



**COMPARATIVE STUDY ON THE IMPACT OF MATERIALS  
WASTAGE ON PROJECT COST BETWEEN PREFABRICATED  
AND ON-SITE BUILDING CONSTRUCTION METHODS: THE  
CASE OF ETHIOPIAN CONSTRUCTION WORKS CORPORATION**

A thesis submitted to Addis Ababa University Institute of Technology School of Civil and Environmental Engineering, Construction Technology and Management Stream, in Partial Fulfillment of the Masters of Science Program.

**By**

**MESERET ASEFA**

**Advisor: - Abebe Dinku, Prof. (Dr.-Ing.)**

**Co-Advisor: - Mr. Bedru Merhaba**

April, 2024

Addis Ababa, Ethiopia

Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC

ADDIS ABABA UNIVERSITY  
SCHOOL OF GRADUATE STUDIES  
ADDIS ABABA INSTITUTION OF TECHNOLOGY  
School of Civil and Environmental Engineering  
Construction Technology and Management Stream

COMPARATIVE STUDY ON THE IMPACT OF MATERIALS WASTAGE ON PROJECT COST BETWEEN PREFABRICATED AND ON-SITE BUILDING CONSTRUCTION METHODS: THE CASE OF ETHIOPIAN CONSTRUCTION WORKS CORPORATION

By  
MESERET ASEFA

Approved by Board of Examiners

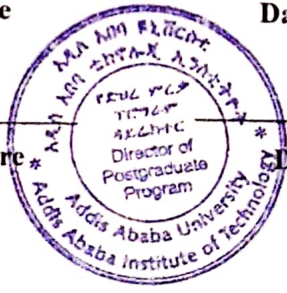
Prof. Dr. - Ing Abebe Dinku Abebe Dinku 24.04.2024

Advisor Signature Date  
Demaw Adissa [Signature] April 24, 2024

Internal Examiner Signature Date  
Esayas G/youhannes [Signature] April-30-2024

External Examiner Signature Date  
Abraham Gebre (Dr.) [Signature] [Date]  
Dean, School of Civil & Environmental Engineering


Chair Person Signature Date  
[Signature] [Date]



## **DECLARATION**

I, the undersigned, declare that the thesis has been carried out by me and prepared under the guidance of my advisor Prof. (Dr.-Ing.) Abebe Dinku and my co-advisor Mr. Bedru Merhaba at Addis Ababa Institution of Technology during the year 2023 as a part of my Masters of Science in Civil Engineering Construction Technology and Management Stream. I further affirm that the thesis has not been submitted in whole or in part to any other university or institution with the intention of conferring a degree.

Name: Meseret Asefa

Signature: 

Place: Addis Ababa Institution of Technology

Date: 24-04-2024

## **ACKNOWLEDGMENTS**

First, I am grateful to Almighty God, who gave me health and strength in my life until this time. Next, I thankfully acknowledge and give my genuine gratitude to my advisor, Prof. (Dr. -Ing.) Abebe Dinku and my co-advisor Mr. Bedru Merhaba for their guidance and advice throughout the study. Their expertise and encouragement helped me to finalize and write this thesis.

I am deeply grateful to Addis Ababa University female scholarship program for giving me the chance for this study.

My sincere gratitude also for all respondents who participated in the information gathering procedure for their support and giving valuable information.

I am thankful to my husband, my family and friends for supporting in many ways from the start till this end.

**Meseret Asefa**

April, 2024

Addis Ababa, Ethiopia

## **TABLE OF CONTENTS**

DECLARATION .....	ii
ACKNOWLEDGMENTS .....	iii
TABLE OF CONTENTS.....	iv
LIST OF FIGURES .....	viii
LIST OF TABLES .....	ix
ACRONYMS .....	xi
ABSTRACT.....	xii
1. INTRODUCTION .....	1
1.1. Background of the Study.....	1
1.2. Statement of the Problem .....	2
1.3. Research Questions .....	3
1.4. Objectives of the Research.....	3
1.4.1. General Objectives.....	3
1.4.2. Specific Objectives .....	3
1.5. Scope of the Study.....	3
1.6. Significance of the Research .....	3
1.7. Limitations of the Study.....	4
2. LITERATURE REVIEW .....	5
2.1. Introduction .....	5
2.2. Definition of Construction Material Waste.....	5
2.3. Types of Construction Waste .....	6
2.3.1. Physical Waste .....	6
2.3.2. Non-physical Waste .....	6
2.4. Quantity of Material Waste in the Construction of a Building .....	7
2.4.1. Material Wastage Standard in Building Construction Projects .....	7
2.4.2. Measurement of Construction Material Waste .....	8
2.5. Sources of Construction Materials Wastage .....	9
2.6. Prefabricated and On-site Construction method .....	11

2.6.1.	Introduction.....	11
2.6.2.	Extent of Material Wastage in Prefabrication and On-site Construction Methods.....	12
2.6.3.	Benefits of Prefabrication .....	13
2.6.4.	Experience of Prefabrication and Growth in ECWC .....	14
2.7.	Construction Material Wastage and Project Cost .....	15
2.7.1.	The Project's Pre-contract Phase.....	15
2.7.1.1.	The Quality of Planning .....	16
2.7.1.2.	The Quality of Design Management .....	16
2.7.1.3.	The Complexity of Design .....	16
2.7.1.4.	The Quality of Estimating .....	17
2.7.2.	The Project's Post-Contract Phase .....	17
2.7.2.1.	Procurement Management Quality .....	17
2.7.2.2.	The standard of Construction Management.....	17
2.7.2.3.	The Quality of Site Management.....	18
2.8.	Construction Waste Management Methods in Different Countries .....	18
2.9.	Waste Minimization Techniques.....	23
2.9.1.	Prefabrication .....	23
2.9.2.	Lean Construction or Just-in-time Delivery Strategy .....	23
2.9.3.	Design Management .....	24
2.9.4.	Materials Management.....	24
2.9.5.	Develop Site Waste Minimization Plan (SWMP) .....	24
2.9.6.	Proper Material Storage and Handling .....	25
2.9.7.	Develop Construction Waste Management Hierarchy .....	25
2.10.	Advantages of Construction Materials Waste Minimization .....	26
2.11.	Gap Identification.....	28
2.12.	Literature Review Summary .....	29
3.	METHODOLOGY .....	31
3.1.	Introduction .....	31
3.2.	Research Design.....	31

3.3.	Data Collection Instrument .....	31
3.4.	Research Population and Sampling.....	32
3.5.	Data Analysis Method.....	34
3.6.	Research Reliability .....	35
4.	RESULTS AND DISCUSSION OF THE STUDY .....	36
4.1.	Introduction .....	36
4.2.	Reliability test .....	36
4.3.	Questionnaire survey response rate.....	36
4.4.	Explanation of Respondents.....	37
4.4.1.	Position of Respondents on the Site.....	37
4.4.2.	Background in Education of Respondents .....	37
4.4.3.	Work Experience of the Respondents.....	38
4.5.	Reasons of Material Wastage in ECWC Prefabricated and On-site Construction Sites.....	39
4.5.1.	Reasons of Concrete Wastage.....	39
4.5.2.	Reasons of Mortar Wastage .....	43
4.5.3.	Reasons Reinforcement Bar Wastage.....	45
4.5.4.	Reasons of Hollow Concrete Block Wastage .....	48
4.5.5.	Reasons of Form work Wastage .....	50
4.6.	Relationship between the Material Waste and Project Cost Overruns.....	53
4.7.	The Extent of Waste Minimization Techniques in ECWC Sites .....	56
4.7.1.	Waste Minimization Techniques of Concrete.....	56
4.7.2.	Waste Minimization Techniques of Mortar .....	57
4.7.3.	Waste Minimization Techniques of Reinforcement Bar .....	58
4.7.4.	Waste Minimization Techniques of Hollow Concrete Blocks .....	58
4.7.5.	Waste Minimization Techniques of Form work .....	59
4.8.	Case Study.....	59
4.8.1.	Measured Construction Material Waste.....	60
4.8.2.	Impact on the Total Project Cost .....	62
4.8.2.1.	Cost of Reused and Recycled Waste Material.....	63

5.CONCLUSIONS AND RECOMMENDATIONS .....	64
5.1. Conclusions .....	64
5.2. Recommendations .....	65
5.3. The Research’s Knowledge Contribution .....	65
REFERENCES .....	67
ANNEX.....	73
Annex 1: Questionnaire for the Contractor.....	73
Annex 2: Questionnaire for the Consultant .....	82
Annex 3: Construction site observation checklist.....	91

## **LIST OF FIGURES**

Figure 2-1: Construction waste type .....	7
Figure 2-2: Construction Waste Management Hierarchy .....	26
Figure 4-1: Damaged prefabricated concrete structure.....	42
Figure 4-2: Bulged shear wall and segregated column structure in on-site construction site .....	42
Figure 4-3: Plastering work covering above the dimension and improper way of work..	45
Figure 4-4: Improper put and unusable quantity of re-bar.....	48
Figure 4-5: Inappropriate storing of HCB .....	50
Figure 4-6: Not timber formwork used in prefabricated site .....	53
Figure 4-7: High amount of timber formwork used in on-site construction site .....	53
Figure 4-8: Graphical description between material wastage and project cost on pre contract stage from both respondents .....	54
Figure 4-9: Graphical description between material wastage and project cost on post contract stage from consultant respondent.....	55
Figure 4-10: Graphical description between material wastage and project cost on post contract stage from contractor respondent.....	56

## **LIST OF TABLES**

Table 2-1: Summary of source and reasons of material wastage in building construction project .....	10
Table 2-2: Summary of waste management methods in different countries .....	21
Table 2-3: Summary of gap identification .....	28
Table 3-1: Analyze population data .....	33
Table 4-1: Reliability statistics .....	36
Table 4-2: Percentage of respondents to the survey .....	37
Table 4-3: Position of respondents on the site .....	37
Table 4-4: The respondents' educational background.....	38
Table 4-5: The respondents' work experience .....	38
Table 4-6: Strength of the rank correlation values for material wastage .....	39
Table 4-7: Main source of concrete waste relative importance and rank .....	40
Table 4-8: Reasons of concrete waste and their relative importance - opinion of contractors.....	40
Table 4-9: Reasons of concrete waste and their relative importance - opinion of consultants.....	41
Table 4-10: Main source of mortar waste relative importance and rank .....	43
Table 4-11: Reasons of Mortar waste and their relative importance - opinion of contractors.....	43
Table 4-12: Reasons of Mortar waste and their relative importance - opinion of consultants.....	44
Table 4-13: Main source of reinforcement bar waste relative importance and rank .....	45
Table 4-14: Reasons of reinforcement bar waste and their relative importance - opinion of contractors.....	46
Table 4-15: Reasons of reinforcement bar waste and their relative importance - opinion of consultants.....	46
Table 4-16: Main source of HCB waste relative importance and rank.....	48
Table 4-17: Reasons of HCB waste and their relative importance - opinion of contractors .....	49
Table 4-18: Reasons of HCB waste and their relative importance - opinion of consultant .....	49

Table 4-19: Main source of formwork waste relative importance and rank.....	51
Table 4-20: Reasons of formwork waste and their relative importance - opinion of contractors.....	51
Table 4-21: Reasons of formwork waste and their relative importance - opinion of consultants.....	52
Table 4-22: Pre-contract stage of project rate of contribution for material waste generation.....	53
Table 4-23: Pre-contract stage of project rate of contribution for project cost overrun ...	54
Table 4-24: post-contract stage of project level of contribution for material waste generation.....	55
Table 4-25: post-contract stage of project level of contribution for project cost overrun	55
Table 4-26: Strength of the rank correlation values for waste minimization techniques .	56
Table 4-27: The extent of waste minimization techniques for concrete waste.....	57
Table 4-28: The extent of waste minimization techniques for mortar waste.....	57
Table 4-29: The extent of waste minimization techniques for reinforcement bar waste..	58
Table 4-30: The extent of waste minimization techniques for HCB waste .....	58
Table 4-31: The extent of waste minimization techniques for form work waste .....	59
Table 4-32: Sample projects basic data .....	60
Table 4-33: Percentage of wastage quantity on each case study sites .....	61
Table 4-34: Total cost of material wastage on each case study sites.....	62
Table 4-35: Cost benefit by recycled waste material.....	63
Table 4-36: Cost benefit by reused waste material.....	63

## **ACRONYMS**

BOQ	Bill of Quantity
EBCA	Ethiopian Building Construction Authority
ECWC	Ethiopian Construction Work Corporation
ERCC	Ethiopian Road Construction Corporation
HCB	Hollow Concrete Block
Kg	Kilo Gram
M <sup>2</sup>	Meter square
PBPPE	Prefabricated Building Parts Production Enterprise
Pcs	Pieces
Qtl	Quintal
SWMP	Site Waste Management Plan
WWCE	Water Works Construction Enterprise
Φ	Diameter

## **ABSTRACT**

Construction material waste is produced due to construction work progress, type of work being done and site procedure on traditional methods of construction projects. As a result, using prefabrication is one of the options for decreasing the waste produced by using prefabricated elements. Prefabrication is the conversion of construction activities from on-site construction methods that produce a lot of waste to industrial procedures that produce little waste.

This study aims to analyze the effects of construction material waste on project costs in Ethiopian Construction Works Corporation between prefabricated and on-site building construction methods. A literature review was carried out to identify sources of construction material waste, prefabricated and on-site construction methods and their material wastage extent, construction material wastage and project cost and waste minimization technics being used in the construction industry. A questionnaire survey, on-site observation, and case studies based on document analysis were carried out in this research. The data obtained from the questioner were analyzed using Microsoft excel. The study focused on the five main materials which are concrete, mortar, reinforcement bar, hollow concrete block and formwork for the greatest influence on the project cost. Based on the respondent answer from contractor and consultant ranked the variable and by document analysis estimate the amount of material waste analytically. From 13 Ethiopian Construction Works Corporation prefabricated and on-site construction project sites, the study show that design change, lack of onsite material control, rework and ordering errors were the main reasons of construction materials wastage.

Finally, according to the results of this study, sand and hollow concrete blocks are largest source of waste in prefabricated and on-site project sites but formwork wastage is only showing on on-site construction and the cost of waste generated at these two sites are 6.23% and 13.84% in prefabricated and on-site construction, respectively. The result of this study recommends that, uses of construction element, proper detail during designing, attention to material control and reduce rework and material ordering errors are the main reasonable technics in Ethiopian Construction Works Corporation construction sites to increase profits and reduce waste.

