complex and a multidisciplinary task regarding technical, environmental, financial, marketing, legal and social aspects (Waitakere City Council's, 2008).

2.8.8 Factors Affecting Recovering of Construction Waste Materials

The choice of what and how construction waste materials can be recovered depends on many factors, including the type of project, space on the building site, the existence of markets for materials, the cost-effectiveness of recovery, the time allowed for the project, and the experience of the contractors (Al-Moghany, 2006).

2.8.8.1 Space on the building site

Materials recovery is often easiest if the building site is spacious enough to allow on-site sorting of materials. Having separate containers for each type of materials can reduce contamination.

2.8.8.2 Materials markets

While it is possible to reuse and /or recycle many of the waste materials generated on site, the feasibility will depend on the market conditions for each type of material. Contractors can maximize recovery by taking advantage of all available markets for recovered materials.

2.8.8.3 Cost-effectiveness

Hauling and disposal costs, the value of recovered materials, and labor costs contribute to whether materials recovery is more or less cost-effective than disposing of materials. Recovery of low value materials may be cost-effective if disposal costs are high and removal and sorting are not labor intensive. The labor cost incurred to remove items for reuse may be offset by savings from both the avoided costs of purchasing new materials and avoided disposal costs.

2.8.8.4 Project timeline

Source separation of materials for reusing and recycling can take more time than disposing of all the generated wastes and often projects are on a tight schedule due to different reasons. Contractors can maximize materials recovery in the time allowed by planning. If necessary, contractors can focus waste reduction efforts on off-site source separation and recycling.

2.8.8.5 Contractor experience

Contractors well experienced in recovery methods and local markets may be able to recover more materials than contractors unfamiliar with reuse and recovery techniques may.

2.8.9 Best International Practice on Building Materials Wastage Minimization

While construction and demolition wastes are usually grouped together under the title "C&D waste" in many countries in the world, the minimization strategy also undergone for waste of both processes. Throughout the construction cycle, and especially at the end of a structure's life, large quantities of material waste are produced. The increasing problems associated with construction and demolish waste have led to a complete rethinking in some of the industrialized countries.

The current tendency in several industrialized countries is to view wastes as resources or by-products, which become new products that can be used for a variety of useful purposes (Begum et al., 2006; David et al., 2006). This is because a large proportion of the waste produced on construction sites is recoverable for reuse and recycling.

2.8.9.1 Experience from Germany

Construction and demolition waste management in Germany is a mature and well-integrated sub industry within the broader German construction market. In 2002, German construction and demolition activity generated 214 Megatons of waste composed two thirds of excavated material, nearly another third of building and road demolition waste and a smaller fraction of mixed construction site waste. Despite these high numbers, only 15% of these materials were disposed of in landfills, while the remaining 85% was recovered and reused in further applications or recycled (David et al., 2006).

Germany's high material and waste disposal costs favor the economics of recovering, reusing and recycling as much construction and demolition waste as possible. Additionally, strong waste management systems have long been required by laws and regulations at all levels of government in order to minimize the impact of construction and demolition waste in the waste stream. More recent versions of these regulations focus on the complete material cycle, working towards a closed loop substance cycle in construction and demolition. This combination of regulatory pushes from the government and economic pulls from the market have helped Germany establish an effective construction and demolition waste management infrastructure. The disposal of waste is only permitted when recycling is much more expensive or impossible and the waste is unavoidable.

Furthermore, waste management practices have been integrated into mainstream architectural and engineering education and practice. Architects and engineers designing and constructing buildings are obliged to consider the entire life cycle of materials, from production, to removal and reuse or recycling, of components they install in buildings. Construction material manufacturers are responsible for ensuring that their products are designed in such a way as to reduce wastage (e.g. different lengths of floor boards to reduce cutoffs), facilitate recovery after usage, work towards making them recyclable and make them environmentally compatible with post recovery applications. Building owners, developers, engineers and architects are responsible for integrating a waste management strategy in their construction plan.

This includes the use of recyclable building materials. Despite this, in order to insure the substitutability of recycled materials for new materials, a quality assurance system has been established in Germany. The government has established strict codes to which recycled material must conform in order to be reused in further applications. These codes give recyclers and contractors clear indications about what can and cannot be done with a particular material.

2.8.9.2 Experience from Australia

A number of states, including Victoria, South Australia and Western Australia, have 'towards zero' waste strategy documents. The strategies set statewide targets for waste reduction, resource recovery and littering (Chris and Emily, 2013).Many local councils require waste management plans before granting development consent. They usually require the builder or designer to estimate the total waste stream volumes from both demolition and new construction.

In addition, nominate the means of disposal, including the recycling contractor, recycling waste station or landfill site. The site plan is often required to show waste storage facilities on site during construction and provide a schedule for delivery or pickup. The time and cost of waste plan preparation is usually recouped through reductions in waste disposal costs or dividends from the sale of salvaged resources. The following list demonstrates some reuse and recycle options in Australia.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

Addis Ababa is the location of this study and this research is carried out a randomly selected of eight (8) projects sites in Addis Ababa Saving Houses development project which their physical status were above 90%.

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 conclusion (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).

In a quantitative study, the steps involved in conducting an investigation are 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 was also used to collect preliminary information to help in structuring the questionnaires.

The questionnaire survey was also adapted to get feedback on opinions of respondents‟ about cost impact of construction materials wastage on housing project in Addis Ababa Saving Houses Development. 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 in the housing construction industry. Photographs were taken to document how these materials were stored and handled on site.

3.3 Source of Data and Research Instrument

Multiple evidences approaches were used for data collection. These are questionnaire survey, observations made on site and case study by analyzing different documents. The study depended on both primary and secondary data. Primary data was made up of first-hand data collected with questionnaires, interviews and site visits (observation). The secondary sources of data were obtained using relevant books, journals, magazines and research papers.

The questionnaire form, which was accompanied by a covering letter, consisted five parts. The questions were structured or closed type questions. The questions were constructed using the Likert scale. The first part sought information about the respondents' profile and the second part identification of mostly wasted construction materials by rating values of 100%, 75%, 50%, 25%, 0% assigned as extremely significant, very significant, moderate significant, slightly significant, no significant respectively.

In the third part, participants were asked to rate causes for materials wastage on their specific site. The respondents were requested to rank these causes in order of importance. The rating values of 5, 4, 3, 2, and 1 were assigned to the options very high influence, high influence ,moderate influence, low influence, no influence respectively in obtaining the respondents' perception of the causes leading to construction material waste generation.

The fourth part of the questionnaire contained questions focused on to what extent construction materials wastages affect housing project cost from the case study. The fifth part of the questionnaire contained some framework and strategy to minimize Construction materials wastage. For each waste minimization measure, the respondents were asked to score the level of contribution to waste minimization on a scale of 5 to 1 where 5= 'Very high'4= 'High' 3= 'Medium', 2= 'low', 1= 'very low'.

Observations made on site have helped the researcher to see the actual condition on the site and is used to countercheck the reliability of the questionnaire response. The data of the case study gathered from drawings of the buildings, bill of quantity, Contact agreement, specification and material dispatch form of Addis Ababa saving houses development enterprise logistic section. The analysis of the data from these documents carried out mainly to obtain the approximate percentage of material wastage and its cost impact on housing project.

3.4 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. 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 included contracting companies, consultants and construction professionals working for Addis Ababa saving Houses Development Enterprise. Therefore, the populations this research, includes General contractors classified as (GC1/BC1 - GC3/BC3), G1 Consultant Company and supervisors working for client. Those selected categories have experience, efficiency and managerial and financial capability. There are 60 total numbers of GC1, GC2 and GC3 contractors and there are 20 G1 Consultant companies and 40 client staff included in this study. The sample population was distributed between contracting companies: 20 of GC1/BC1 contractors, 20 GC2/BC2 contractors, 20 GC3/BC3 contractors, 20 G1Consultant companies and 40 supervisors working for client. Therefore, this research paper considers the supervisors working for client as sample representative.

Table 3.1 Sample population data

No	Site	No of Blocks	No of houses	No of Contractors	Date of Contract
1	SengaTera	5	410	5	Jan-13
2	Kality Crown Hotel	14	882	7	May-13
3	IhilNigdi 1	13	1716	3	Nov-14
4	IhilNigdi 2	6	72	5	Oct-14
5	HintsaAkirabi	8	1056	4	Jan-14
6	Bole Bulbula	28	2850	14	Feb-14
7	Meriloqe	14	1848	7	Feb-14
8	Bole Hayat	133	8937	15	May-14
		221	17771	60	

Source (Saving Houses Development Enterprise /SHDE/) May, 2015

In order to evaluate and assess the cost impact of materials wastage on randomly selected housing project sites in Addis Ababa, a wide range of Construction parties involved in construction of projects were targeted. Therefore, the following equation is used to determine the sample size (Al-Moghany, 2006).

$$Ss = \frac{Z^2 * P(1-P)}{c2} \quad \text{.......... [Eq3.1]}$$

Where Ss=Sample size, Z=Z value 1.96 for 95% confidence level,

P=Percentage picking a choice 0.5 used for sample size

C=Margin of error (9%)

$$Ss = \frac{(1.96)^2 * (0.05) * (1-0.05)}{0.09^2} = \mathbf{119}$$

$$S_{S\ NEW} = \frac{S_S}{1 + \frac{S_S - 1}{POP}} \quad \text{.......... [Eq 3.2]}$$

Where, Contractors=60, Supervisors=40, Consultant=20, Total=120

Total sampled of construction parties = 120 match the proposed contracting companies

$$S_{S\ NEW} = \frac{119}{1 + \frac{119-1}{120}} = 60$$

To ensure good representation of each stratum the following was done.

GC/BC -1=20 Ss new = $\frac{60*20}{120}$ = 10 GC/BC-1 contractors

GC/BC-2=20 Ss new = $\frac{60*20}{120}$ = 10 GC/BC-2 contractors

GC/BC-3=20 Ss new = $\frac{60*20}{120}$ = 10 GC/BC-3 contractors

Consultant =20 Ss new = $\frac{60*20}{120}$ = 10 Consultants

Supervisors=40 Ss new = $\frac{60*40}{120}$ = 20 Supervisors working for client

3.5 Method of Data Analysis

The analysis was done using Microsoft Excel, the responses assigned to each question by the respondents were entered, and consequently the responses from 4 consultants, 17 supervisors and 26 contractor's questionnaires were subjected to statistical analysis. The following statistical techniques, which are grouped under various headings, were then employed to analyze the data collected from the survey.