***Key words:*** *On-site construction method, cost, prefabrication, profit, impact.*

## **1. INTRODUCTION**

### **1.1. Background of the Study**

The enormous construction industry contributes significantly to the growth of nations, particularly those that are still developing like Ethiopia. The need for building supplies is rising drastically day by day. The expansion of the building sectors is driving up the demand for material resources (Subash Thanappan, et al. (2021)). Using traditional methods, building construction projects generate a range of material waste. Construction work progress, type of work being done, and site procedures all affect how much and what kinds of materials are wasted. The management of waste is a crucial area of concern while implementing a construction project.

Waste from construction includes a wide variety of materials, including wood, bricks and blocks, cardboard, concrete, glass, metal, plastic, roofing material, soil, sand, and tiles.

According to Begum, et al. (2010) construction methods classified into two which are, industrial building system (prefabrication) and on-site construction method.

On-site construction method is involved using a lot of laborers, a lot of resources, and a long period to finish the projects. Compared to prefabrication, this process will generate greater waste.

Prefabrication is the conversion of construction activities from on-site construction methods that produce a lot of waste to industrial procedures that produce little waste. As a result, prefabricated building sites typically have a clean plan with organized material stockpiles. The main advantages of prefabricated building techniques include shorter construction times, lower costs overall, less material waste, higher building quality, increased safety, and cleaner and more organized construction sites. And from previous finding different researchers compare material wastage level between prefabricated and on-site construction methods.

According to Cao, et al. (2015), Prefabrication has the ability to reduce construction waste by between 25 and 81.25% when compared to on-site construction methods. This outcome is in line with research by Tam, et al. (2007), which showed that using alternative technologies might decrease construction waste creation by up to 84.7%.

The study findings demonstrate that waste may be reduced when utilizing prefabrication methods as opposed to on-site construction. The average level of reduction was 30% when using prefabrication methods (Nurul Aini Osman. (2016)).

According to the above study, this study suggests that pinpointing the root reasons and how waste is related to those reasons gives the construction company a clear economic advantage. In order to analyze the profitability of two different construction methods on-

site against prefabricated building construction in ECWC this study aims to assess and compute the extent, main reasons, and impacts of material wastage on project cost.

Ethiopia Construction Work Corporation (ECWC) was newly established on December 18/2015. It was created by merging three companies; Prefabricated Building Parts Production Enterprise (PBPPE), Ethiopian Road Construction Corporation (ERCC) and Water Works Construction Enterprise (WWCE). It is one of the biggest governments owned profit-based Construction Company in Ethiopia and engaged in construction of buildings, roads and water works.

ECWC building sector constructs on-site building construction from small to high rise building and prefabricated building construction. Prefabricated construction is still used by the former PBPPE then now ECWC as it is one of the company that construct in this type of construction method, and concrete related products manufacturing section is producing concrete products such as: - ready mix concrete, hollow concrete blocks, concrete pipe, paving blocks and prefabricated structural elements. Of these input products, prefabricated structural elements are generating highest revenue for the center and corporation as well.

## **1.2. Statement of the Problem**

Waste of materials can occur throughout the pre-contract and post-contract phases of the construction process. Pre-contract stage is from the beginning through the final step of contract award and a number of tasks are covered for the waste of materials, including budget proposals, feasibility studies, BOQs, preliminary and final designs, and estimating over to the construction stage, and also on the post-contract construction stage supervision, examination, approval, and value of construction activities mention the identification and understanding of the reasons of material wastage (Nagapan, et al. (2012a)).

Material waste adds a considerable amount of additional cost to construction projects and has an influence on the entire project cost. This includes mainly the cost of new purchases are usually made to replace wasted materials, cost of transporting, costs of rework, delays and disposing of site waste cause financial losses to the contractor (Ekanayake, L.L., & Ofori, G. (2000)).

Although this study is focus on how material waste generated from construction sites (during the construction process) contributes to cost overruns in both prefabricated and on-site construction projects.

Ethiopian construction works corporation are one of the construction company to construct prefabricated and on-site building construction methods in Ethiopia, and no more research is required to determine how material impact project cost on prefabricated and on-site building construction methods. In order to better understand how material

wastage impact project cost and can affect the construction cost of Ethiopian construction Works Corporation a more in-depth investigation was done in this study.

### **1.3. Research Questions**

The following questions were posed in order to fulfill the goals of this research:

1. What are the main sources and reasons of construction material waste on the construction sites of on-site and prefabricated buildings in selected company?
2. What are the impacts of construction materials waste on the project cost?
3. Which materials are highly wasted on the construction sites of on-site and prefabricated buildings in selected company?
4. What are the common waste minimization technics being implemented in selected company with regard to reducing waste?

### **1.4. Objectives of the Research**

#### **1.4.1. General Objectives**

The general objective of this study is to assess the impact of materials wastage on the cost of a project in on-site and prefabricated building construction method at ECWC.

#### **1.4.2. Specific Objectives**

The following points will be specifically covered by this study:

- To identify the main reasons of construction material waste at construction project sites of on-site and prefabricated construction methods.
- To calculate the amount of material wastage in terms of monetary value and assess its impact on project cost of prefabricated and on-site construction project in selected company.
- To determine highly wasted selected materials during the construction process.
- To evaluate the extent of waste minimization technics being implemented in selected company on-site and prefabricated building construction method.

### **1.5. Scope of the Study**

This research is constrained and concentrates on active construction progress of on-site and prefabricated buildings for the ECWC on identification of main reasons of material wastage, relation between material waste and project cost overrun and waste minimization techniques.

### **1.6. Significance of the Research**

The significance of this research is to fill the research gap on the impact of material wastage on project cost between prefabricated and on-site building construction project

on Ethiopian Construction Works Corporation. The research's findings will aid in determining the main reasons and their impact on construction work and project profitability, as well as help develop potential solutions that may be used for future planning on construction projects managed by ECWC, also consultants to review their material wastage reduction plan and future researchers.

### **1.7. Limitations of the Study**

With its limitations, this study looked into material waste in selected prefabricated and on-site ECWC building construction project sites that are under construction. While conducting this study the researcher faced problem like unavailability of full document and empirical checklist for assessing waste quantity and project cost profitability on the construction sites and the unwillingness of some sites to provide information and more of the respondent work on-site construction sites because prefabricated construction is still less experienced.

## **2. LITERATURE REVIEW**

### **2.1. Introduction**

A country's infrastructure and industrial expansion are closely related to the construction sector. How civilization evolves in the future will be heavily influenced by the construction of roads, bridges, and other constructed infrastructure. As a result, the construction industry produces a lot of waste that is bad for the environment and costly for project finances (Augustine, S. (2011)).

According to Al-Moghany, S.S. (2006) and Ekanayake L.L., & Ofori, G. (2000), there are three main categories of waste in the construction industry: waste of materials, waste of time, and waste of machinery. However, this study focuses primarily on waste of materials because they make up the largest input into construction activities and range from 50 to 60% of the project's overall cost (Ibn-Hamid, N.T. (2002) and Ganesan, S. (2000)).

Studies conducted in several nations have demonstrated that all materials not ordered and distributed to sites are used for the intended objectives and end up being wasted for a variety of reasons (Al-Moghany, (2006)). An additional 13 million tons of wastage are produced by material waste due to the process of materials delivered to the site, unused and then sent away for disposal (Augustine, S. (2011)).

Material management is one of the major challenges in the performance of the Ethiopian construction industry (Tadesse Ayalew, et al. (2016)). If the material waste is not properly handled and managed on the project site, this will lead to financial crises, and eventually negatively impact the community and the environment.

The cost of waste is a substantial component of the rising cost of construction projects. Effective waste minimization to reduce the need for natural resources or raw materials, reduce cost of transportation and disposal, has a smaller negative impact on the environment and increases profit (Augustine, S. (2011)).

### **2.2. Definition of Construction Material Waste**

Moreover, the phrase "material waste" was defined by many researchers. Ekanayake., & Ofori. (2004) "define material wastage as any material other than earth material which needs to be transported elsewhere to the construction sites or used within the construction site itself for the purpose of land filling, incineration, recycling, reusing, or composting rather than the intended specific purpose of the project due to material change, excess, nonuse, or noncompliance with the specifications or being a byproduct of the construction process."

Shen, L.Y., & Tam, V.W.Y. (2002) "can also be defined as the difference between the value of materials delivered and accepted on site and those properly used as specified and

accurately measured in the work after deducting the cost saving of substituted materials transferred elsewhere in which unnecessary cost and time may be increased by the material wastage.”

Keal. (2007) "Every material or thing that is not useful now or will be in the future is waste and is subject to a number of restrictions."

Dania, et al. (2007) "construction and demolition waste is a complex waste stream, composed of a wide variety of materials that are in the form of building debris, rubble, earth, concrete, steel, timber, and mixed site clearance materials, arising from various construction activities, including land excavation or formation, civil and building construction site, clearance, demolition activities, road-work, and building renovation.”

Therefore, the better definition for construction material waste is the one defined by Shen, L.Y., & Tam, V.W.Y. (2002), which stated above, because it clearly describes what this study tries to accomplish.

### **2.3. Types of Construction Waste**

Construction waste is the material that was made by human and industrial activities that has no residual value. It can be categorized into two groups of construction waste which are physical waste and non-physical waste.

#### **2.3.1. Physical Waste**

Physical construction waste is defined as "the waste resulting from construction, renovation, and demolition activities, including site preparation, building construction, road construction, and building demolition and renovation" (Kofoworola, O. (2009), Shen, L. (2004), Poon, C. (2007) & Tam, V. (2008)). In other words, it is acknowledged that physical waste constitutes the waste present at any construction site.

Concrete, wood, steel, and other types of material waste are examples of physical waste from building sites. Physical wastes have negative environmental effects in addition to having an impact on project costs. Construction supplies must be used up since they are either lost or damaged beyond repair. Typically, the waste is taken away from the construction site and dumped in landfills. Physical waste, however, is divided into three subcategories: additional material loss, overproduction of labor hours, and machine operating time.

#### **2.3.2. Non-physical Waste**

Often, there is non-physical waste produced during the building process. Cost overrun and time overrun are non-physical wastes, whereas waste from materials is a physical waste. Cost overruns are therefore a waste of resources. Ma. (2011) defines waste as being connected to other activities as well as the wastage of materials, including repair, waiting, and delays. There is a correlation between material waste originating from

physical waste and expense overruns originating from non-physical waste since construction waste includes both physical and non-physical waste. Figure 2-1 below shows that construction waste type summarized from above discussion (Nagapan, S., et.al (2012)).

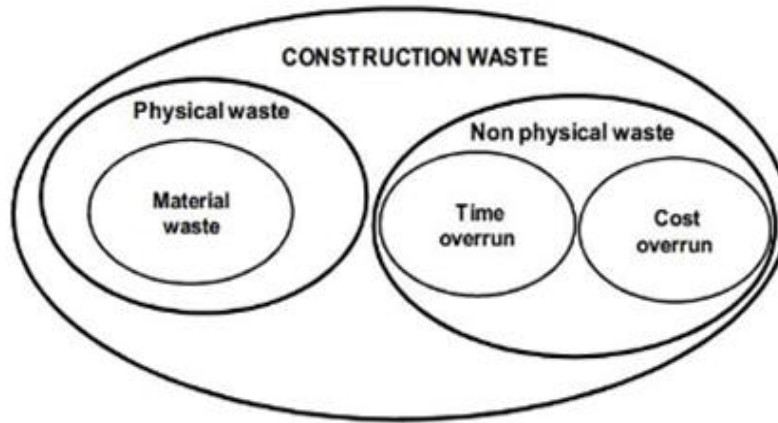


Figure 2-1: Construction waste type

## **2.4. Quantity of Material Waste in the Construction of a Building**

Quantification gives the capabilities needed to assess the true amount of construction waste generated at the sites. While a project is being contracted, the quantities of work involved are specified in bill of quantities for the contract.

Typically, there are different approaches for the calculation of the quantity of material waste. The standard material wastage in which the quantity of materials for a project is imagined during the inception stage using previous experience. They are derived from the plans and drawings, and every type of material has some inherent material waste (Chitkara. (2004)).

Construction material waste in which the amount of material used to construct a structure that is in excess of the quantity take-off, using a mass balance approach as defined by Li, et al. (2013). Also, according to Tam, et al. (2002) the amount of material waste level is calculating from the purchased quantity and actual needed material on the project.

### **2.4.1. Material Wastage Standard in Building Construction Projects**

All types of materials have an inherent tendency to waste materials during use. For instance, the actual quantity needed for concrete works is greater than the theoretical quantities calculated from the drawing because some handling waste happens when placing concrete due to errors in form work leveling, and even though the quantities of aggregate, sand, cement, and water are correctly weighed before mixing. The term “standard wastage”, which is generally expressed as a percentage of the material calculated theoretically from the quantities of work involved. The total amount of

materials to be provided should increase the theoretical quantity correspondingly to account for the standard wastage, as shown below in Equation (1).

$$\text{Actually, needed quantity} = \frac{\text{Theoretical quantity} \times (100 + \text{Standard wastage } \%) \dots}{100} \quad [\text{Eq.1}]$$

Where    Actually, needed quantity = the actual requirement quantity  
           Theoretical quantity = quantity measured from the drawing and  
           Standard wastage = planned wastage expected in actual work.

It should be highlighted that normal wastage only accounts for waste that occurs during use for reasons that are considered uncontrollable at the site. This typical wastage of building materials relies on a number of factors, including the nature of the work, the application method, and the type of materials used. Nonetheless, these exemptions are frequently based on historical precedent, and their veracity or foundation is rarely contested. Instead, the best way to determine the typical wastage is from the expertise of contractors, and it's worth varies for various materials. A likely outcome can be predicted with proper record keeping of previous employment outcomes and by methodically contrasting the present circumstance with similar outcomes in the past (Chitkara. (2004)).

**2.4.2. Measurement of Construction Material Waste**

A key prerequisite for the process of waste minimization is waste quantification. Quantity take off in this study refers to the volume of needed material that will be incorporated permanently into a building. It is the least amount of material required to build a structure and excludes temporary material and equipment for the construction process, and Wastage.

Waste refers to the amount of material used to construct a structure that is in excess of the quantity take-off, using a mass balance approach as defined by Li, et al. (2013). A Material Loss Rate (MLR) then refers to the amount of waste as a fraction of quantity take-off, represented as a percentage, as shown in Equation (2). By this definition, excess material that is incorporated into a structure is still considered to be waste.

$$\text{MLR}_i = \frac{\sum_i(\text{Total material}) - \sum_i(\text{Quantity take - off})}{\sum_i(\text{Quantity take - off})} \% \dots \dots \dots [\text{Eq.2}]$$

Where    MLR = material loss rate  
           Total material = summation of quantity take-off and waste  
           Quantity tack-off = calculated materials used to a structure.