Frequency tables and descriptive statistics were constructed to display results with respect to each of the questions of general information and frequently wasted construction materials on housing project. Whereas the contribution of each of the causes to material wastage generation, its cost effect on project, minimization strategies for each of the selected materials was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by the use of relative importance index (RII).The sample for this study is relatively small. As a result, the analysis had combined all groups of respondents (supervisors from client side, consultants, contractors) in order to obtain significant results. Data was analyzed by calculating frequencies and Relative Importance Index (RII). The Relative Importance Index (RII) is calculated as follows (Aibinu and Jagboro, 2002 cited by Asmara Seyoum, 2014):

$$RII=\frac{4n_1+3n_2+2n_3+1n_4+0n_5}{4N} \quad \text{...} \{Eq.3.3\}$$

Where: N = Total number of respondents

ni = the variable expressing the frequency of the *i*th 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.

Table 3.2; the levels of response

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

RESULT AND DISCUSSION

This chapter aims to display the results of the study. The quantitative research findings are outlined in table, different types of charts, figures and text form. Each result was discussed in short, however; certain results were followed by a more in-depth discussion. The total number of distributed questionnaires in this study consisted of sixty but collected responses were forty-nine. Out of the returned questionnaires, two were rejected for the analysis due to many un-replied questions observed in the questionnaire.

4.1 Results

The results that have been obtained from processing of forty- seven Questionnaires using Excel were described. The results are prepared to present the information about the sample size, response rate and contracting companies' characteristics in Addis Ababa saving houses development enterprise. It also includes the ranking of mostly wasted construction materials wastage, factors incidental for construction materials wastage and waste minimization strategies on housing construction projects based on their relative mean ranks.

4.1.1 Classification of sample size with their categories.

Table 4.1 Classification of sample size

No	Company's classification	Category	Number of respondents	Percent
1	Grade -1	GC	6	23.08
		BC	3	11.54
2	Grade -2	GC	2	7.69
		BC	6	23.08
3	Grade -3	GC	5	19.23
		BC	4	15.38

Table 4.1 shows the characteristics of the sample size for the contracting companies. The sample consists of companies of Grade -1 up to Grade -3 categories of building contractors (BC) and General contractors (GC).

4.1.2 Characteristics of sample size.

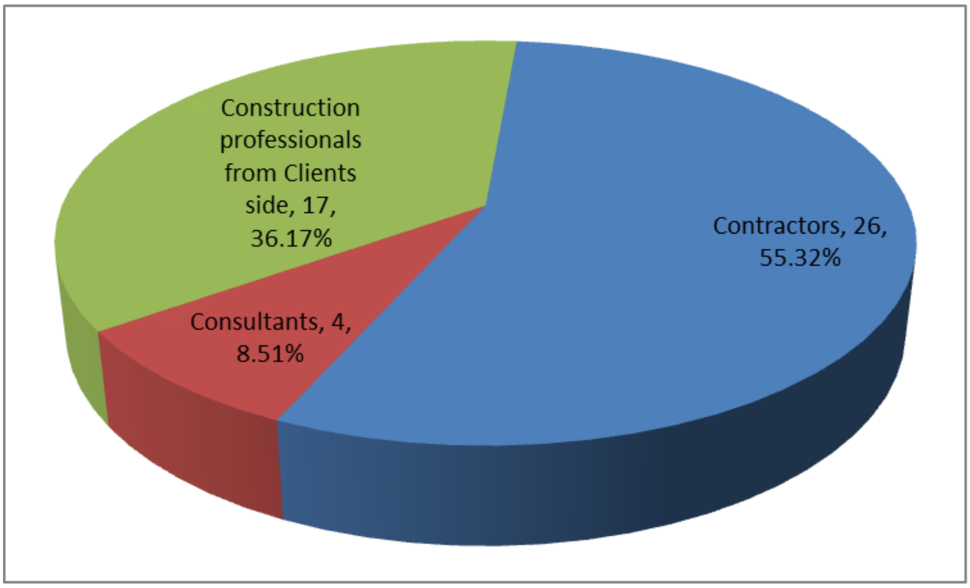

Figure 4.1 characteristics of sample size

4.2.3. Response rate

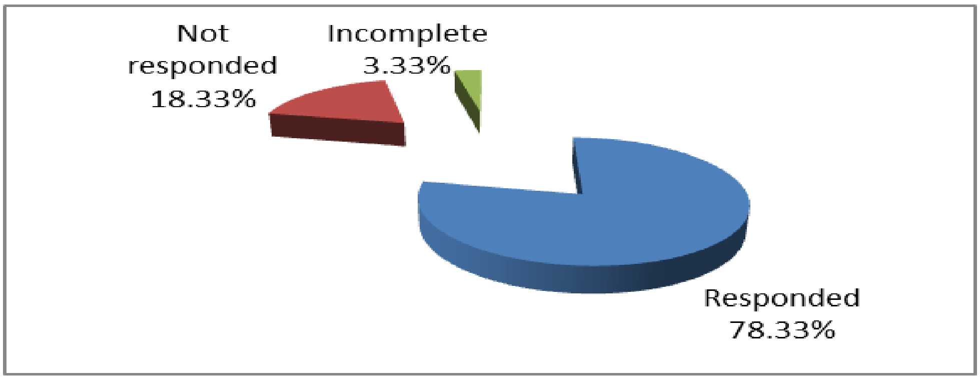

Figure 4.2.Response rate

Out of the 60 questionnaires distributed to the contracting companies, consultant and supervisors working for clients, 47 responses were received with 78.33% return rate in this study. The other 13 questionnaires as follows: 11 (18.3%) have not been received, 2 (3.33%) are uncompleted as shown in Figure 4.3 above.

4.2.4 Years of experience

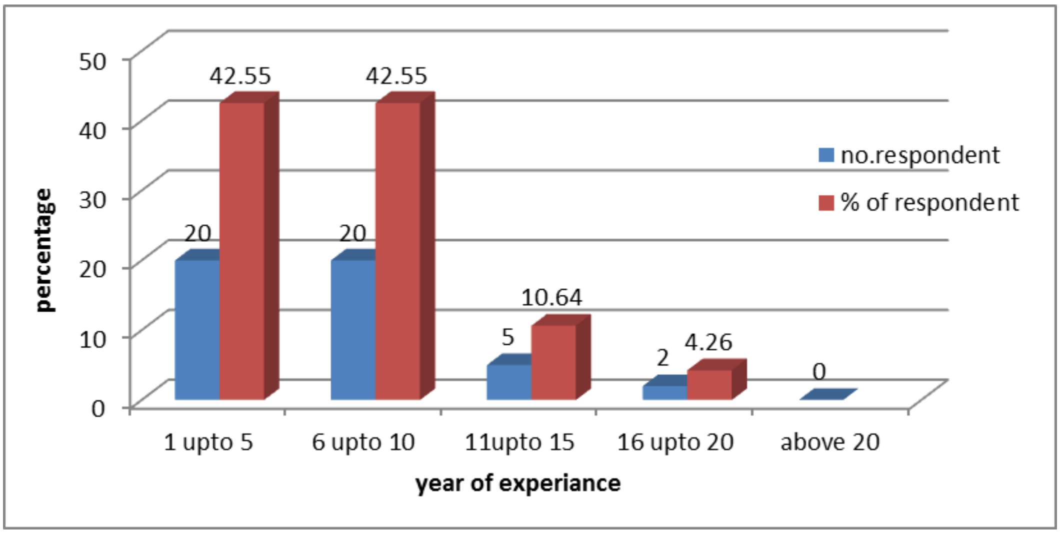

Figure 4.3 Respondent's year of experience

Figure 4.3 shows the years of experience for the respondent's in Addis Ababa Saving Houses Development Enterprise. About 42.55% of respondent's have more than five years of experience, 42.55% of them have more than ten years of experience and 10.64% have more than fifteen years. This gives a higher confidence in the quality of answers.

4.2.5 Contracting companies field work distribution

Table 4.2 Respondent's Field work distribution

No	Field work distribution	Number of respondent's	Per cent
1	Building construction	12	25.53
2	Infrastructure	6	12.77
3	Building and infrastructure	29	61.70

Table 4.2 shows that 12(25.53%) of contracting companies are involved in construction building works, while 6 (12.77%) of them are involved in infrastructure works. 29(61.7%) of contracting companies have been working in both construction and infrastructure in the Addis Ababa saving houses development enterprise. This gives a high confidence in the quality of answers because the study involved both construction and infrastructure for housing projects.

4.2.6 Distribution of respondents' occupation

Table 4.3 Distribution of respondents' occupation

No	Respondent's position	Number of respondents	Percent
1	Project manager	19	40.43
2	Resident Engineer	3	6.38
3	Contract Administration	4	8.51
4	Site Engineer	7	14.89
5	Office engineer	7	14.89
6	Quantity surveyor	5	10.64
7	Designer/Architect	2	4.26

4.2.7 Executed projects and their value during the last three years.

Table 4.4 Distribution of executed projects

No	Number of Projects	Number of respondents	Percent
1	Less than 5 projects	14	29.79
2	6-10 projects	25	53.19
3	11-15 projects	8	17.02

4.2.8 Value distribution of Executed projects

Table 4.5 Value distribution of the executed projects

Value of executed project in Millions	Number of respondents	Per cent
10-30(M.Birr)	2	4.26
31 to 40(M.Birr)	8	17.02
41 to 50(M.Birr)	10	21.28
51 to 60(M.Birr)	7	14.89
61 to 70(M.Birr)	12	25.53
More than 70 (M.Birr)	8	17.02

4.2.9 Number of employees and their qualification in the surveyed companies

Table 4.6 Number of employees in the contracting companies with their qualification

No	Company's workers qualification	Number of workers	Number of companies	Percent
1	PhD	1	1	2.13
2	Masters	23	8	17.02
3	Degree	149	13	27.66
4	Diploma	118	14	29.79
5	Certificate	107	11	23.4

4.3 Identification of the mostly wasted construction materials that would greatly affect the project cost.

In this part, respondents were asked to identify mostly wasted construction materials on housing project sites.