Also, by analyzing the difference between the final evaluated quantities and the actual needed material, it is possible to determine the amount of material waste caused in the projects and as shown in Equation (3).

The concept of material waste level indicates that wastage rate of a given material and the contribution of material wastage to project cost.

From (Tam, et al. (2002)) Wastage Level (in %) =  $\frac{M_p - M_u}{M_p} \times 100\%$ .....[Eq.3]

Where  $M_p$ = Purchased material and  
 $M_u$  = Material used for actual construction work.

## **2.5. Sources of Construction Materials Wastage**

According to its origin, or the stage at which the waste's primary sources originate, material waste can be divided into different categories. These sources, which lead to the waste of building materials, have been identified by various researches.

Ekanayake., & Ofori. (2000) divide the source of construction material waste into four groups design, procurement, handling of material, and operation. Others, according to Lingard, et al. (2000) categorized these sources to procurement, handling, operation, and culture.

Muhwezi, et al. (2012) classified source of materials wastage on building construction projects into 9 groups. These are design and documentations, site management and practices, procurement, materials handling, storage, transportation, operation, and environmental and other conditions.

Andualem., & Aklilu. (2019) stated that design, procurement, material handling, and construction phases of a project are the main sources of material waste in building construction projects.

According to Sasitharan., Ismail., & Asmi. (2012) and Sagoe. (2011) the sources of construction material waste can be measured and assessed using a large number of construction phase related factors such as: -

- Design and documentation

Design change and error in contract document and lack of consideration for the available standard sizes are some of the waste related reasons due to design and documentations. Modifications made to the design while work is still being done can result in demolition, extra and unnecessary materials, discouragement of labour energy and decrease of quality of products.

Moreover, when construction is about to start, insufficient design information frequently results in significant waste. There are always instances where the design requirements do not match the actual material measurements, resulting in significant material waste during construction. A considerable amount of waste can be eliminated if designers can take into consideration specific technical knowledge regarding the construction materials or construction process (Sasitharan., Ismail., & Asmi. (2012)).

- Procurement

Lack of trade’s skill, ordering errors and purchased products that do not meet the specification are some of the waste related reasons on procurement phase.

Errors in the procurement process result in a significant amount of waste. Ordering errors, such as ordering much more or less than necessary, can obstruct the pre-planned flow of materials, resulting in redundant delivery and additional handling with all of the associated expenses (Sagoe. (2011)).

- Material handling

Incorrect materials storing and poor handling are key reason for physical waste generation in the building projects. Planning is essential for proper material handling, particularly for clear, uninterrupted access from the location of storage to the location of use, which includes the provision of temporary roads and the necessary equipment (Sasitharan., Ismail., & Asmi. (2012)).

- Construction phase

Construction errors like rework, damage to work done caused by consequent trades, lack of onsite material control, consuming an extreme amount of materials than required are all due to negligence and carelessness or incapability of construction (Sasitharan., Ismail., & Asmi. (2012)).

Site management practices and site supervision are also related to the site supervisors and the site operatives; people who are directly involved in the art of putting the raw materials together to form the building envelop. Table 2-1: below shows summary of the main source and reason of material wastage at building construction sites from the above researchers Andualem., & Aklilu. (2019).

Table 2-1: Summary of source and reasons of material wastage in building construction project

Source	Reason
Design phase	<ul style="list-style-type: none"> <li>• Modifications made to the design while work is still being done</li> <li>• Inexperience of designers with building sequence and methods</li> <li>• Lack of consideration for the available standard sizes</li> <li>• Designers unfamiliarity with alternative products</li> <li>• Selection of the material's type and dimensions without considering wastage</li> <li>• Error in contract document</li> <li>• Disregard for the product’s dimensional coordination</li> </ul>
Procurement phase	<ul style="list-style-type: none"> <li>• Lack of trades skill</li> <li>• Ordering errors</li> <li>• Purchased products that do not meet the specification</li> </ul>
Construction	<ul style="list-style-type: none"> <li>• Unfriendly attitudes of project team and laborers</li> </ul>

<b>Source</b>	<b>Reason</b>
Material handling	<ul style="list-style-type: none"> <li>• Damages during transportation</li> <li>• Supplies provided in loose form</li> <li>• Use of any material nearby the work area</li> <li>• Material damage resulting from storage and handling</li> </ul>
Construction phase	<ul style="list-style-type: none"> <li>• Errors by trades men or operatives</li> <li>• Accidents due to negligence</li> <li>• Damage to work done caused by consequent trades</li> <li>• Use of incorrect material, thus requiring replacement</li> <li>• Uncertain required as a result of poor planning</li> <li>• Equipment malfunctioning</li> <li>• Lack of onsite material control</li> <li>• Poor coordination among project participant</li> <li>• Chiseling and rework</li> <li>• Consuming an extreme amount of materials than required</li> </ul>
Others	<ul style="list-style-type: none"> <li>• Weather condition, theft and lack of waste management plans</li> </ul>

## **2.6. Prefabricated and On-site Construction method**

### **2.6.1. Introduction**

Modern construction technology is a collective term used to describe a number of construction methods and can be described as the offsite version of traditional methods of construction up to some extent but not exactly. Prefabricated members are utilized in the new house-building techniques that are being introduced to the world, which differ greatly from on-site construction methods. According to Sardinia, Y., et al. (2010), modern construction techniques are recommended to more effectively address the uncertainty present in on-site construction processes, including costs, time, deficiencies, safety, environmental impact, profits, and total life cycle performance. Also, according to Kibirt, B. (2017), the precast methods are better in quality, resource, and time, than on-site construction methods.

Kadir, A., et al. (2006), the difference between on-site and prefabricated methods are in real labor efficiency was largely compensated by a cycle time varying from the size of the crew. A shorter construction period results from a lower cycle time, which reduces logistical costs and enables clients to complete their project on schedule.

On-site construction method uses building parts to assemble and construct the building only once on construction site. Contractors build from the ground up, and foundations, walls, roofs, etc. are created at the construction site. And on prefabricated method construction work is done away from the site manufacturing, and the product is used outside of the area where it was made. A building system offers numerous advantages over on-site production methods as a result of the installation of these kinds of production

facilities and the development of assembly facilities. Prefabrication or precast production system is the name of this system (Ingrao, C., et al. (2014)).

There is no doubt, on-site construction is one of the best methods of construction and people have been using this method for years. But people are demanding for fast construction, it has become very difficult for the contractor to complete the construction fast. Prefabrication can be understood on various levels, taking into account the manufacturing of minute details and elements of a structure, a full house, or volumetric building blocks that can be produced in a factory (Neil., & Deli. (2016)).

### **2.6.2. Extent of Material Wastage in Prefabrication and On-site Construction Methods**

Several researchers analyzed the effects of material waste on different types of construction materials while using prefabricated and on-site construction methods, and timber formworks as the largest source of building waste (Tam, V.W.Y. 2006).

Research revealed that timber formwork produces 32% of the waste, followed by concrete at roughly 27% in on-site construction. Prefabrication had a greater impact on reducing construction waste, particularly in the areas of concrete and timber formwork by 3% and 4% respectively. It is also believed that waste reduction and improved quality control were the two factors that were most crucial to consider when implementing prefabrication in all building projects. Compared to on-site construction, prefabrication also helped to create a cleaner and safer working environment on construction site.

The generation of waste can be reduced up to 80–100% after the adoption of precast technology (Tam, et al. (2007)). Additionally, other studies have produced several implements for evaluating the effects of prefabrication adoption. Based on a questionnaire survey and case study analysis, (Jaillon, et al. (2009)) compared prefabrication with on-site construction in terms of waste reduction. When precast construction was used, the average waste reduction level was found to be approximately 52%.

Sin, T.J. (2013), there are big differences between prefabrication and on-site construction methods for all types of materials. Also, there are significant advantages to the prefabrication process in terms of waste reduction, with a greater proportion of 57% for timber formwork and the lowest percentage of 5% for pipe and cable works.

Tam., & Hao. (2014), compared four projects built using prefabrication technology and on-site construction methods and found that prefabrication technology can reduce plastering waste by up to 100%. Similarly, waste from wooden formwork can be reduced by 80%, and waste from concrete can be reduced by up to 60%.

Nurul Aini Osman. (2016) the study findings demonstrate that prefabrication method was possible to reduce the amount of timber formwork by 57%.

The findings mentioned above lead to the conclusion that prefabrication reduces material waste more than on-site construction, particularly when compared to concrete work, plastering, and timber formwork.

### **2.6.3. Benefits of Prefabrication**

Prefabrication generally has some benefits, which are listed below.

According to Nikolaos Legmpelos. (2013) to show some benefits below:

- Waste minimization. A considerable amount of solid waste is generated during on-site building. In the building sector, prefabrication is commonly acknowledged to significantly reduce solid waste.
- Acceleration of time. Prefabrication may result in a construction timetable that is compressed, which is a significant benefit for any project.
- Cost reduction. If prefabricated components are more affordable than on-site building, there may be financial benefits by construction waste reduction, reduce material stock cost, reduce maintenance cost and accelerated project construction.
- Improving quality. Quality is an important issue and prefabricated components widely accepted for enhanced quality.
- Safer working conditions. Another benefit that is generally acknowledged for the building sector. Because prefabrication is done under regulated settings, there is less risk to construction workers.
- Lower labor costs and easier worker attraction. Construction employees sometimes do challenge tasks in unfavorable circumstances. On the other side, prefabrication facility employees benefit from better working circumstances due to the controlled setting. As a result, finding workers eager to work in a construction factory is simpler.
- Better supervision. (Tam, et al. (2006)) It is simpler to supervise the controlled activities carried out in a prefabrication factory that is typically close to a manufacturing facility.

Some drawbacks of prefabrication are described below (Tam, et al. (2006)):

- Inflexible design. Early design freezing is required. Late-stage decisions by architects and owners cannot be made, which is seen to be advantageous for contractors.
- Higher initial costs. The whole project development phase is shifted towards the start of the project. Many people need to be involved at an early stage. For example, in the case that components are ordered from a third party, extra care must be taken to make sure that the supplier chosen is reliable and can meet schedule and quality requirements. Again, this might actually be considered an advantage for some people depending on how they want to manage their project.

- Aesthetically monotone. There may be some flexibility in the components that prefabrication manufacturers can build. On-site construction, though, is unquestionably more adaptable. In contrast to a prefabrication plant, where the design is more constrained, almost anything can be built on-site.
- The need for more space to move prefabricated components into place. The installation of prefabricated components may require more space. This issue may be significant, especially in large cities.
- Transportation. The limitations and costs associated with transporting prefabricated element to the construction site must be considered when deciding whether it is a good idea to take the modular approach.

#### **2.6.4. Experience of Prefabrication and Growth in ECWC**

Prefabricated Building Parts Production Enterprise (PBPPE), presently known as Ethiopian Construction and Work Corporation (ECWC), was established prefabricated building industry in Ethiopia in 1985 with former Yugoslavian technical help under the previous Ethiopian Building Construction Authority (EBCA).

The prefabrication system has gradually gained support in other nations, including Cuba, Hungary, Egypt, Angola, China, Italy, Austria, and Ethiopia. The construction industry has benefited from the introduction of new technology brought about by the opening of a prefab home plant in Addis Ababa. Also, it was intended to meet the rising demand for homes in the shortest amount of time possible and to lessen the urgent requirement for timber for formwork. The factory has been employing the precast concrete system to create structural elements for the construction of office buildings, residences, hotels, schools, and other structures (currently from G+0-G+4). Precast concrete also used in Ethiopia for works like pipelines, lintels, cladding, and for institutions fence work.

With the exception of a few places that are close to the factory, the development of the technology was not widely distributed to other regions. Prefab construction was concentrated and at its highest rate (87%) in Addis Ababa. This indicates that the technology's dissemination or development was constrained to a certain region. The least (2%) were found in Nazeret, Hawassa, Dewele, and Galafi, while the second (4%) were located in Debrezeit. This suggests that the growth of prefabrication building in other locations around the nation was significantly constrained because of transportation and logistical issues because the distance from the plant grows and only fabricated on A.A. It is one of the issues preventing this technology's rapid advancement (Birhanu Muluken Tessera. (2020)).

However, in Ethiopia prefabrication construction activity is very low when compared with other countries. But in near recent, i.e., starting from June 2013 E.C. the production center has aggressively engaged in production of structural elements, which is to be used for constructing building projects on the corporation, is running under one of its units the

Housing Development Center. Since then, some projects have been completed and others are on progress, for instance, more than 5,000 housing projects are being constructed.

## **2.7. Construction Material Wastage and Project Cost**

The socioeconomic development of any country is aided by the building sector, yet there are issues with wasteful use of materials, time overruns, and costs (Abdul-Rahman, et al. (2013)). Many construction projects struggle to be finished under budget due to global issues such project cost overruns and material waste (Saidu., & Shakantu. (2015), Ameh., & Itodo. (2013), Abdul-Rahman, et al. (2013) and Nagapan, et al. (2012a)).

Research conducted by numerous experts and from various parts of the world has demonstrated that a sizable portion of manufacturing expenses is attributable to material waste. For instance, research from the United Kingdom (UK) found that material waste added an extra 15% to building project cost overruns (Tam, et al. (2007)). Also, according to research by Ameh., & Itodo. (2013), material waste accounts for between 21% and 30% of cost overruns in construction projects.

According to Eskedar Girma (2016), material waste cost effect extent up to 10 % of the project cost in 40/60 condominium construction projects.

Saidu., & Shakantu. (2016c), material waste accounts for an average 4% of project cost overruns. During a desk research study, (Saidu., & Shakantu (2016a)) came to the conclusion that material waste also contributes to cost overruns in the pre-contract and post-contract phases of a project. According to the research, 96.88% and 81.81%, respectively, of the cost overruns result in material waste during the pre-contract and post-contract phases.

Furthermore, the research has identified similar factors that contribute to both material waste and project expense overruns. These causes arise from a single source or a combination of numerous causes at various project stages (the pre-contract and post-contract stages), and it is crucial to identify them for efficient cost performance and environmentally friendly building.

### **2.7.1. The Project's Pre-contract Phase**

From the beginning through the final step of contract award, a project's pre-contract stage involves a number of tasks. These actions consist of:

- **Feasibility:** This entails meeting with the client, getting the customer's brief, input from all the consultants, gathering survey data, and developing a design timeline.
- **Outline proposal:** This entails developing an idea from the specifications of the design brief.
- **Designing a scheme** entail turning an accepted concept into a functional plan

- Providing complete working drawings and specifications, developing the concept fully, incorporating specialized design work proposition; preparing bills of quantities with numerical measurement; and setting up tendering arrangements (Dennis. (2010)).

If not effectively managed and controlled, these activities help in material waste and expense overruns. Therefore, it is important to comprehend the primary factors contributing to material waste and cost overruns in the pre-contractual stage of a project. Consequently, the quality of planning, the quality of design management, the complexity of the design, and the quality of estimating are the four main phases that are used to identify the reasons of material waste and cost overruns.

#### **2.7.1.1. The Quality of Planning**

Chitkara. (2011) listed the following as the primary, controllable reasons of cost overruns during a project's planning phase:

- ✓ Inadequate project formulation: Poor field investigation, inadequate project information, bad cost estimates, lack of experience, inadequate project formulation and feasibility analysis, poor project appraisal leading to incorrect investment decisions.
- ✓ Poor planning for implementation: inadequate resource plan, inadequate equipment supplies plan, poor organization, and poor cost planning.
- ✓ Lack of proper contract planning and management: Improper pre-contract actions, poor post-award contract management.

#### **2.7.1.2. The Quality of Design Management**

Below are the main reasons for cost overruns and material waste during the project design management phase.

- ✓ Design errors. Project deliverables that are incorrectly or inadequately represented result in additional work, change orders, revisions to the scope of work, etc (Francois buys. (2015)).
- ✓ Changes made to the design by the client or consultant, problems obtaining permissions or approvals from other parties, and labor skill level (Mohammed Gopang, et al. (2020)).

#### **2.7.1.3. The Complexity of Design**

Adewuyi., & Oтали. (2013) and Nagapan, et al. (2012) listed the following as the primary, factors that may contribute to material waste and cost overruns in projects with complicated designs.

- ✓ Designing uneconomical shapes and outlines, sophisticated systems and components/complexity, resulting to difficulties in interpreting specification.

- ✓ Designing irregular shapes and forms, designing non-standard dimensions, allowing cutting and chiseling, lack of experience.
- ✓ Incomplete drawings.

#### **2.7.1.4. The Quality of Estimating**

The factors that contribute to cost overruns and material waste during the building project estimation phase are: -

- ✓ Poor cost estimation and poor tendering documentation: over or under estimation and allowance, Inaccurate quantity takeoff, Insufficient time for estimate, Different methods used in estimation, Late engagement of estimator (Nagapan, et al. (2012)).

#### **2.7.2. The Project's Post-Contract Phase**

The following are some of the activities that go on during a project's post-contract phase: supervision, examination, approval, and value of construction activities. Finishing touches include turning over control to the customer and user, fixing any problems, finishing the tasks required by the contract, and paying the final bills. Yet, this area of research focuses on problems in the building industry. The procurement management quality, the standard of construction management, and the quality of site management are the three main phases that are used to identify the reasons of material waste and cost overruns in this stage (post-contract).

##### **2.7.2.1. Procurement Management Quality**

This section summarizes the factors that contribute on what leads to cost overruns and material waste during the procurement management stage of construction projects are summarized in this section.

- ✓ Inappropriate and inadequate procurement: business correlation, including terms of payment, costs, and services offered (Francois buys. (2015)).
- ✓ Faulty contractual management system, slowness in decision making, lack of experience, late procurement of materials, and delay in approving design documents.
- ✓ Errors in shipping/supply, Damage of material during transportation, Non-standard sizes of materials (Osmani. (2011)).

##### **2.7.2.2. The standard of Construction Management**

This section summarizes the findings of several studies conducted over the years on the factors that contribute to cost overruns and material waste during the construction management phase of projects.

- ✓ Complexity: affected by inflation, variation in material price and fluctuations in exchange rates, client's cash flow problems or delays in contractor's payment,

contractor's financial difficulties, and poor site organization and coordination between various parties (Francois buys. (2015)).

- ✓ Lack of contractor experience, Poor building techniques (Nagapan, et al. (2012)).
- ✓ Workers: Shortage of skilled workers, inappropriate use of materials and equipment, Damage caused by workers (Nagapan, et al. (2012)).

### **2.7.2.3. The Quality of Site Management**

This section summarizes the findings of several studies conducted over the years on the factors that contribute to cost overruns and material waste during the site management phase of construction projects.

- ✓ Post-execution (Closure) Phase: Slow closeout, unresolved disputes linked with client acceptance, change order issues not resolved, final change orders not issued, poor documentation of project success and lessons learnt, slow client acceptance and failing to close the work order (Francois buys. (2015)).
- ✓ Ineffective material management: Wrong material storage, transfer of materials from storage to application, damage of materials by other trades, poor site storage area, long distance from storage to application point and damage by weather.
- ✓ Poor project management during implementation: Insufficient and ineffective working, delays, changes in scope of work and location, law and order (Chitkara. (2011)).

In general, the cost of any project is greatly influenced by the materials used in construction. Hence, material waste has a negative impact on construction expenses, the contractor's profit margin, and the length of the project. It can also be a potential source of conflict amongst the parties involved in the project. A contractor's main goal is to complete a job safely and profitably. Contractors must make a profit in order to live, and this profit is derived from their competence (Adewuyi., & Otali (2013)).

## **2.8. Construction Waste Management Methods in Different Countries**

The methods used to handle construction waste vary per country. For more developed countries, construction waste has become one of the main problems due to high awareness of environmental issues. On the other hand, a lot of developing nations continue to prioritize the construction and completion of infrastructure, which could lead to various waste management strategies.

Fitri, L., et al. (2019) demonstrate the values of construction waste management used by several nations.

## **1. United States**

There are numerous waste management strategies that can be used on projects and construction sites. There are two waste management models that can be used in the US (Dajadian, S. A., & Koch, D. C. (2014)).

- a) Using a separate subcontractor for waste management

The main contractor must think about waste management in addition to ensuring that the project is completed effectively. The company's obligation for managing waste on sites may be lessened by using a separate subcontractor. The waste management (WM) contractor is accountable for managing waste as well as for estimating and calculating the volume of waste generated by the project.

- b) Having a department of waste management that will employ specialty staff

The management and correct disposal of waste is the duty of waste management staff. In addition to managing waste on-site, this department also creates training sessions for the employees and enhances their understanding of the many types of construction waste and the disposal procedure. The waste management department is also in charge of estimating waste production during the design phase so that waste management planning may be started early and a lot of money can be saved during construction.

## **2. United Kingdom**

Like to other large countries, the UK's construction industry is the largest contributor of waste disposed in landfills (Yedele, O., et al. (2014)). The adoption of proper rules is one of the main elements that significantly contribute to lowering the amount of construction waste dumped in landfills.

According to Ajayi, et al. (2017), waste management laws and regulations could successfully promote the reduction of construction waste. In the UK, there are six considerations that might be made, including.

- (i) Awarding of tax reduction and incentives to good waste performers and waste management companies.
- (ii) Increased targeting of design phases in policies.
- (iii) Extension of a sustainable design assessment system by allocating more points to a proven measure of waste performance.
- (iv) Increase the firmness of legislative steps by requiring the use of proven efficient waste design, procurement and construction.
- (v) Strict fiscal policy improvement by increasing penalties for poor waste performance.
- (vi) Strengthen policy requirements with enablers and facilitators.

### **3. Spain**

The waste management practices most frequently used in Spain's construction industry are on-site organization and cleanliness, proper raw material storage, and prioritization when selecting the most nearby licensed waste managers (Gangolells, et al. (2014)). The use of a mobile crusher on the job site, the creation of custom designs for each construction site, and the distribution of the waste management plan's contents to all employees are waste management methods that are frequently used to help workers comply with the plan's requirements.

### **4. Australia**

A number of states have "towards zero" waste strategy documents, including Victoria, South Australia, and Western Australia. The initiatives establish statewide goals for resource recovery, waste reduction, and littering. Before approving a development, many local types of council need waste management plans. Usually, they call for the builder or designer to make an educated guess as to the overall volume of waste generated by both demolition and new construction. Also, specify the disposal method, such as the recycler, the recycling facility, or the landfill location. It is frequently necessary to include waste storage facilities on the site during construction as well as a delivery or pickup schedule in the site plan.

A study in Australia's Alice Springs, a remote area, revealed that landfill dumping is the typical approach for managing construction waste (Crawford, et al. (2017)).

### **5. Hong Kong**

The research from Lu., & Tam (2013) demonstrated that Hong Kong's Construction Waste Management (CWM) policy used the 3R (reduce, reuse and recycle) and polluter pays concepts. The framework for establishing policy that is relevant and effectively used to handle CWM in Hong Kong. Waste management in Hong Kong often takes place in the construction processes by applying a number of efforts beginning with avoidance, minimization, recycling, treatment, and disposal. This is in accordance with the "reduce, reuse, and recycle (3R)" approach. Contractors must develop a waste management strategy with waste reduction targets and programs before beginning construction on site.

### **6. Malaysia**

In Malaysia, landfills are the primary method for disposing of construction waste. The 3R idea is rarely used by construction professionals to control construction waste (Sin, et al. (2012)). In reality, unlawful dumping is a common form of waste management in the Malaysian construction sector (Nagapan, et al. (2012)).

According to Rahim, et al. (2017), unlawful dumping activities in Malaysia were brought on by a variety of causes, including a lack of facilities for managing construction waste, a

lack of awareness and education, and an increase in the number of construction and restoration projects.

**7. Germany**

Within the larger German construction sector, the handling of construction and demolition waste is an established and well-integrated sub industry. German construction and demolition projects produced 214 Megatons of waste in 2002, which consisted primarily of excavated material (about two thirds), building and road demolition waste (about one third), and mixed construction site waste (a much smaller portion). Despite these large amounts, only 15% of these items were dumped in landfills; the remaining 85% were reuse and recycled (Zebau, et al. (2006)). The financial improvement, reusing, and recycling as much construction and demolition waste as feasible are favored by Germany's high material and waste disposal prices. Rules and regulations at all stages of government have long mandated the implementation of effective waste management systems in order to lessen the impact of construction and demolition debris on the waste stream.

**8. Nigeria**

According to Nathaniel, O.O., et al (2023) Construction and demolish waste in Nigeria in the last decade which remains a challenge attributable to factors like rapid urbanization, population growth, and economic development. And construction and demolish waste is still perceived and managed like municipal solid waste. The lack of policy, legislation, education and regulation leaves stakeholders with no option but to use their initiatives in dealing with the CDW leading most construction firms and contractors to employ unsustainable approaches like open dumping, burning, and landfilling even though sustainable CDWM practice of reusing, recycling, and compositing still exist.

**9. Thailand**

The research from Ektewan Manowong (2010), In Thailand a construction waste management practice is lack of motivation and encouragement in implementing 3R practice results in a high rate of landfilling and little presence of a market for recycled material. In addition, there is no specific law to deal with construction and demolish waste and the enforcement of related environmental law and regulation is ineffective.

Table 2.2: below summarizes the above research discussion of different countries that have practice of various waste management methods.

Table 2-2: Summary of waste management methods in different countries

Country	Waste Management methods
United States	According to Dajadian, S.A., & Koch, D.C. (2014). <ul style="list-style-type: none"> <li>• Having a subcontractor for waste management</li> <li>• Having a department of WM in the contractor company</li> </ul>

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

Country	Waste Management methods
United Kingdom	Study from Yedele, O., et al. (2014) and Ajayi, et al (2017). <ul style="list-style-type: none"> <li>• Waste disposed in landfill</li> <li>• Waste management laws and regulations</li> </ul>
Spain	According to Gangolells, et al. (2014). <ul style="list-style-type: none"> <li>• On-site organization and cleanliness</li> <li>• Proper raw material storage</li> <li>• Prioritization when selecting the most nearby licensed waste managers</li> </ul>
Australia	According to Crawford, et al. (2017). <ul style="list-style-type: none"> <li>• Resource recovery, waste reduction, and littering</li> <li>• Landfill dumping</li> </ul>
Hong Kong	Research from Lu., & Tam (2013). <ul style="list-style-type: none"> <li>• 3R principle - reduce, reuse, and recycle</li> <li>• Polluter pays principle</li> </ul>
Malaysia	Study from Sin, et al. (2012), Nagapan, et al. (2012) and Rahim, et al. (2017). <ul style="list-style-type: none"> <li>• Landfills of construction waste</li> <li>• The 3R idea is rarely used</li> <li>• Unlawful dumping by the reason of lack of facilities for managing construction waste, a lack of awareness and education, and an increase in the number of construction and restoration projects.</li> </ul>
Germany	According to Zebau, et al. (2006). <ul style="list-style-type: none"> <li>• Dumped in landfills</li> <li>• Reuse and recycled</li> <li>• Rules and regulations at all stages of government</li> </ul>
Nigeria	According to Nathaniel,O,O.et,al (2023). <ul style="list-style-type: none"> <li>• Managed like municipal solid waste</li> </ul>
Thailand	Research by Ektewan Manowong (2010). <ul style="list-style-type: none"> <li>• High rate of landfilling</li> <li>• Little presence of a market for recycled material</li> </ul>

The above table shows that different countries achieve construction waste reduction in different ways. Some nations take steps to reduce waste production, while others practice efficient management.

## **2.9. Waste Minimization Techniques**

Following a review of the literature, the techniques used in this study to reduce waste on prefabricated and on-site construction sites were categorized into seven main categories.

### **2.9.1. Prefabrication**

Prefabrication is a technique in construction that moves the majority of work from the project site to a distant factory or workshop (Shahzad. (2016)). Transported to the project site, the remotely manufactured modules or parts are put together there. Off-site manufacturing (OSM) and off-site construction (OFC) are other names for it (Cao, et al. (2015), Boafu, et al. (2016), Page., & Norman. (2014)).

The major components of waste materials are concrete, aggregate, sand, bricks, and blocks, and this is supported by several studies. The ratio, however, varies amongst the elements. There is a significant difference between the overall amount of waste produced by on-site projects and prefabricated projects, and this fact has been supported by numerous studies. Its use also has the potential to significantly alter site operations, reducing the number of trades and site activities and turning construction into a quick assembly of parts, which can have numerous positive effects on the environment, business, and society, including (Shen., Tam., & Drew. (2004), Andrew., & Richard. (2004)).

### **2.9.2. Lean Construction or Just-in-time Delivery Strategy**

This strategy differs from the typical method of material storage because less time is spent on site storing materials. This somewhat lessens the possibility that the materials will sustain damage as a result of improper handling. The materials are specifically requested and delivered as close as possible to the start of the work. As a result, there are fewer excess materials ready on site. Lean construction also guards against material deterioration brought on by site conditions. As materials won't be kept on the site for an extended period of time before being used in the project, long-term site storage is avoided (Badir, Y.F., & Hashim, A.H. (2002)). With this technique, the contractor and supplier have a strong and well-coordinated connection. But, before ordering supplies, careful consideration must be given to how long delivery processes would take. Together with effective communication, the estimator or contractor must justify the quantity to be ordered. Being able to anticipate the importance of acquiring goods also helps with project management. Over ordering can be avoided altogether by using appropriate estimation and ordering techniques.