Table 4.7 RII and Rank of Mostly wasted construction materials

Construction materials	RII	Rank
Concrete Hollow Block	0.73	1
Timber form work	0.69	2
Cement	0.68	3
Steel reinforcement	0.66	4
Tiles	0.65	5
Terrazzo	0.63	6
sand	0.53	7
Glass work	0.52	8
Paints	0.51	9
Coarse aggregate	0.45	10
Electric wire	0.44	11
Water pipe	0.38	12
Steel structure(RHS)	0.35	13
LTZ	0.34	14
EGA(Roof cover)	0.31	15

The results in table 4.7 exposed that the key materials, which are wasted most on housing project sites, are Concrete Hollow Blocks (0.73), Timber formwork (0.69), Cement

(0.68), reinforcement steel bar (0.66), Tiles (0.65). The first five key materials, which frequently wasted on site, were discussed in depth below.

4.3.1 Concrete Hollow Block

The relative importance index values of the concrete hollow block wastage in the sites were 0.73 and positioned in the first rank as shown in table 4.7. Hollow concrete blocks are the most common walling material in Addis Ababa housing project. During site visit, it was observed that the main cause of Concrete hollow blocks waste was cutting due to lack of attention paid to dimensional coordination of floor width and height with dimension of concrete hollow blocks on the markets during design stage, improper handling and storages.

Past researchers in their study revealed that choice of low quality products are the main cause of construction waste (Bossink and Brouwers, 1996) and they didn't consider Concrete hollow blocks as frequently wasted materials on site.

Figure 4.4 Broken concrete hollow blocks due to improper handling on site observed during site visit.

Figure 4.5 shows some of the ways in which blocks are wrongly stored on site.

Besides, in almost all of the sites it is common to look significant quantity of damaged concrete block left on site and this leads to excessive wastage and hence greatly affect project cost.

4.3.2 Timber Form-work

The relative importance index values of the timber formwork wastage in the sites were 0.69 and positioned in the second rank as shown in table 4.7. Timber board is another major material used on construction sites. The main causes of wastage of timber boards are the natural deterioration resulted from usage and cutting waste.

Figure 4.6 Timber form-work poorly stored on site.

Figure 4.6 shows timber that has been poorly stored on site. Among the projects surveyed there is one construction site bearing wastage of 20% in timber formwork used on site.

Bad handling and poorly organized storage of timber and wood-based products are major causes of wastage on housing project sites. Proper storage and handling can ensure that the wastage of timber formwork can be minimized.

4.3.3 Cement

The relative importance index values of the cement wastage in the sites were 0.68 and positioned in the third rank as shown in table 4.7. Waste of cement was observed on housing construction sites in the production of mortar and concrete on site. This material is used as component of mortar used in block works, plastering, floor screed and cast in-place concrete for reinforced concrete structure.

Figure 4.7 improper storage and handling of cement that leads to wastages.

Much waste of cement was observed in the production of mortar on site. Cement and other materials are usually loaded manually in the mixer using inadequate equipment, and this type of loading leads to wastages of cement. Waste of cement also observed in most sites during handling, transportation and operation.

(a) Excess cement mortar left on site (b) wastage of cement mortar

Figure 4.8 wastage of cement on site

The above figures show that wastage of cement mortar due to improper handling during operation. The production of block work was also responsible for some waste of cement, due to the excessive consumption of mortar dropped in hollow section. The excessive thickness of plaster and floor screed due to lack of skilled labor was also identified as a major cause of cement waste. By contrast this material is a relatively expensive that has high levels of waste and greatly affect the cost of the housing project.

4.3.4 Reinforcement

The study revealed that reinforcement bar is the fourth mostly wasted construction materials on site. The relative importance index values of the reinforcement bars wastage in the sites were 0.66 as shown in table 4.7. Steel reinforcement bars are common materials used on building site. The main cause of wastage is resulted from cutting (some short unusable pieces are produced when bars are cut), damages during storage and rusting. Controlling the use of steel reinforcement in building sites is relatively difficult because it is cumbersome to handle due to its weight and shape. In most of the sites it was common to look short unusable pieces of reinforcement bars which are produced during cutting and bending of the bars. This indicates that the structural design was poor in terms of standardization causing waste due to non-optimized cutting of bars and greatly affects project cost. Besides on most of the sites the researcher have also observed poorly stored reinforcement bars which results in large disorganized stocks.

Figure 4.9 wastage of steel reinforcement bar due to Non-optimized cutting and poorly stored on site

4.3.5 Tiles

The study revealed that tiles are the fifth mostly wasted construction materials on site. The relative importance index values of the tiles wastage in the sites were 0.65 as shown in table 4.7.The tile has a fragile nature of the materials. On the sites, the researcher observed that excessive quantities of tiles are left on site as waste. Cutting the tiles in great quantities, that results when insufficient attention was paid to the dimensions of the available tiles in the design stage so lack 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 used for cut, and inadequate skill of labor.

Figure 4.10 Excessive tiles wasted in the construction site.

4.4 Investigation of the major cause of construction materials wastage on housing project.

In this part, the respondents were asked to identify the main causes of material waste.

4.4.1 Mean and ranking of design group

The relative importance index of each of the sub-factors of the design group which causes materials waste are presented in Table 4.8 in an ascending order. Rank of each factor is also listed.

Table 4.8 Relative Importance Index and rank of Design group

Design group (1)	RII	RANK
Design changes and revisions	*0.72*	*1*
Lack of information about types and sizes of materials on the market	0.68	2
Rework that do not comply with drawing and specification	0.64	3
Designer's inexperience in method and sequence of construction.	0.60	4
Errors in contract documents	0.52	5

"Design changes and revisions, Rework that do not comply with drawing and specification and lack of information about types and sizes of materials had the highest mean 0.72, 0.68 and 0.64 respectively. The first three factors have to be discussed as following:

The results in Table 4.8 showed that "design changes and revisions "factor was ranked in the first position with mean value 0.72. It was also ranked in the first position among the thirty factors that caused material waste as shown in Table 4.15

Construction plans exist in the form of designs, drawings, quantities, and specifications specialized for a specific construction site. Design changes result from design errors (contradictions, discrepancies, inconsistencies) and changes in the owner's requirements (scope of work).

In Addis Ababa housing project design changes and revisions was a significant variable causing waste during the construction project, which greatly affects housing cost. Changes to the original design can result in waste in different ways. If the construction materials have already been purchased on the base of the original design, waste might result if the materials cannot be resold or returned to the supplier, and the only option is to dispose the materials. Similarly, if a structure has already been constructed, a change in the design may result in part of the structure being taken apart. In such a situation, waste results if the materials cannot be salvaged.

The results in Table 4.8 showed that "Lack of information about types and sizes of materials on the market or lack of attention paid to dimensions of products “factor was ranked in the second position with mean value 0.68. It was also ranked in the fifth position among the thirty factors that caused material waste as shown in Table 4.15. During the site visit, the researcher observed that in all sites under study cutting is the main cause of waste and this is often excessive because the design takes no account of the practical sizes of building materials on the market. This situation may result from lack of knowledge about standard sizes of products on the market, which are related to the design process.

The results in Table 4.8 showed that "rework that don't comply with drawings and specifications" factor was ranked in the second position with mean value 0.64. It was also ranked in the ninth position among the thirty factors that caused material waste as shown in Table 4.15.Sometimes the executed work don't comply with drawings and used materials don't comply with specifications. The main causes for this problem at Addis Ababa housing project were lack of supervision, poor management, and inadequate subcontractors and labor who execute some works.

Rework leads to waste in materials if the construction materials have already been used to execute the required work, waste could be resulted of the materials which don't comply with specification or the done work don't comply to drawings, so the only solution is to remove the materials.

4.4.2 Mean and ranking of materials Procurement factors

The mean of each of the sub-factors of the materials Procurement group which causes materials waste is presented in Table 4.9 in a descending order. Rank of each factor is also listed.

Table 4.9 Relative Importance Index and rank of procurement group

Procurement group (2)	RII	Rank
Purchased materials that don't comply with specification	0.65	1
Over ordering due to mistakes in quantity surveys	0.63	2
Poorly schedule to procuring the materials	0.59	3
Changes in materials prices	0.45	4

The first three factors have to be discussed as following:

The results in Table 4.9 showed that "purchased materials that do not comply with specification or project requirements defined on design documents, factor was ranked in the first position with mean value 0.65. It was also ranked in the eighth position among the thirty factors that caused material waste as shown in Table 4.15. The respondents in housing project considered that ordering of materials that do not fulfill project requirements defined on design documents; in terms of quality, type and dimensions are the most important cause of waste. This situation may result from poor coordination and communication between site manager and his suppliers.

The results in Table 4.9 showed that "over ordering of a quantity due to mistakes in quantity surveys." factor was ranked in the second position with mean value 0.63. It was also ranked in the tenth position among the thirty factors that caused material waste as shown in Table 4.15. The respondent considered that over ordering of a quantity due to mistakes in quantity surveys as a major contribution to site waste generation. On the surveyed housing construction sites, there are materials left on site after the completion of work. These excess materials considered as waste unless transferred to other site, which incurred additional transportation, loading and unloading cost.

The results in Table 4.9 showed that "poorly schedule to procuring the materials" factor was ranked in the third position with mean value 0.59. It was also ranked in the fifteen positions among the thirty factors that caused materials waste as shown in Table 4.15. The surveyed contractors in housing projects considered that poor schedule of materials procurements was the main causes of waste and this problem leads to delay in material supply and causes materials waste resulting from the waiting period.

4.4.3 Materials handling and storages factors group

The mean of each of the sub-factors of the materials handling group, which causes materials waste, are presented in Table 4.10 in a descending order. Rank of each factor is also listed.