### **2.9.3. Design Management**

Waste can be reduced when the designs are uniform and consistent during the design phase. In reality, design standardization is used to increase constructability and decrease the number of off-cuts. The manufacturing process will go more smoothly if a region of the building has a consistent design. Standardization is a more preferable solution in design because it has been shown to dramatically lower the amount of building waste currently produced (Begum, R.A., et al. (2007)).

### **2.9.4. Materials Management**

In order to supply construction products efficiently and effectively, there are various important management strategies. Among the most crucial are time management, plant and machinery management, materials management, and management of human resources. Cost management, quality control, risk mitigation, communication management, and procurement management are additional. In order to achieve optimal resource use and maximize profitability of construction costs throughout the construction production process, this section assesses material management approaches for reducing material waste and relates their significance.

On-site material management should work to minimize revenue loss from theft, damage, and wastage as well as stock outs (Kasim., Anumba., & Dainty. (2005)). Management of construction materials in building projects can also significantly increase project profit and save a lot of time (Zeb., Malik., Nauman., Hanif., & Amin. (2015)).

Effective materials management results in the following advantages:

- a) Less material delays
- b) Having the right resources available at the right time increase production.
- c) Having better inventory management results in lower interest rates, which lowers costs.

### **2.9.5. Develop Site Waste Minimization Plan (SWMP)**

Contractual clauses can assist control waste by enforcing poor waste performance because site management and contracts are closely coordinated, and create site waste minimization plan (SWMP).

SWMP is a simple list of requirements that informs the contractor (WRAP. 2007);

- To know the waste amount
- Conclusions must be taken in relation to the amounts of waste produced
- To provide strategic alternatives for recycling and reusing and
- The disposal options

Also, if a waste manager is in charge overall, the site waste management plan will typically be successful. The waste manager should have the following powers:

- Choice his waste crew
- Supervise, document, and provide response on everyday waste practices
- Give responsibility to sub-contractors and
- Work together with dealers, service firms and self-employed workers to avoid waste.

#### **2.9.6. Proper Material Storage and Handling**

Once the materials required for the project have been identified, work should begin on how they will be delivered to the site and kept. The site manager should provide adequate storage space in advance to prevent products from deteriorating or being damaged by moisture or the elements (Dennis. (2002)).

Top suggestions for materials storage on construction projects

- Setting aside separate storage spaces for plants, supplies, waste, and combustible items.
- Stored goods must not spread out uncontrollably on walks and other places.
- All storage areas, including those on the site itself, should be kept clean.
- Storage areas needed to be secure, weatherproof and safe.
- Excessive vegetation should be controlled.

Direct cost and time savings can be achieved by using the right tools for material handling and by planning ahead to reduce multiple handling. Material waste on the job site is decreased by careful handling of the materials. To minimize damage, this process will start with the supply of appropriate trucks or delivery facilities for moving materials from the storage area at the workplace. Also, avoid double handling by making the end position of the stacking area the points of unloading (Poon, et al., & Jaillon. (2004)).

#### **2.9.7. Develop Construction Waste Management Hierarchy**

They are the "3Rs," which stand for reduction, reuse, and recycling (Ayarkwa. (2007)).

##### **1. Reduction**

Source reduction, often known as waste reduction, refers to stopping the production of waste in the original place (Begum, et al. (2006)), and (Dennis. (2002)) the greatest chance to reduce waste production via preventative strategies is at,

- Design: By using low-waste building technologies and providing designs and specifications for prefabricated, recyclable, and other waste-reducing materials.
- Operations: The designer must clearly communicate with the project team in order to prevent wasteful mistakes and repeat.
- Procurement: Involving suppliers in the delivery of high-quality materials and establishing take-back arrangements for unnecessary material.

Reduction is the preferred action at the top of the grading for minimizing construction waste because it directly benefits the environment. Numerous design and construction site methods can drastically save waste and material costs with relatively minor procedural changes.

## **2. Reuse**

Reuse means taking something out of the waste stream and using it again for the same or a different purpose without affecting its shape or other characteristics. This comprises used materials and on-site scrap. Even more than recycling, reuse extends resource supply and lowers energy and pollution (Begum, et al. (2006)).

## **3. Recycling**

Recycling is the process of separating waste from the waste stream for later use and processing that material to create a finished good or a raw resource. Recycling waste is a crucial environmental management strategy for ensuring sustainable development, according to Ekanayake., & Ofori. (2000) since recycling frequently involves the change of materials through remanufacture, it generally needs more technical innovation than minimization strategies of reduction and reuse. Yet, recycling wastage without first conducting sound scientific research and development might lead to environmental issues that are worse than the problems caused by the waste itself (Begum, et al. (2006)). Figure 2-2: below shows that the above types of construction waste management hierarchy.

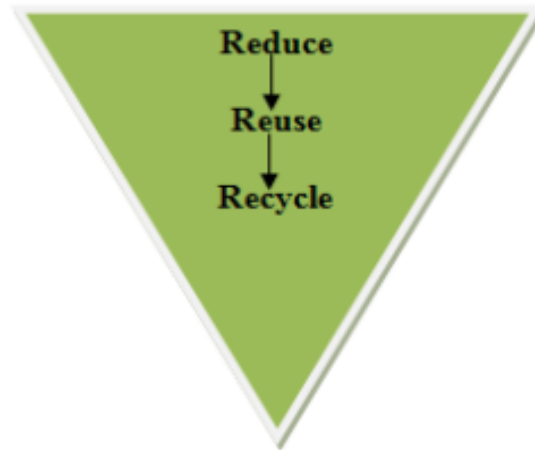


Figure 2-2: Construction Waste Management Hierarchy

Adopted from Waitakere City Councils, 2008.

### **2.10. Advantages of Construction Materials Waste Minimization**

Hence, it is essential to inform and educate contractors and other stakeholders on the advantages of waste minimization on construction projects and the cost-saving strategies that can be used for waste reduction, which can ultimately lead to greater profit margins

(Muhwezi, et al. (2012)). When waste management is successfully performed in accordance with the framework, it can produce a number of advantages over the course of the waste's whole lifecycle, from its generation to its final completion.

**a. Economic Advantage**

Intended for economic advantage, people in the construction business need to have an understanding into the cost ramifications of building waste. Significant savings could be gained by minimizing the quantity of building waste (Begum, et al. (2006)).

The economic advantage from waste minimization increased during either a short- or long-term timeframe. This economic advantage results from the following:

- Decreased raw material purchases due to waste avoidance.
- Lower waste material transportation expenses.
- Lower costs associated with wastage disposal.
- Decrease of delays, poor quality, and health and safety issues on construction sites.

**b. Environmental Advantage**

The environmental advantage is essential since it plays a significant part in enhancing the planet's atmosphere and protecting the environment for future generations. Due to the amount of material waste on building sites, waste minimization can have positive effects on the environment. The environmental advantage results from the following (Sagoe. (2011)).

- Reducing the amount of waste disposed at landfills
- Decreases the environmental effects of disposal, such as noise and pollution.
- When reused the material waste, decreasing its impact on the environment through less processing and reduces the need to extract raw resources.

**c. Image Enhancement**

The capacity to exhibit effective waste management may set one contractor apart from the rivals. Adopting waste management as a corporate policy may enable businesses to improve their public perceptions as environmentally friendly businesses, improving their clientele. A clear waste management policy that calls for efficient resource recovery and recycling could boost a contractor's image and provide them an advantage when they submit a bid for new projects (Narimah. (2008)).

**d. Increasing Output and Standard of Performance**

By minimizing delays brought on by having to restock and buy supplies that have already been wasted once, output can be increased. A considerable percentage of waste creation brought on by the replacement of poor-quality material during the life cycle of facilities can be prevented by choosing materials of high quality and durability.

**e. Other Benefits**

- Better resource management
- More effective work efficiency
- Increased job prospects

As was previously discussed, implementing waste management has many advantages. The construction industry can better understand the relationship between these benefits by looking at how various project parameters affect them.

**2.11. Gap Identification**

Despite the fact that numerous investigations were carried out locally and internationally to find the impact of material wastage on project cost. But in Ethiopia most of the research conduct on-site construction site not refers about prefabricated sites for the impact of material wastage. Ethiopian Construction Works Corporation are constructed both on-site and prefabricated building construction, there is no research conducted on this title and it needs to be conducted.

In Ethiopia prefabrication construction experience is very low and insufficient when compared with other countries and no research conduct about prefabrication and its material waste impact and a lack of information on construction waste quantities for some materials are the key gaps found in these studies. However, waste control requires thoughtful consideration and focus because the construction sector uses huge amount of construction material. This study intention was to fill the literature and practical gaps on impact of material wastage on project cost between prefabricated and on-site construction methods on Ethiopian construction works corporation projects. Table 2.3: below shows the summary of gap identification.

Table 2-3: Summary of gap identification

Source	Gap
Eskedar Girma (2016)	The research asses on material wastage impact only on-site construction projects not its impact on prefabricated construction projects.
Andualem., & Aklilu. (2019)	The researchers only study on source of material wastage not its impact on project cost.
Kibirt Bayou (2017)	The researcher study on precast construction in Ethiopia and compare to on-site construction method due to quality, resource, time and its initial cost and not including material wastage cost impact on project cost.

Source	Gap
Tam, V.W.Y. 2006, Jaillon, et al. (2009), Sin, T.J. (2013), Tam., & Hao. (2014) & Nurul Aini Osman. (2016	The researchers asses prefabricated construction project waste reduction level on timber formwork, concrete, plastering and pipe and cable work but not its impact on project cost separately on prefabricated and on-site construction projects.
Ameh., & Itodo. (2013), Saidu., & Shakantu. (2016c), Saidu., & Shakantu (2016a	The researchers study cost overrun in construction project due to material wastage not examine on prefabricated and on-site construction projects separately.

### **2.12. Literature Review Summary**

The literature review typically consists of ten sections, including definition, type, quantity and sources of material wastage, prefabrication experience and growth in Ethiopia, construction material wastage and project cost, waste management methods in different countries, waste minimization techniques, and advantage of material wastage minimization. These sections provide an in-depth review for the basic understanding of the research objective. This study compares the prefabricated and on-site construction methods to determine the inherent material waste associated with particular kinds of materials. All researchers concur that on-site construction building methods waste more materials than prefabricated methods as a result, which raises project costs. In order to identify the gap and present the key idea for this study, the literature review compares prefab and on-site construction methods and conducts a critical analysis of published literatures related to building material waste.

Numerous researches have shown that material waste has a significant impact on the financial success of construction initiatives. In addition, managing waste from construction materials can increase project profit and save a lot of time, whereas disposing of extra waste requires additional resources, which could delay the growth of construction.

Construction waste comes from a variety of sources during the entire implementation of a construction project as a result of one or a number of different reasons. So, to understand the reasons that contribute to material waste in construction projects, numerous studies have been conducted globally. This is due to the fact that it is necessary to identify the reasons of construction waste in order to decrease its volume. Therefore, companies in the construction industry can prevent unnecessary waste from being produced on construction sites by identifying the reasons. There are also numerous studies conducted on waste minimization techniques, such as prefabrication and waste minimization hierarchy, on construction projects.

So, required to carry out this research in order to adopt an acceptable construction waste minimization practice that will outline the procedures to close the knowledge gaps indicated above. In order to close this gap, from a literature review identified 9 main wastage minimization techniques, 5 sources and 27 subtitle potential reasons leading to construction material wastage, 4 main reasons and 31 subtitle potential reasons of material waste found in the causes of cost overruns at the pre- contract stages and on post-contract stages 3 main and 36 subtitle reasons of material waste and has been developed a questionnaire. After the questionnaire surveying and document analysis measuring material wastage impact on project cost of prefabricated and on-site construction building site in Ethiopian construction works corporation and finalized by conclusion and recommendation.

## **3. METHODOLOGY**

### **3.1. Introduction**

The research methodology justifies the procedures chosen to accomplish the goal of the study, which is stated at the outset. It also provides information about the research population, sample size, and data analysis technique.

### **3.2. Research Design**

According to Macmillan and Schumacher (2001) research design is a plan for selecting subjects, research sites, and data collection procedures to answer the research questions. The study started with secondary data collection through an extensive literature review from various sources comprising thesis paper, journals, and websites. After conducting a thorough assessment of the literature, a questionnaire survey was created and distributed to contractors and consultants to get their opinion based on their experience. Upon obtaining the desired data, checking and sorting of data has been done. The data were then analyzed for extracting the information obtained through the overall research work. This was followed by thorough discussions in order to draw a conclusion and to forward recommendations based on the findings of the study.

### **3.3. Data Collection Instrument**

Various evidences approach was used for data collection. These are questionnaire survey, on site observation and case study by evaluating different documents.

#### **✓ Questionnaire Design**

A questionnaire survey was selected as the research instrument due to its suitability to the level of information required, cost and time limitations and the high number of participants. The questionnaire form, which was accompanied by a covering letter, consisted four parts common question for both group of respondents.

The first part required overall data about the respondents and the second part, participants were asked the reasons of material waste on their specific sites. The respondents were requested to rank these reasons in order of importance. The rating values of 1, 2, 3, 4, and 5 were assigned to the options not a waste reason, insignificant waste reason, moderately a waste reason, significant waste reason and extremely a waste reason respectively in obtaining the respondents' perception of the reasons leading to construction material waste generation.

In the third part, participants were asked to the relation between the cause of material waste and project cost overruns. The respondents were requested to rate of influence for material waste generation and cost overrun. The rating values also 1, 2, 3, 4, and 5 were

assigned to the options very low influence, low influence, medium influence, high influence and very high influence respectively in obtaining the respondents' perception of material waste generation and cost overrun.

The fourth and last part of the questionnaire contained questions focused on waste management techniques. The respondent's assess their perception on how the techniques identified from literature contribute to materials waste management and the level of exercise of these techniques on their site.

For each waste management techniques, the respondents were asked to grade the level of exercise to waste management on a scale of 1 to 5 where 1= not exercise, 2= usually experienced, 3= experienced, 4= commonly experienced and 5= most commonly experienced.

✓ **On site observation**

Derbisa (2018) asserts by investigating and comprehending the background of the operations, researchers can build the comprehensive grasp of a topic by observing operations and activities. There are two types of observations this are direct observation and participant observation. In this research direct observation was used in which the observer watches rather than takes part in the activities focused. The observation can be so valuable that one may even consider taking photograph at the site. Also, observations made on site have helped me to see the actual condition on the site and is used to countercheck the reliability of the questionnaire response.