Table 4.10 Mean and Ranking of materials handling and storages on site factor

Materials handling and storages group(3)	RII	Rank
Damage materials on site	0.71	1
Poor storage of materials	0.7	2
Conversion waste from cutting uneconomical shapes	0.69	3
Lack of on-site materials control	0.65	4
Damage during transportation	0.59	5
Theft and vandalism	0.57	6

The first three factors have to be discussed as following:

The results in table 4.10 showed that "damage materials on site” factor was ranked in the first position with mean value 0.71. It was also ranked in the second position among the thirty factors that caused material waste as shown in Table 4.15. Material damaging on site results from poor storage, or putting the material in unsuitable place onsite. In most of the sites, construction materials are stored in unsuitable places like on the walkway, some materials stacked on open areas where likely to be hit by site vehicles and equipment, and the same occur to sand, aggregate and base course. Damage of material increased if the material wasn't packed and tied and unpacked supply of material often increase wastage of broken damage especially of the fragile nature of the material such as tiles, blocks. This damaged material was considered as waste and greatly affects the project budget.

The results in Table 4.10 showed that "poor storage of materials leading to damage “factor was ranked in the second position with mean value 0.70. It was also ranked in the third positions among the thirty factors that caused material waste as shown in Table 4.15. Stacking the materials without pallets such as blocks and (cement, gypsum,) bags; exposing the materials to weather conditions such as steel bars, which cause rusting and damage. Some materials such as pipes stacked on open areas where likely to be hit by site vehicles and equipment, and the same occur to sand, aggregate and base course. This indicates that training of both management and labor in the planning and provision of adequate storage is necessary.

The results in Table 4.10 showed that "conversion waste from cutting uneconomical shapes “factor was ranked in the third position with mean value 0.69. It was also ranked in the fourth position among the thirty factors that caused material waste as shown in Table 4.15. The respondents consider that conversion waste from cutting uneconomical shapes lead to material waste. The main causes of wastage in site is resulted from unusable pieces produced when materials are cut and poor planning in the distribution of materials, which don't encourage cutting optimization.

4.4.4 Mean and Ranking of Operation factors Group

Table 4.11 showed the mean of each of the sub-factors of the operation group, which causes material waste in a descending order. Rank of each factor is also listed.

Table 4.11 Mean and ranking of operation on site factors

Operation Group (4)	RII	Rank
Rework due to workers’ mistakes	0.69	1
Use of incorrect material, thus requiring replacement	0.64	2
Poor workmanship	0.63	3
Choice of wrong construction materials and techniques	0.61	4
Damage to work done caused by subsequent trades	0.60	5

The first three factors have to be discussed as following:

The results in Table 4.11 showed that "rework due to workers’ mistakes “factor was ranked in the first position with mean value 0.69. It was also ranked in the fourth position among the thirty factors that caused material waste as shown in Table 4.15. Errors by trades persons or labors were considered the main cause of material waste in operational group. Workers' mistakes may be because of their inefficiency, inexperience, because untrained labors make mistakes more frequently.

The results in Table 4.11 showed that "use of incorrect material that requires replacement “factor was ranked in the second position with mean value 0.64. It was also ranked in the ninth position among the thirty factors that caused material waste as shown in Table 4.15. Use of incorrect materials causes waste in materials e.g., a wall may be built with blocks 15*20*40 instead of 20*20*40 in this case, it will be against drawings and specifications, so it must be demolished.

The results in Table 4.11 showed that "poor workmanship" factor was ranked in the third position with mean value 0.63. It was also ranked in the tenth position among the thirty factors that caused material waste as shown in Table 4.15. Poor workmanship may result from lack of trades' skills, which lead to waste. For example, waste of material resulting from deviations in the dimensions of structural elements.

4.4.5 Labor culture factors Group

Table 4.12 Mean and ranking of Labor culture factors

Labor culture Group (5)	RII	rank
Lack of coordination among crews	0.66	1
Accidents due to negligence	0.61	2
Tradesmen slow/ineffective	0.60	3

The first three factors have to be discussed as following:

The results in Table 4.12 showed that "lack of coordination among crews “factor was ranked in the first position with mean value 0.66. It was also ranked in the sixth position among the thirty factors that caused materials waste as shown in Table 4.15. Poor coordination and communication between the consultant engineer and contractor may create disagreement and brought materials waste.

The results in Table 4.12 showed that "accidents due to negligence “factor was ranked in the second position with mean value 0.61. It was also ranked in the twelve positions among the thirty factors that caused materials waste as shown in Table 4.15. The study revealed that accidents due to negligence in Addis Ababa housing project considered as a cause for materials waste in case where concrete mixed manually. Often accident happen due to negligence on labors working on concrete mixing and the concrete mix accidentally stopped for a while .Consequently the concrete set before pouring in position and discarded as waste hence greatly affect the project cost.

The results in Table 4.12 showed slow/in-effective that "tradesmen “factor was ranked in the third position with mean value 0.6. It was also ranked in the thirteen positions among the thirty factors that caused material waste as shown in Table 4.15.

4.4.6 Equipment and machinery factors

Table 4.13 Mean and ranking of Equipment and machinery

Equipment and machineries Group(6)	RII	Rank
Shortage of tools and equipment required	0.62	1
Equipment frequently breakdown	0.61	2
Poor technology of equipment	0.50	3

The results in Table 4.13 showed that "shortage of tools and equipment required" factor was ranked in the first position with mean value 0.62. It was also ranked in the eleventh position among the thirty factors that caused materials waste as shown in Table 4.15. In housing projects, most construction companies have not all the equipment due to the high prices, so contractors have to rent the needed tools and equipment, which may reach late. (Al-Khalil and AL-Ghafly, 1999) mentioned that shortage of tools and equipment required was ranked in the forty-eighth position among sixty factors, which causes waste and project delay. Other researchers also mentioned that shortage of tools and equipment required had a major effect on waste in Indonesian construction projects with mean value 3.14(Alwi et al. 2000).

The results in Table 4.13 showed that "equipment frequently breakdown" factor was ranked in the second position with mean value 0.61. It was also ranked in the thirteen positions among the thirty factors that caused materials waste as shown in Table 4.15. The contracting companies were often using old equipment on housing sites, because the new need high price and Working on them for long hours leads to materials waste. If equipment broke down, work will stop and in turn it causes materials waste.

4.4.7 Site management and supervision factors Groups

Table 4.14 Mean and ranking of site management and supervision factors.

Site management and supervision factors Group (7)	RII	Rank
Lack of supervision and delay of inspections	0.66	1
Poor management and distribution of labors, materials and equipment	0.65	2
Lack of waste management plan	0.59	3
Lack of strategy to waste minimization	0.53	4

The results in Table 4.14 showed that "lack of supervision and delay of inspections" factor was ranked in the first position with mean value 0.66. It was also ranked in the sixth position among the thirty factors that caused materials waste as shown in Table 4.15. Waste in materials can be resulted when a contractor executes work, which is not clear in drawings without any supervision, after execution the supervisor may discover the mistakes, so he changes what is executed according to the drawings.

The results in Table 4.14 showed that "poor management and distribution of labors, materials and equipment" factor was ranked in the second position with mean value 0.65. It was also ranked in the eighth position among the thirty-factors that caused materials waste as shown in Table 4.15. The respondents considered poor management and distribution of labors, materials and equipment as a major factor that affect materials waste in Addis Ababa construction projects. Sometimes there are shortages of work force or materials on housing sites to execute the required work, which leads to waste.

The results in Table 4.14 showed that "lack of waste management plan" factor was ranked in the third position with mean value 0.59. It was also ranked in the eleventh position among the thirty factors that caused materials waste as shown in Table 4.15.All the respondents underscored the need to implement waste minimization plans in their companies. All the parties involved in housing construction would be motivated to reduce waste by the implementation of this program. It was known that the waste management plan would help them to improve their performances. The respondents considered that work that is more productive could be done if waste minimization plans are introduced.

4.4.8 Summary

Table 4.15 Mean and ranking of all factors

No	Designation	Factors	RII	Rank
1	G1	Design changes and revisions	0.72	1
2	G3	Damage materials on site	0.71	2
3	G3	Poor storage of materials	0.70	3
4	G3	Conversion waste from cutting uneconomical shapes	0.69	4
5	G1	Lack of information about types and sizes of materials on the market	0.69	4
6	G4	Rework due to workers' mistakes	0.68	5
7	G5	Lack of coordination among crews	0.66	6
8	G7	Lack of supervision and delay of inspections	0.66	6
9	G3	Lack of onsite materials control	0.65	7
10	G2	Purchased materials that don't comply with specification	0.65	8
11	G7	Poor management and distribution of labors, materials and equipment	0.65	8
12	G1	Rework that do not comply with drawing and specification	0.64	9
13	G4	Use of incorrect material, thus requiring replacement	0.64	9
14	G2	Over ordering or under ordering due to mistakes in quantity surveys	0.63	10
15	G4	Poor workmanship	0.63	10
16	G6	Shortage of tools and equipment required	0.62	11
17	G4	Choice of wrong construction materials and techniques	0.61	12
18	G5	Accidents due to negligence	0.61	12
19	G6	Equipment frequently breakdown	0.61	12
20	G1	Designer's inexperience in method and sequence of construction.	0.60	13
21	G4	Damage to work done caused by subsequent trades	0.6	13
22	G5	Tradesmen slow/ineffective	0.6	13
23	G3	Damage during transportation	0.59	14
24	G2	Poorly schedule to procuring the materials	0.59	15
25	G7	Lack of waste management plan	0.59	15
26	G3	Theft and vandalism	0.57	16
27	G7	Lack of strategy to waste minimization	0.53	17
28	G1	Errors in contract documents	0.52	18
29	G6	Poor technology of equipment	0.5	19
30	G2	Changes in materials prices	0.45	20

The questionnaire of this study considered 30 factors, which cause material waste in construction, and those factors were distributed into seven groups as mentioned before, namely, Design, Procurement, Materials handling and storage, Operation, Labor culture, Equipment and machineries, Site management and supervision. Table 4.15 outlines the factors causing material waste in materials group in descending manner.

The study indicate that the highest five factors are "design changes and revision, damages materials on sites, poor storages of materials ,conversion waste from cutting uneconomical shapes, Lack of information about types and sizes of materials on the market with mean ranks 0.72,0.71,0.70,0.69,0.69 respectively. It has been noticed that "Theft and vandalism, Lack of strategy to waste minimization, Errors in contract documents, Poor technology of equipment and Changes in materials prices;" are the lowest five factors that causing material waste with mean ranks 0.57,0.53,0.52,0.5,0.45 respectively.