✓ **Case study analysis**

Case study research design usually involves qualitative method and good for describing, comparing, evaluating and understanding different aspects of a research problem. In this study using document analysis for case study research designs. Document analysis is a systematic procedure for reviewing and evaluating documents by printed or electronic (softcopy) materials. Like other analytical methods in qualitative research, document analysis requires that data be examined and interpreted in order to elicit meaning, gain understanding and develop empirical knowledge (Corbin & Strauss. (2008). The data of the case study gathered from quantity of actual building work as well as the payment and material requesting form of contractor. The analysis of the data from these documents carried out mainly to obtain the approximate percentage of material wastage.

### **3.4. Research Population and Sampling**

The construction sites selected for this study are ECWC construction sites. Currently this company constructs both type of construction methods prefabricated and on-site building construction. 10 on-site building construction and 3 prefab building project sites are selected for this study. These sites are selected because they are all the projects are being executed by ECWC building construction sector and currently the sites are on progress

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

and still active projects. From on-site construction building projects there are a total of 43 blocks from G+2 to 4B+G+21 and from prefab building projects a total of 27 G+4 blocks are included. This selected site compares due to using the same material from both site, there is no any design complexity and for wastage calculation using the same building story and also both sites are work by the same working methodology.

Construction supervision consultants and contractors make up the target group for the data collection using the questionnaires. The professionals that are directly involved in the construction process are included in this study. Project managers, site team leaders, office team leaders, site engineers, and office engineers are among the experts employed by the contractor. On the side of the construction supervisors, resident engineers and site supervisors are also employed. Table 3-1 below shows that the population data analyze for sample selection.

Table 3-1: Analyze population data

<b>No.</b>	<b>Project name</b>	<b>Total No. of block</b>
<b>1</b>	<b>Prefabricated construction</b>	
1.1	Apartment of addis ketema sub city woreda 06 paulos site	1
1.2	Housing development projects to Akaki kaliti sub city woreda 05 (LOT-1)	10
1.3	Housing development projects to Akaki kaliti sub city woreda 05 (LOT-2)	16
	<b>Total No.</b>	<b>27</b>
<b>2</b>	<b>On-site construction</b>	
2.1	Federal document authentication and registration agency	1
2.2	Kolfe keraniyo hospital phase 1	7
2.3	Kolfe keraniyo hospital phase 2	7
2.4	Nifas silk hospital phase 1	10
2.5	Nifas silk hospital phase 2	7
2.6	Akaki Public service project and Ethio engineering maintenance building	4
2.7	Jemo Public service project	2
2.8	Gulele Public service project	2
2.9	Yeka Public service project	2
2.10	Kolfe keraniyo health center building project	1
	<b>Total No.</b>	<b>43</b>

From this the above selected project sites 260 professionals from contractors and 25 professionals from consultant sides participate on the project for office and site

engineering works and total populations are 285 participated in the questionnaire sample size calculation.

The following Taro Yemane sampling formula (Yemane, 1967) is used to calculate the sampling size for the questionnaire.

Yamane's formula

$$n = \frac{N}{1+N(e)^2} \dots\dots\dots [Eq. 3.1]$$

Where: n = Sample size.  
N= Population size.  
e= Level of precision (+/-5%).  
n = 285 / (1+285\*0.0025)  
=166.4=167

Therefore, depending on the proportionate population size of the respondent on the project, 167 questionnaires were issued to the respondents.

### **3.5. Data Analysis Method**

The analysis was performed using Microsoft Excel for questionnaire survey and case study analysis, and for site observation analyzed by using direct on site observation and construction site observation checklist and the respondents' answers to each question as well as the consultants' and contractors' professionals' responses were entered. Consequently, the responses from consultants and contractor's questionnaires were subjected to statistical analysis for further insight. The following statistical techniques which are grouped under various headings were then employed to analyze the data collected from the survey.

Whereas the contribution of each of the source of material waste, the relationship between material waste and project cost overruns and management techniques 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 weight (RW).

Calculate by using the following equation.

$$RW = \frac{\sum (f \times S)}{N} \dots\dots\dots [Eq. 3.2]$$

Where: RW = Relative weight.  
f = Frequency of response for each score.  
S= Score given to each causes/strategy (1to 5).  
N= Total number of responses for each causes/ measure.

In order to determine the difference in perception of the consultant and contractors, there was also need to further ascertain if consultant perceptions were statically different from the contractor’s perception. This leads to use of Spearman rank correlation coefficient test; it has an advantage of monotonic association and homogeneity of variances.

$$Rho (r_s) = 1 - \frac{6 \sum d_i^2}{(n^3 - n)} \dots\dots\dots [Eq. 3.3]$$

Where  $r_s$  = strength of the rank correlation between variables.  
 $d_i$  = the difference between the x-variable rank and the y-variable rank for each pair of data.

$\sum d_i^2$  = sum of the squared differences between x- and y-variable ranks, and  $n$  = sample size.

### **3.6. Research Reliability**

The Cronbach alpha coefficient is used to determine the consistency or reliability of data collected through surveys.

Calculate by using the following equation.

$$\alpha = \frac{K}{K-1} (1 - \frac{\sum \sigma_i^2}{\sigma_t^2}) \dots\dots\dots [Eq. 3.4]$$

Where  $\alpha$  = Cronbach alpha  
 $K$  = Total number of questions  
 $\sum \sigma_i^2$  = Sum of variance of a questions  
 $\sigma_t^2$  = Variance for the total scores

## **4. RESULTS AND DISCUSSION OF THE STUDY**

### **4.1. Introduction**

The findings of this study are presented in this chapter. Table, graphic, and text formats are used to define the quantitative study findings. However, each finding was only briefly reviewed; specific outcomes were then followed by a more thorough explanation. Also, questionnaires for contractors and consultant were provided. While the study sought to conduct an exhaustive research examination, the questionnaires for both groups of respondents had four sections and discuss about the source of material waste, the relationship between material waste and project cost overruns and management techniques for each of the selected materials was examined.

### **4.2. Reliability test**

The reliability study using Cronbach alpha was done to make sure the questions were internally consistent. The Cronbach alpha coefficients minimum level of reliability is 0.7, and any result below this level denotes that the variables are inconsistent and unreliable (Fellows &Liu. (2007)). Table 4-1 below, shows that the reliability statistics of the questionnaire answers.

Table 4-1: Reliability statistics

<b>No.</b>	<b>Section</b>	<b>Cronbach alpha</b>	<b>No. of items</b>
1	Two	0.846	27
2	Three	0.733	67
3	Four	0.726	9

As shown from the above result there is internal consistency between the item and the Cronbach alpha value on section two is good and section three and four is acceptable.

### **4.3. Questionnaire survey response rate**

One hundred sixty-seven questionnaires were given in total for this study, however only one hundred four were returned with responses. Four of the returned questionnaires were excluded for analysis because the answers too many of the questions were not complete. As may be seen in Table 4-2 below, the respondent returned, failed, and analyzed questionnaires.

Table 4-2: Percentage of respondents to the survey

No.	Respondent	Delivered Questionnaire		Returned Questionnaire		Failed Questionnaire		Analyzed Questionnaire	
		no.	%	no.	%	no.	%	no.	%
1	Consultant	17	10.18	17	10.18			17	10.18
2	Contractor (ECWC)	150	89.82	91	54.49	4	2.4	87	52.1
		167	100	108	64.67	4	2.4	104	62.28

#### 4.4. Explanation of Respondents

##### 4.4.1. Position of Respondents on the Site

Table 4-2 displays the respondents' positions for both consultants and contractors. 3.85% of project managers, 24.04% of project team leaders, 26.92% of office engineers, and 28.85% of site engineers for both prefabricated and on-site construction projects were identified from the contractor (ECWC) data that was returned. Similarly, on the consultant's side, there were 5.77% resident engineers and 10.57% site supervisors. So, rather than any other individual, all responses are the body responsible for the building practice in their project. They must therefore provide accurate information. Table 4-3 below, shows that the position of respondent on the site from contractor and consultant.

Table 4-3: Position of respondents on the site

Respondent	Position on the site						Total
	Contractor				Consultant		
	Project Manager	Project Team Leader	Office Engineer	Site Engineer	Resident Engineer	Site Supervisor	
No.	4	25	28	30	6	11	104
Percentage (%)	3.85	24.04	26.92	28.85	5.77	10.57	100

##### 4.4.2. Background in Education of Respondents

The results of respondent's education background shows that the site staffs were qualified to provide accurate information by comprehending each of the questionnaire's questions about the causes of material waste on the site, the impact of material waste on project costs, and site waste minimization techniques. Table 4-4 below, shows that the respondents educational background.

Table 4-4: The respondents' educational background

Educational Background	Contractor		Consultant		Total	
	no.	(%)	no.	(%)	no.	(%)
MSC.	17	19.54	8	47.06	25	24.04
BSC.	69	79.31	9	52.94	78	75
Diploma	1	1.15			1	0.96
Total	87	100	17	100	104	100

#### 4.4.3. Work Experience of the Respondents

From the returned questioner the maximum years of respondent experience in the construction industry is between 5-10 years, whereas in the prefabricated building construction is 3-5 years. In Table 4-5 below, the respondents experience in year.

Table 4-5: The respondents' work experience

Experience in years		Contractor	Consultant	Total
		no.	no.	no.
Experience in the construction industry	<1			
	1-3	4		4
	3-5	9	3	12
	5-10	46	5	51
	10-15	3	6	9
	15-20	2		2
	>20			
Experience in the prefabrication construction site	<1	5		5
	1-3	5	3	8
	3-5	12		12
	5-10	1		1
	10-15			
	15-20			
	>20			
	There is no experience			

#### **4.5. Reasons of Material Wastage in ECWC Prefabricated and On-site Construction Sites**

This section presents and discusses the findings of the questionnaire survey and site observation data regarding the reasons of material waste. This provides a good indication of the actions that should be concentrated on for each item to decrease waste.

27 reasons of materials waste in construction were taken into account by the questionnaire for this study, and those reasons were divided into the five sources of design, procurement, material handling, construction phase, and others. Questionnaires were created to assess respondents' contributions to the development of specific material waste at the sites. The statistics for the top five waste sources and their reasons are presented and examined for each item in this study's survey. The reasons that fall into each category and have a relative mean value of 3.0 or above are considered to be waste-reasoning variables since they have a considerable impact on waste formation. Excel was used to analyze the respondent's responses for correlation using Spearman rank correlation coefficients to determine whether there were any differences in the rankings between two groups of respondents and also calculate the reliability of the data by using Cronbach alpha coefficient.

As a consequence, the result showed the material except mortar and HCB the significant difference at the 5% significance level when the consultants and contractors' responses on the reasons of waste in the studied materials were compared. Table 4-6 below, shows that the strength of the rank correlation values analysis for reasons of material wastage.

Table 4-6: Strength of the rank correlation values for material wastage

<b>Wastage Material</b>	<b><math>r_s</math></b>	<b>p value</b>
Concrete waste	0.80	0.106
Mortar waste	0.95	0.014
Reinforcement bar waste	0.32	0.601
HCB waste	0.99	0.001
Form work waste	0.86	0.064

##### **4.5.1. Reasons of Concrete Wastage**

The statistics are given individually since there was a significant difference between the contractors' and consultants' replies on the source of concrete wastage at the 5% significance level.

##### **a. Main sources of Waste**

Table 4-7 shows below, the relative importance and rank for main sources of concrete by the two respondents.

Table 4-7: Main source of concrete waste relative importance and rank

Sources	Consultant		Contractor	
	RW	Rank	RW	Rank
Design phase	2.99	4	2.38	3
Procurement	1.82	5	2.35	4
Material handling	4.89	1	3.56	1
Construction phase	4.03	2	3.09	2
Others (weather and theft)	3.58	3	2.22	5

According to consultants, material handling, the construction phase, and other factors are the top three sources of waste. Whereas, according to the contractors, the generation of concrete waste on the sites is significantly influenced by material handling, the construction phase, and designs. The findings indicate that the first and second sources of waste are the same in the opinions of both groups of respondents, although professionals from the contractor attribute the third source of waste to the designs. But consultants put other sources next to at the third. In the research here is the third variance in this response is due to the resultant impact, which is directly tied to who is at fault.

**b. The Extent to which Waste Reasons Contribute to the Concrete Waste**

From the perspective of the two respondents, the rank of each concrete waste reasons are shown in Tables 4-8 and 4-9.

Table 4-8: Reasons of concrete waste and their relative importance - opinion of contractors

Reasons	Source	RW	Rank
Modifications made to the design while work is still being done	Design	4.93	1
Lack of onsite material control	Construction phase	4.90	2
Equipment malfunctioning	Construction phase	4.83	3
Material damage resulting from storage and handling	Material handling	4.70	4
Poor coordination among project participant	Construction phase	4.34	5
Damages during transportation	Material handling	4.12	6
Unfriendly attitudes of project team and laborers	Material handling	3.60	7
Chiseling and rework	Construction phase	3.46	8
Consuming an extreme amount of materials than required	Construction phase	3.41	9
Use of any material nearby the work area	Material handling	3.31	10
Inexperience of designers with building sequence and methods	Design	3.06	11
Purchased products that don't meet the specification	Procurement phase	3.01	12

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

Table 4-9: Reasons of concrete waste and their relative importance - opinion of consultants

Reasons	Source	RW	Rank
Unfriendly attitudes of project team and laborers	Material handling	5.00	1
Damages during transportation	Material handling	5.00	1
Supplies provided in loose form	Material handling	5.00	1
Material damage resulting from storage and handling	Material handling	5.00	1
Equipment malfunctioning	Construction phase	5.00	1
Lack of onsite material control	Construction phase	5.00	1
Chiseling and rework	Construction phase	5.00	1
Required quantity unclear due to improper planning	Construction phase	4.77	8
Use of any material nearby the work area	Material handling	4.46	9
Accidents due to negligence	Construction phase	4.15	10
Consuming an extreme amount of materials than required	Construction phase	4.08	11
Poor coordination among project participant	Construction phase	3.92	12
Weather condition	Others	3.69	13
Error in contract document	Design	3.62	14
Theft	Others	3.46	15
Errors by trades men or operatives	Construction phase	3.31	16
Selection of the material's type and dimensions without considering wastage	Design	3.23	17
Disregard for the product's dimensional coordination	Design	3.00	19
Modifications made to the design while work is still being done	Design	3.00	19

The contractors and consultants believe that 12 and 19, respectively, out of the 27 reasons, contributed to the development of concrete waste on their sites. According to the contractors, modifications made to the design while work is still being done, lack of onsite material control and equipment malfunctioning are the top three waste reasons extent and according to the consultant unfriendly attitudes of project team and laborers, damage during transportation, supplies provided in loose form, material damage resulting from storage and handling, equipment malfunctioning, lack of onsite material controls and chiseling and rework are the top one issues. This suggests are play a substantial role in the production of concrete waste and some of these criteria were also present on the sites when the researcher visited them.