Table 4.16 Mean and ranking of main groups

main factors	Mean	Rank
Group (3) Materials handling	0.65	1
Group (1): Design	0.63	2
Group (4): Operation	0.63	2
Group (5): Labor culture	0.62	3
Group(6): Site managements and supervision	0.61	4
Group (2): Procurement	0.58	5
Group(6): Equipment and machineries	0.58	5

The survey revealed that the materials handling and storage is the major causes of materials waste with mean 0.65 highest ranking, while the lowest mean 0.58 is for equipment, machineries, and Procurement group as shown in Table 4.16.

4.5 To determine and analyse the extent of construction materials wastages and costs of 40/60 housing projects.

4.4.5 Case Study

The aim of this case study is to illustrate the effect of construction material wastage on project cost. One almost finished block type (2B+G+13) on four sites were chosen to show the actual levels of material wastage and its impact on project cost occurring on sites. The basic information about the projects is tabulated below

Table 4.17 Finished blocks considered for case study

Site	Block Type	Number of Block	Number of Room	Contract Amount	Physical status (%)
A	2B+G+13	5	710	230,191,555.05	90.40
B	2B+G+13	6	852	276,229,866.06	92.10
C	2B+G+13	8	1136	368,306,488.08	96.20
D	2B+G+13	10	1420	460,383,110.10	92.80
		29	4118	1,335,111,019.29	92.87

In this case study the quantity of waste estimated only for the five mostly wasted construction materials on housing project that revealed from questionnaires. Hollow concrete blocks, Timber-form work, Cement, reinforcement steel bar, tiles are the five mostly wasted construction materials on housing construction sites. The amount of waste generated in these sites found out by calculating the difference between the needed quantity of materials and actual quantities of the materials taken by the contractors during the course of construction of the buildings. The data for estimating this waste amount taken from the design drawings, specification and material requesting forms of 2B+G+13 blocks on the site. Therefore, data were collected from these documents to get the planned and actual quantity of material used for each block respectively. Finally, the results compared against the 5% material wastage allowance included in the contract document. Besides, its side effect on the project cost also calculated.

4.4.6 Comparison of Theoretical and Actual Percentage of Wastage

In this part, the quantities of material waste produced during the construction of these new buildings presented. There is a significant difference between the theoretical and actual quantities of Hollow concrete blocks, Timber-form work, Cement, reinforcement steel bar, tiles used in the four case study sites. Table 4.18 gives average quantity and percentage of wastage of these materials for the selected four condominium project sites.

Table 4.18 Comparison of Quantity of waste per Site.

No	Construction materials	Unit	price	Design Qty	Actual Qty per site							
					Site A	Waste Qty (%)	Site B	Waste Qty (%)	Site C	Waste Qty (%)	Site D	Waste Qty (%)
1	Cement	qun	273	31,585.4	35,615.0	13	38,230.0	21	40,146.7	27	37,011.0	17
5	Ø8	kg	22	46,256.0	50,635.7	9	48,628.2	5	49,123.9	6	47,270.4	2
6	Ø10	kg	22	114,436.5	128,361.4	12	140,872.8	23	147,088.8	29	124,527.2	9
7	Ø12	kg	22	82,203.8	89,353.6	9	98,338.5	20	100,624.3	22	93,368.3	14
8	Ø14	kg	22	88,796.1	125,617.8	41	116,615.1	31	125,617.1	41	112,345.2	27
9	Ø16	kg	22	138,696.6	140,452.4	1	139,171.6	0	146,499.6	6	139,932.4	1
10	Ø20	kg	22	114,342.1	169,319.3	48	168,147.0	47	170,387.3	49	171,227.6	50
11	Ø24	kg	22	99,253.0	101,825.4	3	101,600.1	2	101,600.1	2	102,304.5	3
12	20cm HCB	No	8	57,683.0	78,880	37	85,231	48	82,350	43	78,880	37
14	10cm HCB	No	4	70,088.0	85,825	22	86,488	23	80,317	15	87,617	25
17	Tiles	m2	215	3,361.4	3,871	15	3,952	18	3,645	8	3,435	2
18	Timber form work	m3	7210	155.4	158	2	211	36	178	15	211	36

The result in Table 4.18 indicates that the largest source of waste in both sites is HCB. Six and three times larger than the allowable percentage of wastage are noticed for 20cm and 10cm wall block in all four sites respectively. Whereas, the average smallest percentage of wastage noticed in ф24 and ф16 reinforcement bar for all site respectively, which are almost less than the allowable limit of wastage.

There is also a variation in waste percentage of the four sites for the same material. For instance, the wastage of cement at site C is almost two times higher than at site A. This may be due to the firm's experience and technological development among the contractors in the site. Furthermore, a large variation of wastage was also found at a single site for different building materials. For instance, in site A the wastage of reinforcement bar for ф10 is 12%, which is more than four times of ф20, 48% percentages of wastage. This possibly reflects the non-standardized building structures resulting in the much cut off for ф20 reinforcement bar that generate higher levels of material wastage. Similarly the waste percentage of 20 cm Concrete Hollow Block is more than two times of 10 cm Concrete Hollow Block in site C. Generally, this variation in the percentage of wastage from site to site and from material to material indicates the possibility of improvement in this wide range of materials waste.

Table 4.19 Average waste quantity and percentages against allowable waste

No	Construction materials	Unit	price	Design Qty	Average quantity (on four sites)	Qty waste	Waste in %	Allowable waste (%)	Allowable waste Qty	Excess waste (%)	Net Qty waste
			A	B	C	D	E	F	G	H	K
						C-B	D*100/B		B*F/100	E-F	D-G
1	Cement	qun	273	31,585.4	38,000.7	6,415.3	20.3	5	1,579.3	15.3	4,836.0
2.1	Ø8	kg	22	46,256.0	48,914.5	2,658.5	5.7	5	2,312.8	0.7	345.7
2.2	Ø10	kg	22	114,436.5	135,212.6	20,776.1	18.2	5	5,721.8	13.2	15,054.3
2.3	Ø12	kg	22	82,203.8	95,421.2	13,217.4	16.1	5	4,110.2	11.1	9,107.2
2.4	Ø14	kg	22	88,796.1	120,048.8	31,252.7	35.2	5	4,439.8	30.2	26,812.9
2.5	Ø16	kg	22	138,696.6	141,514.0	2,817.5	2.0	5	6,934.8		
2.6	Ø20	kg	22	114,342.1	169,770.3	55,428.2	48.5	5	5,717.1	43.5	49,711.1
2.7	Ø24	kg	22	99,253.0	101,832.5	2,579.5	2.6	5	4,962.7		
	Re-bar Ø8-Ø24 (Av.)	kg	22	97,712.0	116,102.0	18,390.0	18.3	5	4,885.6	13.3	13,504.4
3.1	20cm HCB	No	8	57,683.0	81,335.3	23,652.3	41.0	5	2,884.2	36.0	20,768.1
3.2	10cm HCB	No	4	70,088.0	85,061.8	14,973.8	21.4	5	3,504.4	16.4	11,469.4
	HCB (Av.)		6	63,885.5	83,198.5	19,313.0	31.2	5	6,388.6	26.2	12,924.5
4	Tiles	m2	215	3,361.4	3,725.7	364.3	10.8	5	168.1	5.8	196.2
5	Timber form work	m3	7210	155.4	189.5	34.1	21.9	5	7.8	16.9	26.3

The case study confirms that the average actual waste level for mostly wasted construction materials on housing projects sites were 26.2% for Concrete Hollow Block, 16.9% for Timber Form work,15.3% for Cement,13.3% for Reinforcement bar and 5.8% for Tiles. This waste level for key materials compared against 5% materials wastages allowance included in the contact document as shown in table 4.19.

4.4.7 Effect on the Total Project Cost

Table 4.20 Estimated cost of materials waste on the case study site

No	Materials	Unit	Unit price	Average cost of waste							
				Site A		Site B		Site C		Site D	
				Excess quantity	Total cost	Excess quantity	Total cost	Excess quantity	Total cost	Excess quantity	Total cost
1	Cement	qun	273	4,029.6	1,100,440.7	6,644.6	1,814,571.1	8,561.3	2,338,013.6	5,425.6	1,481,674.4
2	Re-bar Ø8-Ø24 Average	kg	22	17,368.8	382,113.2	18,484.2	406,652.3	22,422.5	493,294.0	15,284.5	336,259.4
9	HCB Average	No	6	18,467.0	117,265.5	21,974.0	139,534.9	17,448.0	110,794.8	19,363.0	122,955.1
11	Ceramic wall	m2	215	509.4	109,535.7	590.6	127,012.8	283.6	60,992.5	73.6	15,832.0
12	Timber form work	m3	7,210	2.6	18,601.8	55.6	400,731.8	22.6	162,801.8	55.6	400,731.8
	Total for all blocks on sites				8,639,784.3		14,442,514.8		15,829,483.3		11,787,263.2
	Av.cost incurred per block				1,727,956.9	-	2,888,503.0	-	3,165,896.7	-	2,357,452.6
	Cost effect per block				5.2		8.6		9.5		7.1

Table 4.20 presents the result of cost incurred due to excessive material wasage in the four sites in which the case study undergone. The cost of waste incurred, on average in these four sites is 7.6 % of the total cost, ranging from 5.2 % at site A to 9.5 % at site C. This indicates that minimization of material waste in the construction projects would therefore lead to substantial saving on the purchasing cost of building materials, in addition to savings on dumping costs. This cost impact estimated only based on the pure material purchasing cost, it doesn't include storage cost, transportation cost and disposal cost.

4.5 Strategy to minimize construction materials waste

Table 4.21 Strategy to minimize Construction materials wastages

No	Ways of Minimizing and reducing waste	Degree of contribution					RII	Rank
		1	2	3	4	5		
1	Proper storage and handling of materials	3	4	7	8	25	0.76	1
2	Using low waste building technologies	2	5	7	11	22	0.74	2
3	Design of offsite construction	2	5	8	16	16	0.71	3
4	Standardization of design	3	5	8	14	16	0.68	4
5	develop site waste management plan	5	4	10	12	16	0.66	5
6	Improved the skill of the work force	5	7	7	13	15	0.64	6
7	Applying materials Re-use and recycle strategy	5	5	10	15	12	0.63	7
8	Proper detailing during design	6	6	12	9	14	0.60	8
9	correct materials planning and ordering	7	10	10	13	7	0.52	9
10	Just-in -time delivery strategy	5	13	13	7	9	0.51	10

The results revealed that Proper storage and handling of materials, Using low waste building technologies, Design of offsite construction, Standardization of design, develop site waste management plan are the first five ways or frame work that contribute for the minimization of materials wastages with mean value 0.76, 0.74, 0.71, 0.68, 0.66, respectively. The mean of the first five factors, which contribute for waste reduction in housing construction project, listed below.

Waste minimization is a shared responsibility between all parties of the construction process from the client down to the contractor. The five best strategies of construction materials waste minimization identified from the study discussed below.

4.4.5 Proper storage and handling of materials

The results in Table 4.21 showed that Proper storage and handling of materials considered as waste minimization strategy which would be used in Addis Ababa housing project ranked in the first position with RII value 0.73.

Once what materials need for the housing project established, there should be work on how those materials will be received and stored on the site. The site manager on each site should plan in advance suitable storage space to protect materials degradation or damage from weathering or moisture.

Figure 4.11 Recommended ways of storing cement on building site

Figure 4.12 properly packed HCB on building construction site

Figure 4.13 Proper handling of sand and coarse aggregate on building site

There should be a strategy in place on each housing project sites which makes the best use of a central storage area with procedures for moving materials to the workplace as moving materials increases the risk of damage. All storage areas should be tidy, even in the site itself; safe, secure and weather proof. Stored materials shall not spread in an uncontrolled manner on footpaths and other walkways. Further materials do not store where they could obstruct access routes or where they could interfere with emergency escape. Careful handling of materials reduces risk of wastage of materials on site. This will begin with the provision of suitable vehicles or delivery plants for transporting material from the storage area in the workplace so as to make the waste to the minimum.

4.6.2 Using low waste building technology

The results in Table 4.21 showed that using low waste building technology considered as waste minimization strategy, which would be used in Addis Ababa housing project ranked in the second position with RII value 0.72.Buildings are usually constructed by the conventional cast in-situ method. However, material wastage can be minimized in buildings construction project with the following technologies and practices described below.

4.6.2.1 Drywall partition

Dry wall is a system of factory made wall panels. It replaces the traditional brick and block walls. It has a number of advantages. It requires less labor and skill for installation, and provides better product qualities and higher flexibilities for future layout changes. Full height panels are assembled and conduits can be easily installed through its tubular spaces with minimal cutting, jointing and patching. The surface of the panel can be easily finished with a thin coat skim plaster in place of the thick cement sand plaster in traditional block walls. Hence, much less wet trade work is involved in the assembly process and less construction waste is generated at the end.

4.6.2.2 Precast concrete element

Financially viable and technologically sound construction solution for Addis Ababa housing project on the basis of prefabricated elements have been demonstrated ,applied, trained and multiplied to make the approach sustainable and applicable. The Precast concrete system is commonly applied to beams, facades and staircases. These precast elements may be cast in a factory or cast at the site. In precast concrete construction the materials can be better utilized and wastage can be kept to a minimum because its effectiveness in replacing traditional wet-trade practices. Hence, it contributes significantly to reduce materials waste.

4.6.2.3 Machinery sprayed plaster

Machine sprayed plaster now replaces traditional cement mortar in developed countries building projects. The major difference between the mechanized plaster and the traditional cement mortar is that the former is mixed and applied mechanically whilst the latter is applied and troweled smoothly by hand. The use of mechanized spraying has the merits of high productivity, low labor demand and less waste.

4.6.3 Design for offsite construction

The results in Table 4.21 showed that using design for offsite construction considered as waste minimization strategy, which would be used in Addis Ababa housing project ranked in the third position with RII value 0.71.In Addis Ababa housing project it was not common practice of off-site construction. It refers to structures built at a different location than the location of use and occurs in a manufacturing plant specifically designed for this type of process. Off-site processes have been proved to decrease waste by optimizing cutting patterns and schedules.

4.6.4 Standardization of design

The results in Table 4.21 showed that standardization of design considered as waste minimization strategy, which would be used in Addis Ababa housing project ranked in the fourth position with RII value 0.70.Standardization means to design items with generally accepted and uniform procedures, dimensions or materials. Standardization has the potential to dramatically reduce the current production of construction waste. This is by designing the building size and space to eliminate unnecessary elements, and to reduce off-cuts resulting from the construction process.

Figure 4.14 Wastage of steel reinforcement bar due to Non-optimized cutting of bars and design change

Standardization of design in building construction ensures compatibility between market supply and specification. In housing projects, by designing room areas and ceiling heights in multiples of standard material sizes a substantial reduction in off-cuts can be achieved.

4.6.5 Develop site waste minimization plan (SWMP)

The results in Table 4.21 showed that development of site waste management plan considered as waste minimization strategy which would be used in Addis Ababa housing project ranked in the fifth position with RII value 0.69.All the respondents underscored the need to implement waste minimization plans in their companies. All the parties involved in housing construction would be motivated to reduce waste by the implementation of this program. It was known that the waste management plan would help them to improve their performances. The respondents considered that more work that is productive could be done if waste minimization plans are introduced.

CHAPTER FIVE
CONCLUSIONS AND RECCOMENDATIONS

5.1 Conclusions

Based on the results obtained, the following major conclusions have been made in accordance with the objectives of this research.

The respondents agreed that Hollow concrete blocks, timber-formwork, cement, reinforcement bar, Tiles, sand, Aggregate, Terrazzo, paints, pipes all contribute to the generation of waste on construction sites. The results revealed that the five key materials which are wasted most on housing construction sites are Concrete hollow block, Timber form -work, Cement, Reinforcement bar, and Tiles. The case study confirms that the average actual waste level 26.2% for Concrete hollow block 15.3% for Cement, 13.3% for Reinforcement bar, 16.9% for Timber form -work and 5.8% for Tiles are significantly affect the housing project cost up to 7.6%.

It is also concluded that the three most important factors contributory to construction material waste generation on building sites in Addis Ababa Saving Houses Development Enterprise are "materials handling and storage, design and operation," respectively. In addition, all the factors in this study are considered important in waste generation on the project site. Moreover this study revealed that the cost of waste incurred, on average in these four sites is 7.6 % of the total cost, ranging from 5.2 % to 9.5 %. Therefore, this indicates that minimization of material waste in the housing construction projects would lead to substantial saving on the purchasing cost of building materials, in addition to savings on dumping costs.

The application of methods of waste identification and minimization strategy is required urgently within the construction industry in Addis Ababa housing project. These methods are needed to assist construction managers to detect, to identify waste and eliminate it within construction process. It is clear that the responsibility of the elimination of waste depends on client, consultants, construction managers, suppliers, supervisors and workers. By identifying the incidence of waste during a project, construction professionals are able to identify easily the strategy and frame work for preventions for reduction of waste, leading to increase project profit. In this particular, it is concluded that Proper storage and handling of materials, using low waste building technology, design of offsite construction ,standardization of design and development of site waste management plan are the five best strategy to mitigate impact of construction materials wastages on project cost in Addis Ababa Housing Project.

5.2 Recommendation

Based on the findings of this study, the following recommendations are forwarded to the different stakeholders in order to manage and minimize construction material wastage and mitigate its cost impact at Addis Ababa Saving Houses Development Enterprise.

5.2.1 Government

A new construction waste department in the concerned ministries and City administration has to be established and enact laws and policies toward waste management and minimization and implementation guidelines prepared at all levels in construction projects. Project management team should play a vital role in giving useful practical information and recommendation in improving the policy and its implementation.

This will help Addis Ababa housing project and government to take immediate measure in order to avoid cost effects on over all projects of the city and the country as well since the projects are considerably big in investment. Furthermore, the government assists the construction industry to adopt low waste building technologies and encourage waste reduction strategies.

5.2.2 Owners

During bidding, the owner should select the contractors by considering their wastage reduction plan matching with the nature of the project and waste management history as part of assessment criteria. Provision of waste reduction training to on-site staff is also considered important in raising environmental awareness and helping site staff generating a better working procedure to reduce generation of materials wastage and should arrange visits to construction sites at all critical stages during the project period.

5.2.3 Consultants

The buildings should be designed considering the low waste building technologies and off site construction to reduce materials wastages due to operation. The architect and the structural engineer should feel responsible for probable material waste and take into account the design’s effect on waste. In relation to this consciousness, these professionals should also have a wide material knowledge and their nominal dimension in the market. The design program should be complete and consistent in order to minimize waste due to design change and revisions.

5.2.4 Contractors

Contractors should focus on quality in their construction activities in order to mitigate rework or improvement, which is the major cause of material wastage. He should also plan and organize site layout to avoid difficulty in movement of materials on sites and adopt appropriate materials handling and storage methods to mitigate material wastage. The firm should provide waste reduction training to site staff to raise their effect of waste on project cost and improve working procedures to reduce waste generation in construction projects. Finally, skilled labor should be employed or labor should be educated on waste prevention strategies throughout the construction process.

5.2.5 Proposed further studies

It is necessary to repeat this research every five years to observe the new trends of contractors and consultants about waste minimization strategies. Further studies could be done on feasibility of reusing and recycling as minimization measures of construction materials waste in housing project.