Figure 4-1 and 4-2 below shows damaged prefabricated concrete structure due to transportation, lack of onsite material control and storage and handling of material and bulged shear wall and segregated column structure in on-site construction sites due to

equipment malfunctioning and unfriendly attitudes of project team and laborers and thus results an extra use of material and additional work like chiseling.



Figure 4-1: Damaged prefabricated concrete structure



Figure 4-2: Bulged shear wall and segregated column structure in on-site construction site

**4.5.2. Reasons of Mortar Wastage**

Since there were no statistically significant variations between contractors' and consultants' responses at the 5% level of significance when comparing the ranks of all sources of mortar waste, the summarized result of the two groups of respondents are presented as a whole.

**a. Main sources of Waste**

In Table 4-10 below, the relative importance and respondents' response rankings are shown for each source of mortar waste.

Table 4-10: Main source of mortar waste relative importance and rank

Source	Consultant		Contractor	
	RW	Rank	RW	Rank
Design phase	2.54	4	2.44	4
Procurement	1.85	5	2.06	5
Material handling	4.74	1	4.03	1
Construction phase	3.85	2	3.38	2
Others	3.50	3	2.60	3

According to the survey results, material handling accounts for the majority of the two respondents' mortar wastage, with a relative mean of 4.74 and 4.03 from consultant and contractor respectively, and procurement accounts for the least amount.

**b. The Extent to which Waste Reasons Contribute to the Mortar Waste**

From the perspectives of respondents, the rank of each reason of mortar waste are shown in Tables 4-11 and 4-12.

Table 4-11: Reasons of Mortar waste and their relative importance - opinion of contractors

Reasons	Source	RW	Rank
Modifications made to the design while work is still being done	Design	4.95	1
Lack of onsite material control	Construction phase	4.88	2
Material damage resulting from storage and handling	Material handling	4.67	3
Poor coordination among project participant	Construction phase	4.48	4
Chiseling and rework	Construction phase	4.31	5
Consuming an extreme amount of materials than required	Construction phase	4.31	5
Damages during transportation	Material handling	4.13	7

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

Reasons	Source	RW	Rank
Unfriendly attitudes of project team and laborers	Material handling	4.08	8
Equipment malfunctioning	Construction phase	3.99	9
Use of any material nearby the work area	Material handling	3.71	10
Supplies provided in loose form	Material handling	3.57	11
Disregard for the product's dimensional coordination	Design	3.10	12
Weather condition	Other	3.10	12

Table 4-12: Reasons of Mortar waste and their relative importance - opinion of consultants

Reasons	Source	RW	Rank
Modifications made to the design while work is still being done	Design	5.00	1
Unfriendly attitudes of project team and laborers	Material handling	5.00	1
Damages during transportation	Material handling	5.00	1
Supplies provided in loose form	Material handling	5.00	1
Material damage resulting from storage and handling	Material handling	5.00	1
Lack of onsite material control	Construction phase	5.00	1
Poor coordination among project participant	Construction phase	5.00	1
Chiseling and rework	Construction phase	5.00	1
Consuming an extreme amount of materials than required	Construction phase	5.00	1
Weather condition	Other	4.23	10
Accidents due to negligence	Construction phase	3.92	11
Use of any material nearby the work area	Material handling	3.69	12
Required quantity unclear due to improper planning	Construction phase	3.31	13
Use of incorrect material, thus requiring replacement	Construction phase	3.08	14

Out of the 27 reasons identified on the abovementioned survey data, 14 are thought to have contribution to the development of mortar waste as per the opinion of contractors' and consultants. Modifications made to the design while work is still being done, lack of onsite material control, material damage resulting from storage and handling are the top three reasons in the opinion of contractor and the consultants agree with contractors in this regard. Furthermore, consultant's additional main reasons like unfriendly attitudes of project team and laborers, damages during transportation, supplies provided in loose form, poor coordination among project participant, chiseling and rework and consuming an extreme amount of materials than required.

Figure 4-3 below shows mortar waste due to plastering work cover above the dimension and improper way of work due to lack of onsite material control and consuming an extreme amount of materials than required. This problem results from inadequate supervision and insufficient material management of the contractor.



Figure 4-3: Plastering work covering above the dimension and improper way of work

**4.5.3. Reasons Reinforcement Bar Wastage**

The results of the Spearman's rank correlation coefficient test indicated that there were differences between the responses of the two groups of respondents on the source of reinforcement bar waste, hence all the statistics are provided here separately.

**a. Main sources of Waste**

Table 4-13 below shows the relative importance and respondents' response rankings for each source of wasteful production of reinforcement bars.

Table 4-13: Main source of reinforcement bar waste relative importance and rank

Source	Consultant		Contractor	
	RW	Rank	RW	Rank
Design phase	3.07	5	3.42	2
Procurement	4.90	1	3.46	1
Material handling	4.26	2	2.98	4
Construction phase	3.61	3	3.28	3
Others	3.19	4	2.92	5

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

According to consultants, material handling, construction phase, and procurement are the top three sources of waste producers. While the construction phase, design, and procurement all play a significant role in the production of reinforcing waste on the site, according to the contractors. The findings reveal that both groups of respondents agree on the first and third sources of waste, but the contractor also attributes responsibility for the waste to the designs.

**b. The Extent to which Waste Reasons Contribute to the Reinforcement bar Waste**

From the perspective of the respondents, the rank of each reinforcement bar waste reasons are shown in Tables 4-14 and 4-15.

Table 4-14: Reasons of reinforcement bar waste and their relative importance - opinion of contractors

Reasons	Source	RW	Rank
Selection of the material's type and dimensions without considering wastage	Design	5	1
Modifications made to the design while work is still being done	Design	4.88	2
Lack of onsite material control	Construction phase	4.84	3
Purchased products that don't meet the specification	Procurement	4.83	4
Material damage resulting from storage and handling	Material handling	4.69	5
Consuming an extreme amount of materials than required	Construction phase	4.55	6
Poor coordination among project participant	Construction phase	4.51	7
Supplies provided in loose form	Material handling	4.47	8
Ordering error	Procurement	4.29	9
Disregard for the product's dimensional coordination	Design	3.39	10
Error in contract document	Design	3.35	11
Theft	Other	3.25	12
Lack of consideration for the available standard sizes	Design	3.07	13

Table 4-15: Reasons of reinforcement bar waste and their relative importance - opinion of consultants

Reasons	Source	RW	Rank
Ordering error	Procurement	5	1
Purchased products that don't meet the specification	Procurement	5	1
Material damage resulting from storage and handling	Material handling	5	1
Unfriendly attitudes of project team and laborers	Material handling	4.99	2

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

<b>Reasons</b>	<b>Source</b>	<b>RW</b>	<b>Rank</b>
Supplies provided in loose form	Material handling	4.93	3
Errors by trades men or operatives	Construction phase	4.88	4
Lack of onsite material control	Construction phase	4.86	5
Poor coordination among project participant	Construction phase	4.83	6
Chiseling and rework	Construction phase	4.77	7
Consuming an extreme amount of materials than required	Construction phase	4.77	7
Theft	Other	4.77	7
Selection of the material's type and dimensions without considering wastage	Design	4.77	7
Modifications made to the design while work is still being done is in progress	Design	4.69	8
Lack of trades skill	Procurement	4.69	8
Use of any material nearby the work area	Material handling	3.85	9
Designers' unfamiliarity with alternative products	Design	3.46	10
Lack of consideration for the available standard sizes	Design	3.31	11
Uncertain required quantity as a result of poor planning	Construction phase	3.15	12

The first ranked, according to the contractor response, selection of the material's type and dimensions without considering wastage; this clarifies conversion waste from cutting reinforcement bars into unfeasible shapes as the major reasons of this material waste. Modifications made to the design while work is still being done ranked second, these issues occur when a client has a last-minute request, and necessitating the usage of a different type of bar during construction. From the consultant response, ordering more or less material, purchased products that don't meet the specification and material damage resulting from storage and handling are the top one reason.

Figure 4-4 below shows reinforcement bar wastage and rusting due to improper stockpiling. During the site visit it was typical to see reinforcing bars that were cut into useless pieces. This indicates the dimension of re-bar consideration without waste during design preparation and there is a lack of cut-off schedule at the project site.



Figure 4-4: Improper put and unusable quantity of re-bar

**4.5.4. Reasons of Hollow Concrete Block Wastage**

The results of comparing the respondents’ responses to the question of where the waste from hollow concrete blocks was coming from did not reveal any significant differences at the 5% level of significance.

**a. Main sources of Waste**

The relative importance and respondents' response rankings for each of the sources of HCB waste are shown below in Table 4-16.

Table 4-16: Main source of HCB waste relative importance and rank

Source	Consultant		Contractor	
	RW	Rank	RW	Rank
Design phase	2.54	4	2.85	4
Procurement	3.54	3	3.46	3
Material handling	4.71	1	3.95	1
Construction phase	4.00	2	3.54	2
Others	2.15	5	2.70	5

According to survey results, material handling accounts for the majority of HCB waste from the two respondents, with a relative mean of 4.71 from consultant and 3.95 from contractor, and other reasons account for the least amount of waste.

**b. The Extent to which Waste Reasons Contribute to the HCB waste**

From the respondents' perspectives, the rank of each reason of HCB waste are shown in Tables 4-17 and 4-18.

Table 4-17: Reasons of HCB waste and their relative importance - opinion of contractors

<b>Reasons</b>	<b>Source</b>	<b>RW</b>	<b>Rank</b>
Modifications made to the design while work is still being done	Design	4.96	1
Damages during transportation	Material handling	4.87	2
Lack of onsite material control	Construction phase	4.84	3
Purchased products that don't meet the specification	Procurement	4.83	4
Chiseling and rework	Construction phase	4.55	5
Consuming an extreme amount of materials than required	Construction phase	4.55	5
Poor coordination among project participant	Construction phase	4.51	7
Supplies provided in loose form	Material handling	4.42	8
Ordering more or less material	Procurement	4.29	9
Use of any material nearby the work area	Material handling	4.27	10
Material damage resulting from storage and handling	Material handling	4.27	10
Inexperience of designers with building sequence and methods	Design	4.08	12
Equipment malfunctioning	Construction phase	3.87	13
Disregard for the product's dimensional coordination	Design	3.39	14

Table 4-18: Reasons of HCB waste and their relative importance - opinion of consultant

<b>Reasons</b>	<b>Source</b>	<b>RW</b>	<b>Rank</b>
Material damage resulting from storage and handling	Material handling	5.00	1
Errors by trades men or operatives	Construction phase	5.00	1
Modifications made to the design while work is still being done	Design	4.92	3
Use of incorrect material, thus requiring replacement	Construction phase	4.92	3
Lack of onsite material control	Construction phase	4.92	3
Poor coordination among project participant	Construction phase	4.92	3
Chiseling and rework	Construction phase	4.92	3
Damages during transportation	Material handling	4.85	8
Supplies provided in loose form	Material handling	4.85	8
Damage to work done caused by consequent trades	Construction phase	4.85	8
Purchased products that don't meet the specification	Procurement	4.77	11

Reasons	Source	RW	Rank
Unfriendly attitudes of project team and laborers	Material handling	4.54	12
Ordering errors (e.g., ordering significantly more or less)	Procurement	4.54	12
Use of any material nearby the work area	Material handling	4.31	14
Uncertain required quantity as a result of poor planning	Construction phase	4.23	15
Accidents due to negligence	Construction phase	3.54	16
Inexperience of designers with building sequence and methods	Design	3.15	18
Lack of consideration for the available standard sizes	Design	3.31	17

The top three reasons of HCB wastage, according to the contractors are modifications made to the design while work is still being done, damages during transportation, and lack of onsite material control and from the consultant response, material damage resulting from storage and handling and errors by trades men or operatives are the top one reasons.

Figure 4-5 below shows HCB damage of material due to storage and handling of material and lack of onsite material control.



Figure 4-5: Inappropriate storing of HCB

#### **4.5.5. Reasons of Form work Wastage**

The outcomes demonstrated a significant difference at the 5% significance level when the replies of the contractors and consultants were compared regarding the source and reasons of form work waste.

**a. Main sources of Waste**

The relative importance and respondents' response rankings are shown in Table 4-19 below for each source that results in form work wastes.

Table 4-19: Main source of formwork waste relative importance and rank

Cause	Consultant		Contractor	
	RW	Rank	RW	Rank
Design phase	2.89	5	3.00	4
Procurement	3.97	1	3.47	2
Material handling	3.29	3	3.18	3
Construction phase	3.71	2	3.61	1
Others	3.04	4	2.70	5

According to survey data, the main sources of formwork waste for consultant respondents are procurement, while for contractor respondents, the main sources are construction phase.

**b. The Extent to which Waste reasons Contribute to the form work waste**

From the perspective of the respondents, the rank of each reason of the form work waste are shown in Tables 4-20 and 4-21.

Table 4-20: Reasons of formwork waste and their relative importance - opinion of contractors

Reasons	Source	RW	Rank
Modifications made to the design while work is still being done	Design	4.96	1
Chiseling and rework	Construction phase	4.87	2
Consuming an extreme amount of materials than required	Construction phase	4.86	3
Lack of onsite material control	Material handling	4.86	3
Unfriendly attitudes of project team and laborers	Construction phase	4.84	5
Ordering more or less material	Procurement	4.66	6
Poor coordination among project participant	Construction phase	4.50	7
Supplies provided in loose form	Material handling	4.43	8
Selection of the material's type and dimensions without considering wastage	Design	4.40	9
Equipment malfunctioning	Construction phase	3.89	10
Purchased products that don't meet the specification	Procurement	3.57	11
Disregard for the product's dimensional coordination	Design	3.06	12
Damage to work done caused by consequent trades	Construction phase	3.02	13

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

Table 4-21: Reasons of formwork waste and their relative importance - opinion of consultants

Reasons	Source	RW	Rank
Modifications made to the design while work is still being done	Design	5	1
Selection of the material's type and dimensions without considering wastage	Design	5	1
Lack of trades skill	Procurement	5	1
Ordering more or less material	Procurement	5	1
Supplies provided in loose form	Material handling	5	1
Lack of onsite material control	Construction phase	5	1
Chiseling and rework	Construction phase	5	1
Consuming an extreme amount of materials than required	Construction phase	5	1
Uncertain required quantity as a result of poor planning	Construction phase	4.77	9
Injury of material due to stockpiling and material handling	Material handling	3.9	10
Unfriendly attitudes of project team and laborers	Material handling	3.77	11
Poor coordination among project participant	Construction phase	3.77	11
Equipment malfunctioning	Construction phase	3.54	13
Weather condition	Other	3.15	14

Modifications made to the design while work is still being done, rework, consuming an extreme amount of materials than required and lack of onsite material control are the top three reasons of formwork according to the contractors and according to the consultant modifications made to the design while work is still being done, selection of the material's type and dimensions without considering wastage, lack of trades skill, ordering more or less material, supplies provided in loose form, lack of onsite material control, rework and consuming an extreme amount of materials than required are the top reasons.