REFERENCES

1. *Addis Ababa Housing Construction Project Office, (2005). A study conducted around the utilization of a condominium building by those residents, who are dwelling at the Gerji model houses.*
2. *Adewuyi, T. a. (2013). Evaluation of Causes of Construction Material Waste -- Case of Rivers State, Nigeria. Ethiopian Journal of Environmental Studies and Management Vol. 6, pp. 746-753.*
3. *Al-Hajj, A., &Hamani, K. (2011). Material Waste in the UAE Construction Industry: Main Causes and Minimization Practices. Architectural Engineering and Design Management, Heriot-Watt University Research Gateway.*
4. Al-Moghany, S. S. (2006). Managing and Minimizing Construction Waste in Gaza Strip.A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science inConstruction Management The Islamic University of Gaza - Palestine .
5. *Arslan et al. License INTECH (2012) Construction and demolition waste management in Turkey.*
6. *Babatunde, S. O. (2012). Quantitative Assessment of Construction Materials Wastage in the Nigerian Construction Sites, Department of Quantity Surveying, ObafemiAwolowo University, IleIfe, Nigeria. Journal of Emerging Trends in Economics and Management Sciences (JETEMS) 3(3), pp. 238-241.*
7. *Begum, S. P. (2006). Implementation of waste Management and minimization in the Malaysian construction industry. Conservation and Recycling,pp 190-202.*
8. *Bossink, B. A. (1996). Construction waste: Quantification and source evaluation. Journal of Construction Engineering and Management, Vol. 122, No. 1 , pp55-60.*
9. Carlos Torres Formoso et al.(1999) method for waste control in the building industry proceedings university of California, berkeley, CA, USA
10. *Carlos Torres Formoso, L. S. (2002). Material Waste in Building Industry: Main Causes and Prevention. Journal of construction Engineering and Management, Vol. 128, No. 4, pp., 316-317.*
11. *Central Statistical, a. (2008/09).The Federal Democratic Republic of Ethiopia. Report on Contract construction survey.*

12. *Condominium housing in Ethiopia. The integrated housing development program Un habitat(2011)*
13. *Condominium Proclamation No. 370/2003.(2003). Federal Democratic republic of Ethiopia.*
14. *Datta, M. (2004).Challenges facing the Construction Industry in Developing Countries. Proceeding of 2nd International Conference on Construction in Developing Countries, 15-17 November, Gaborone, Botswana*
15. *Ekanayake, L. L. (2000). Construction Material Waste Source Evaluation. Proceedings of the 2nd Southern African Conference on Sustainable Development in the Built Environment, Pretoria, South Africa.*
16. *Ethiopian, E. A. (2006/07). The current state of the construction industry.Report on the Ethiopian economy, Volume VI .*
17. *Formoso, C. T, Soibelman L. and Isatto, E. L. (2002). Material Waste in Building Industry: Main Causes and Prevention in California, USA. Journal of Construction Engineering and Management, Vol. 128, No. 4 ,pp. 316-324.*
18. *Formoso, C. T., Isatto, E. L. and Hirota, E. H., (1999).Method for Waste Control in the Building Industry. Proceedings of the Seventh Annual Conference of the International Group for Lean Construction IGLC-7, University of California, Berkeley, CA, USA.*
19. *Gebo et al. Impact of Integrated Urban housing development program on house hold poverty alleviation:Adama City Oromia,Ethiopia,Asian journal of empirical research 3(3) 237-250*
20. *Jonathan (2010) Measuring materials wastage on construction site; A case study of local authority high way projects, Built and natural environment research papers,Vol 3 No 1*
21. *Jones and Greenwood. (2003). Construction Waste Minimization in Housing. Center of Research in the Built Environment, Cardiff University, Wales UK .*
22. *Jones, P. and Greenwood, R., (2001). Construction Waste Minimization in Housing. Center of Research in the Built Environment, Cardiff University, Wales, UK.*
23. *Koskela, L., (2004). Making-Do – The Eighth Category of Waste. Proceedings of the 12th Annual Conference of the International Group for Lean Construction IGLC-12, August, Denmark.*

24. *Lee, S. H. (1999). Identifying Waste: Applications of Construction Process Analysis. Proceedings of the Seventh Annual Conference of the International Group for Lean Construction IGLC-7,University of California, , Berkeley, CA, USA .*
25. *Low cost housing (cost efficient construction)Technical manual Vol II(2005)*
26. *LY Shen, VWY Tam. (2002). Material wastage in construction activities a Hong Kong survey. Department of Building & Real Estate, The Hong Kong Polytechnic University, Hong Kong, pp, 2.*
27. *Macozoma, D. S. (2002).Construction Site Waste Management and Minimization. International Council for Research and Innovation in Building and Construction (CIB)/ (CSIR) Building and Construction Technology, Report No.BOU/C361, Pretoria, South Africa.*
28. *Mansi, J. (2012). Economic Aspects of Construction Waste Materials in terms of cost savings – A case of Indian construction Industry. International Journal of Scientific and Research Publications, Volume 2, Issue 10.*
29. Mehamet(2007) Origins and magnitude of waste in the Turkish construction industry.a thesis submitted to the graduate school of natural and applied science of middle east technical university
30. *MekonenWubeErmed. (2008). Shelter Development: Increasing Affordability of Housing to the Low-income Families in Addis Ababa, Ethiopia, Town planner. Addis Ababa Housing Construction project office, Ethiopia.*
31. Merid et al. (2012) The role of construction management professionals in building construction: The case of Addis Ababa. A thesis submitted to department of Construction Technology &Management in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Construction Technology & Management.Addis Ababa University Ethiopian Institute of Architecture, Building Construction and City Development
32. Merkebu K., (2014), Assessment on the performance of integrated housing development program with particular reference to the programs Objectives: Focusing on Addis Ababa “Submitted in Partial Fulfillment of the Requirements for the Executive Master ofBusiness Administration (EMBA) degree”

33. *Ministry of Urban Development and Housing Construction. 2005E.C.. Urban Housing Supply Strategy Framework, Addis Ababa (Amharic).*
34. *MoWUD.(2013). (Ministry of Urban Development and Construction) Directives for the Registration of Construction Professionals and Contractors.Amended,Directive No 19*
35. *Olatunji J. (2008). Lean-in-Nigerian Construction: State, Barriers, Strategies and "Goto-gemba" Approach. Proceedings 16th Annual Conference of the International Group for Lean construction, Manchester, United Kingdom.*
36. *Poon, C. Y. (2001).A Guide for Managing and Minimizing Building and Demolition Waste. The Hong Kong polytechnic University .pp55-60.*
37. *B.Prakash et al. (2014) Waste minimization in construction industry. Indian journal of applied Research ,research paper in engineering Vol 4 Issue 6*
38. *Rameezden, R. a. (2004). Materials wastage on construction sites: identification of major causes. Journal of Built Environment, Sri Lanka, Vol (4), pp. 35-41.*
39. Sagoe, A. (2011). Managing waste and cost in the construction industry: A case study of the Road construction industry in Ghana. A thesis submitted to the Institute of Distance Learning, KwameNkrumah A thesis submitted to the Institute of Distance Learning, Kwame Nkrumah requirements forthe degree of common wealthexecutive masters of Business Administration.
40. Seyoum, 2015, Managing and minimizing wastage of construction materials on selected public building project in Addis Ababa. Thesis submitted to school of graduate studies in partial fulfillment of the requirements for the degree of masters of Science in civil engineering.
41. Semere, T. A. (2006). Assessment of Delays in Building Construction Projects in Ethiopia.B.Sc.Degree Thesis paper in Construction Technology &Management,Addis Ababa University, Faculty of Technology (South), Department of Construction technology & management.
42. Shen, V. T. (*2002). Material wastage in construction activities a Hong Kong survey. Department of Building & Real Estate, the Hong Kong Polytechnic University, Hong Kong, pp., 2.*
43. *Tameru (2009). Affordable Houses for Middle and Low Income Group in Ethiopia: Self-help housing with innovative construction technology.*

44. *The current state of the construction industry.Report on the Ethiopian economy, Volume VI.*

45. *Tobias(2012) Effective material logistics in construction: Lessons from a Swedish apartment-block:projectMaster's Thesis in the Master's program Design and Construction ProjectManagement*

46. *UN-Habitat.(2007). Situation Analysis of Informal Settlements in Addis Ababa. United Nations, Human Settlements Programme.*

47. *www.wrap.org.uk/construction.(n.d).Reducing material wastage in construction.Guidance for clients, contractors and sub-contractors on how to deliver good practice in materials procurement and usage.*

48. Yimam, A. H. (2011). Project Management maturity in the construction industry of developing country (the case of Ethiopian contractors). Thesis submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment Of the requirements for the degree of Master of Science .

APPENDIX –A

Questionnaire Survey for Thesis paper **on:**

Investigation of cost impact of Construction Materials wastages on housing project. A case study on Addis Ababa city administration saving houses development enterprise.

Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering Department

Construction Engineering and Management Stream

Questionnaire Survey for Thesis paper on

Investigation of cost impact of construction materials wastages on housing project. A case study of Addis Ababa housing project.

I am presently pursing a Master of Science degree in civil and environmental Engineering under construction engineering and management at Jimma University, Technology Institute, school of graduate studies.

The aim of this questionnaire is to study cost effect of construction materials wastage on housing project in Addis Ababa condominium. 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 and companies involved.

Thank you in advancing for your time and kind cooperation.

Yours faithfully

By: Kumshel Geneti Alle

Mobile: 0917599669

Supervised by: Prof. Emer T.Quezon

Part one: Profile of the company

Company Name: ____

☐ Owner	☐ Contractor	☐ Consultant	☐ Sub-contractor

Year of establishment____

Classification

Grade	GC	BC
G-1		
G-2		
G-3		
G-4		
G-5		

Position

☐ Owner
☐ Project manager
☐ Architect/Designer
☐ Site engineer
☐ Office engineer
☐ Quantity surveyor
☐ Contract administration
☐ Other

Years of experience in the line of work

☐ 1-5 years
☐ 6-10 years
☐ 11-15 years
☐ 16-20 years
☐ above 20 years

Number of housing project constructed during the last three years
Districts__________________
Site______________________
Floor type__________________
Number of Blocks____________
Value of Executed projects during the last three years(in Millions)

☐ Less than 10
☐ 11-20
☐ 21-30
☐ 31-40
☐ 41-50
☐ 51-60
☐ 61-70
☐ More than 70

Company's employee's according to their qualification
PhD number______________Certificate number _____________
Master, number _____________Diploma number _____________
Degree number ______________

Part Two: Mostly wasted construction materials on housing project

The given below are construction materials list frequently used on housing project. Please indicate the significance of mostly wasted construction materials by ticking the appropriate boxes.

Please indicate

Symbol	Effects' degree
100 %	Extremely significant
75%	Very significant
50%	Moderate significant
25%	slightly significant
0%	no significant

No	Construction materials wastage	100%	75%	50%	25%	0%
		Extremely significant	Very significant	Moderately significant	Slightly significant	no significant
1	Cement					
2	Steel reinforcement					
3	Form work					
4	Coarse aggregate					
5	sand					
6	Hollow concrete block					
7	Ceramic					
8	Terrazzo					
9	Paints					
10	EEGA(Roof cover)					
11	Steel structure(RHS)					
12	LTZ					
13	Water pipe					
14	Electric wire					
15	Glass work					

Part Three: Causes and factors of construction material wastage on housing project.

The given below are factors of sources and causes of construction materials wastage in Addis Ababa housing project. Please indicate the significance of each factor by ticking the appropriate boxes.

Symbol	Effects' degree
1	Very low influence
2	Low influence
3	Moderate influence
4	High influence
5	Very high influence

No	Factors	Effect's degree				
		1	2	3	4	5
	Group (1): Design					
1	Design changes and revisions					
2	Lack of information about types and sizes of materials					
3	Poor /wrong specification					
4	Errors in contract documents					
5	Lack of knowledge about construction techniques during design activities					
6	Lack of attention paid to dimensions of products					
7	Designer's inexperience in method and sequence of construction					
	Group (2): Procurement					
1	Over ordering or under ordering due to lack coordination between ware house and construction crews					
2	Over ordering or under ordering due to mistakes in quantity surveys					
3	Poorly schedule to procurement the materials					
4	Purchased materials that don't comply with specification					
5	Changes in materials prices					
	Group (3) Materials handling					
1	Damage materials on site					
2	Conversion waste from cutting uneconomical shapes					
3	Theft and vandalism					
4	Lack of onsite materials control					
5	Poor storage of materials					
6	Damage during transportation					
	Group (4): Operation					
1	Rework due to workers' mistakes					
2	Damage to work done caused by subsequent trades					
3	Use of incorrect material, thus requiring replacement					
4	Poor workmanship					
5	Choice of wrong construction method and techniques					
6	Change orders					

	Group (5): Labor culture					
1	Difficulty in performance and professional work					
2	Accidents due to negligence					
3	Tradesmen slow/ineffective					
4	Lack of coordination among crews					
5	Unfriendly attitudes of project team and labors					
	Group(6): Equipment and machineries					
1	Equipment frequently breakdown					
2	Poor technology of equipment					
3	Shortage of tools and equipment required					
	Group (7): Site management and supervision factors					
1	Lack of strategy to waste minimization					
2	Lack of waste management plan					
3	Ineffective planning and scheduling of the project by the contractor					
4	Lack of supervision and delay of inspections					
5	Slow response from the consultant engineer to to the contractor inquiries					

Part Four: ways or strategy to minimize construction material wastage on housing project.

The given below are some strategies or ways to minimize construction materials wastage in Addis Ababa housing project. Please indicate the degree of contribution of each strategy by ticking the appropriate boxes.

Symbol	degree of contribution
1	Very low
2	Low
3	Moderate
4	High
5	Very high

Some frame work to minimize Construction materials wastages						
No	Ways of Minimizing and reducing waste	Degree of contribution				
		1	2	3	4	5
1	Proper storage and handling of materials					
2	Using low waste building technologies					
3	Design of offsite construction					
4	Standardization of design					
5	develop site waste management plan					
6	Improved the skill of the work force					
7	Applying materials Re-use and recycle strategy					
8	Proper detailing during design					
9	correct materials planning and ordering					
10	Just-in -time delivery strategy					

APPENDIX- B

Response and Computation of Relative important index and Rank

Part one: Mostly wasted construction materials on housing project

No	Construction materials wastage	100%	75%	50%	25%	0%			
		Extremely significant	Very significant	Moderately significant	Slightly significant	no significant	Total	RII	R
1	Hollow concrete block	15	20	7	4	1	47	0.73	1
2	Form work	12	22	4	7	2	47	0.69	2
3	Cement	15	12	8	8	1	44	0.68	3
4	Steel reinforcement	15	12	10	8	2	47	0.66	4
5	Tiles	14	16	6	6	5	47	0.65	5
6	Terrazzo	14	12	10	6	5	47	0.63	6
7	sand	9	7	13	17	1	47	0.53	7
8	Glass work	11	10	8	8	10	47	0.52	8
9	Paints	9	7	15	9	7	47	0.51	9
10	Coarse aggregate	7	4	9	26	1	47	0.45	10
11	Electric wire	2	13	11	14	7	47	0.44	11
12	Water pipe	2	8	9	21	7	47	0.38	12
13	Steel structure(RHS)	1	5	10	26	5	47	0.35	13
14	LTZ	1	6	7	28	5	47	0.34	14
15	EEGA(Roof cover)		4	10	27	6	47	0.31	15

Part two: Causes and factors of construction material wastage on housing project.

Symbol	Effects' degree
1	Very low influence
2	Low influence
3	Moderate influence
4	High influence
5	Very high influence

No	Factors	Effect's degree					Total	RII	R
		1	2	3	4	5			
	Group (1): Design								
1	Design changes and revisions	2	5	8	14	18	47	0.72	1
2	Rework that do not comply with drawing and specification	3	8	12	7	17	47	0.68	2
3	Lack of information about types and sizes of materials on the market	6	6	12	9	14	47	0.64	3
4	Designer's inexperience in method and sequence of construction.	7	10	10	13	7	47	0.60	4
5	Errors in contract documents	5	13	13	7	9	47	0.52	5
	Total for sub factors							0.63	
	Group (2): Procurement							-	
1	Purchased materials that don't comply with specification	5	9	6	12	15	47	0.65	1
2	Over ordering or under ordering due to mistakes in quantity surveys	7	5	8	11	16	47	0.63	2
3	Poorly schedule to procurement the materials	8	7	6	12	14	47	0.59	3
4	Changes in materials prices	7	5	6	10	19	47	0.45	4

	Total for sub factors							0.58	
	Group (3) Materials handling							-	
1	Damage materials on site	3	3	10	14	17	47	0.71	1
2	Lack of onsite materials control	1	5	11	17	13	47	0.69	2
3	Conversion waste from cutting uneconomical shapes	4	9	16	6	12	47	0.57	3
4	Damage during transportation	2	5	11	12	17	47	0.70	4
5	Poor storage of materials	8	5	8	14	12	47	0.59	5
6	Theft and vandalism	2	3	19	10	13	47	0.65	6
	Total for sub factors							0.65	
No	Factors	Effect's degree							
		1	2	3	4	5			
	Group (4): Operation							-	
1	Rework due to workers’ mistakes	1	6	15	6	19	47	0.69	1
2	Choice of wrong construction method and techniques	6	5	9	10	15	45	0.64	2
3	Use of incorrect material, thus requiring replacement	5	7	8	12	15	47	0.63	3
4	Poor workmanship	3	12	7	12	13	47	0.61	4
5	Damage to work done caused by subsequent trades	5	5	11	11	15	47	0.6	5
	Total for sub factors							0.63	
	Group (5): Labour culture							-	
1	Lack of coordination among crews	3	8	10	12	14	47	0.66	1
2	Accidents due to negligence	8	5	6	14	14	47	0.61	2
3	Tradesmen slow/ineffective	7	5	11	10	14	47	0.6	3
	Total for sub factors							0.62	
	Group(6): Equipment and machinaries							-	
1	Shortage of tools and equipment	6	5	12	11	13	47	0.62	1

	required								
2	Equipment frequently breakdown	15	7	2	9	14	47	0.61	2
3	Poor technology of equipment	4	6	13	11	13	47	0.5	3
	Total for sub factors							0.58	
	Group (7): Site management and supervision factors								
1	Lack of supervision and delay of inspections	6	5	12	11	13	47	0.66	1
2	Poor management and distribution of labors, materials and equipment	15	7	2	9	14	47	0.65	2
3	Lack of waste management plan	4	6	13	11	13	47	0.59	3
4	Lack of strategy to waste minimization	6	5	12	11	13	47	0.53	4
	Total for sub factors							0.61	

Some frame work to minimize Construction materials wastages								
		Degree of contribution						
No	Ways of Minimizing and reducing waste	1	2	3	4	5	Total	RW
1	Proper storage and handling of materials	3	4	8	10	22	47	0.73
2	Using low waste building technologies	2	5	9	12	19	47	0.72
3	Design of offsite construction	2	5	8	16	16	47	0.71
4	Standardization of design	3	5	8	14	17	47	0.70
5	develop site waste management plan	5	4	10	12	17	48	0.68
6	Improved the skill of the work force	5	7	7	13	15	47	0.64
7	Applying materials Re-use and recycle strategy	5	5	10	15	12	47	0.63
8	Proper detailing during design	6	6	12	9	14	47	0.60
9	correct materials planning and ordering	7	10	10	13	7	47	0.52
10	Just-in -time delivery startegy	5	13	13	7	9	47	0.51

APPENDIX-C

Waste and cost calculation format

Block type:-													
No	Construction materials	Unit	price	Design Qty	Actual qty				Average (four sites)			
					Site A	Site B	Site C	Site D		Qty waste	Waste in %	Cost of waste
1	Cement	qun										
5	Ø8	kg										
6	Ø10	kg										
7	Ø12	kg										
8	Ø14	kg										
9	Ø16	kg										
10	Ø20	kg										
11	Ø24	kg										
12	20cm HCB	No										
14	10cm HCB	No										
17	Ceramic wall	m2										
18	Timber form work	m3										
	Total cost of waste											

Effect of construction materials wastages on project cost

No	Materials	Unit	Unit price	Average cost of waste							
				Site A		Site B		Site C		Site D	
				Excess quantity	Total cost	Excess quantity	Total cost	Excess quantity	Total cost	Excess quantity	Total cost
1	Cement	qun									
2	Ø8	kg									
3	Ø10	kg									
4	Ø12	kg									
5	Ø14	kg									
6	Ø16	kg									
7	Ø20	kg									
8	Ø24	kg									
9	20cm HCB	No									
10	10cm HCB	No									
11	Tiles	m2									
12	Timber form work	m3									
	Total for all blocks on sites										
	Av.cost incurred per block										
	Cost effect per block										