Figure 4-6 and 4-7 below shows not using timber formwork on prefabricated site only using by bracing and using excessive quantity of timber formwork in on-site construction site and lack of onsite material control compare to prefabricated site.



Figure 4-6: Not timber formwork used in prefabricated site



Figure 4-7: High amount of timber formwork used in on-site construction site

#### **4.6. Relationship between the Material Waste and Project Cost Overruns**

This section presents the findings of the questionnaire survey regarding the project cost overrun due to material wastage. The survey's findings show the rate of contribution on material wastage and project cost on pre and post construction stage.

Table 4-22: Pre-contract stage of project rate of contribution for material waste generation

Cause	Consultant		Contractor	
	RW	Rank	RW	Rank
The quality of planning	3.03	4	3.00	4
The quality of design management	3.97	2	4.12	2
The complexity of design	4.33	1	4.36	1
The quality of estimating	3.83	3	3.83	3

According to the survey results in the above table 4-22, from both respondents, the complexity of design, the quality of design management and the quality of estimating are the top three causes of material wastage contribution on pre contract stage.

Table 4-23: Pre-contract stage of project rate of contribution for project cost overrun

Cause	Consultant		Contractor	
	RW	Rank	RW	Rank
The quality of planning	3.03	4	3.06	4
The quality of design management	3.97	3	4.02	3
The complexity of design	4.33	1	4.35	1
The quality of estimating	4.11	2	4.13	2

According to the survey results in the above table 4-23, from both respondents, the complexity of design, the quality of estimating and quality of design management are the top three of causes of affect project cost overrun on pre contract stage.

Figure 4-8 below, shows the above table 4-22 and 4-23 of surveying result supported by graphical description directly affecting material wastage and project cost on the pre contract stage.

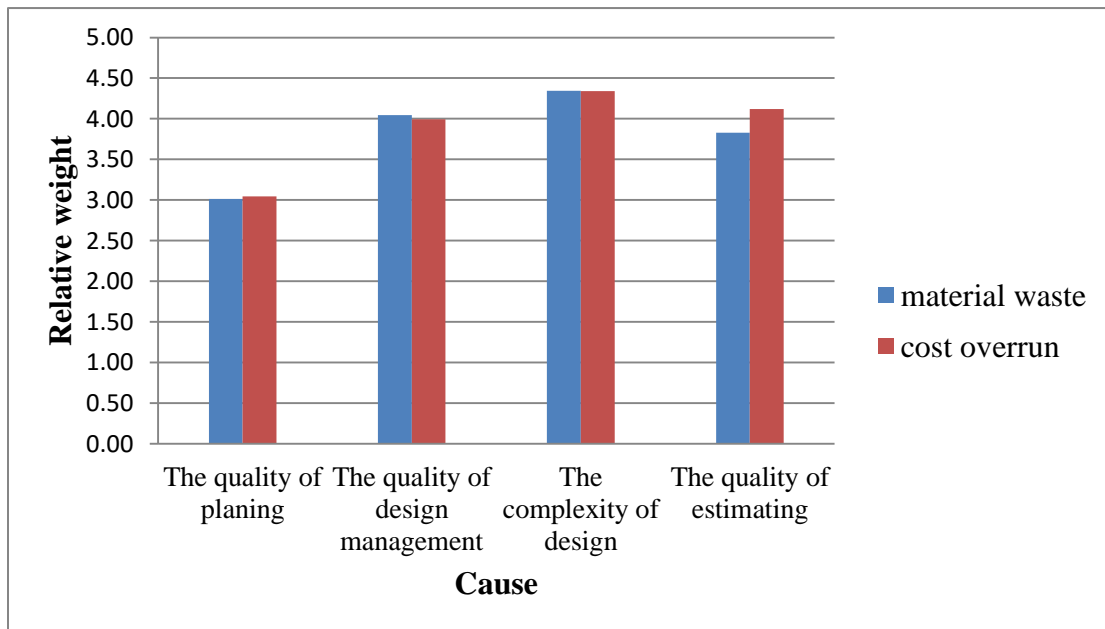


Figure 4-8: Graphical description between material wastage and project cost on pre contract stage from both respondents

Table 4-24: post-contract stage of project level of contribution for material waste generation

Cause	Consultant		Contractor	
	RW	Rank	RW	Rank
Procurement management quality	2.64	3	2.81	3
The standard of construction management	4.11	1	4.16	1
The quality of site management	3.87	2	3.96	2

According to the survey results in the above table 4-24, from both respondents, the standard of construction management is the first causes of material waste contribution on post contract stage.

Table 4-25: post-contract stage of project level of contribution for project cost overrun

Cause	Consultant		Contractor	
	RW	Rank	RW	Rank
Procurement management quality	2.64	3	3.46	3
The standard of construction management	4.12	1	4.18	2
The quality of site management	4.10	2	4.21	1

According to the survey results in the above table 4-25, the standard of construction management and the quality of site management are the first causes of project cost overrun on post contract stage from consultant and contractor response respectively.

Figure 4-9 and 4-10 below, shows the above table 4-24 and 4-25 of surveying data conclude by graphical description directly affecting material wastage and project cost on the post contract stage.

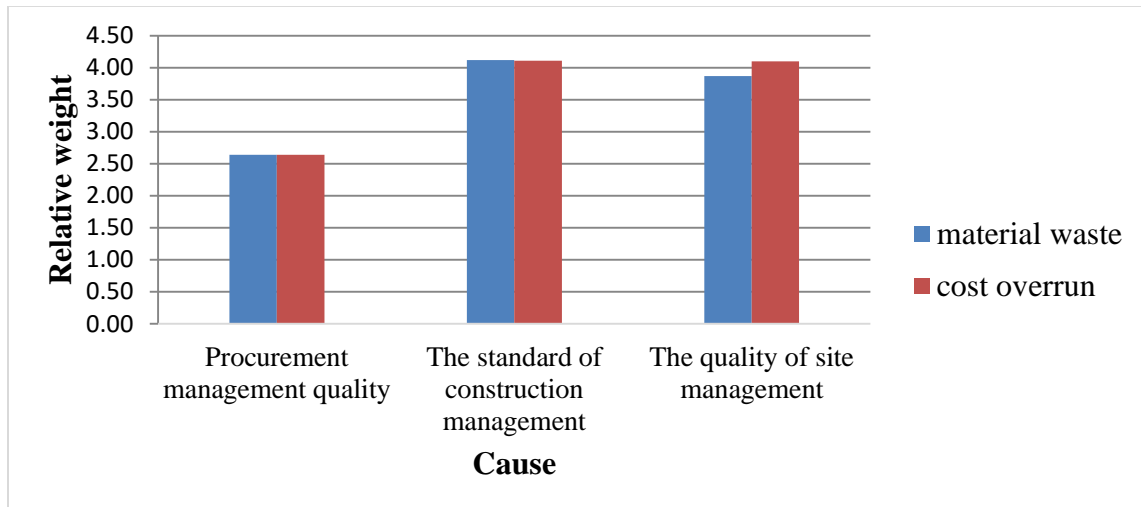


Figure 4-9: Graphical description between material wastage and project cost on post contract stage from consultant respondent.

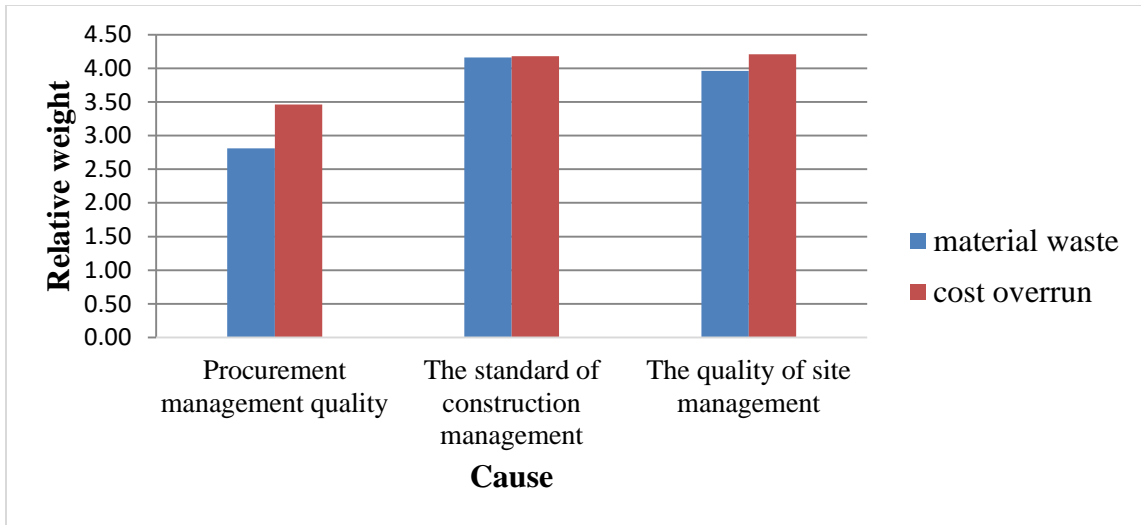


Figure 4-10: Graphical description between material wastage and project cost on post contract stage from contractor respondent

#### **4.7. The Extent of Waste Minimization Techniques in ECWC Sites**

The survey's findings demonstrate the degree to which nine waste management techniques are used in both on-site and prefabricated construction sites at the ECWC. From the result of Spearman rank correlation coefficients, there was no difference in ranking between the respondents except the reinforcement bar minimization techniques and by Cronbach alpha coefficient is 0.73 and the reliability also acceptable. Table 4-26 below shows spearman rank correlation coefficients value of waste management techniques practice.

Table 4-26: Strength of the rank correlation values for waste minimization techniques

<b>The extent of waste minimization techniques</b>	<b><math>r_s</math></b>	<b>p value</b>
Concrete	0.828	0.006
Mortar	0.792	0.011
Reinforcement bar	0.628	0.070
HCB	0.786	0.012
Form work	0.881	0.002

##### **4.7.1. Waste Minimization Techniques of Concrete**

Nine techniques have been recommended to minimize concrete waste in ECWC prefabricated and on-site construction sites, according to statistical analysis of the minimization techniques. The extent of waste minimization techniques for concrete waste are discussed empirically in Table 4-27.

Table 4-27: The extent of waste minimization techniques for concrete waste

No.	Waste minimization techniques	Consultant		Contractor	
		RW	Rank	RW	Rank
1	Use of Prefabrication on construction technology	1.92	7	3.01	6
2	Lean construction	3.38	5	3.66	5
3	Design management	4.54	1	4.53	1
4	Materials management	4.31	3	3.88	3
5	Develop site waste minimization plan	3.31	6	2.16	9
6	Proper material storage and handling	4.38	2	3.78	4
7	Waste reduction	4.23	4	3.90	2
8	Re-use	1.38	8	2.29	7
9	Recycling	1.38	8	2.17	8

Design management, proper material storage and handlings and materials management are the top three waste management techniques recommended by the consultants and whereas contractors recommended design management, waste reduction and materials management used on the job site for concrete work out of nine measures.

More respondents work in on-site construction sites than prefabricated construction sites, but prefabricated site workers respond at the highest level for concrete waste minimization techniques because on prefabricated sites concrete construction element like footing, column, beam, stair and slab are produced in production center in uniform and consistent design. The results also demonstrate that prefabrication use in construction technology is at the lowest level.

#### **4.7.2. Waste Minimization Techniques of Mortar**

The extent of waste minimization techniques for mortar waste are discussed below empirically in Table 4-28.

Table 4-28: The extent of waste minimization techniques for mortar waste

No.	Waste minimization techniques	Consultant		Contractor	
		RW	Rank	RW	Rank
1	Use of Prefabrication on construction technology	1.00	9	1.01	9
2	Lean construction	2.85	7	3.65	4
3	Design management	4.00	4	3.49	5
4	Materials management	4.54	1	3.87	2
5	Develop site waste minimization plan	3.31	6	2.16	8
6	Proper material storage and handling	4.38	2	3.78	3
7	Waste reduction	4.08	3	3.90	1
8	Re-use	4.00	4	2.29	6
9	Recycling	2.38	8	2.17	7

Materials management, proper material storage and handling and waste reduction are top mortar waste management techniques according to both respondents.

**4.7.3. Waste Minimization Techniques of Reinforcement Bar**

Based on a statistical study of the responses from contractors and consultants, all reduction techniques had a positive impact on the wastage of reinforcing bars. The extent of waste minimization techniques for reinforcement bar waste is discussed in Tables 4-29.

Table 4-29: The extent of waste minimization techniques for reinforcement bar waste

No.	Waste minimization techniques	Consultant		Contractor	
		RW	Rank	RW	Rank
1	Use of Prefabrication on construction technology	4.31	5	4.60	1
2	Lean construction	3.85	7	3.67	6
3	Design management	4.46	2	4.08	2
4	Materials management	4.69	1	3.88	4
5	Develop site waste minimization plan	3.31	8	2.14	9
6	Proper material storage and handling	3.92	6	3.78	5
7	Waste reduction	4.46	2	3.90	3
8	Re-use	2.92	9	2.17	8
9	Recycling	4.38	4	2.29	7

The development of site waste minimization plans and reuse are at the lowest levels for practice of waste minimization techniques for reinforcing bar, according to the data from the two tables above.

**4.7.4. Waste Minimization Techniques of Hollow Concrete Blocks**

The effectiveness of the nine-building material waste minimization techniques chosen for lowering HCB waste is discussed in Table 4-30.

Table 4-30: The extent of waste minimization techniques for HCB waste

No.	Waste minimization techniques	Consultant		Contractor	
		RW	Rank	RW	Rank
1	Use of Prefabrication on construction technology	5.00	1	4.35	1
2	Lean construction	3.92	5	3.66	6
3	Design management	4.77	2	3.86	3
4	Materials management	4.46	3	3.84	4
5	Develop site waste minimization plan	3.31	7	2.16	8
6	Proper material storage and handling	3.38	6	3.76	5
7	Waste reduction	4.15	4	3.90	2

No.	Waste minimization techniques	Consultant		Contractor	
		RW	Rank	RW	Rank
8	Re-use	3.31	7	2.29	7
9	Recycling	1.00	9	2.16	8

According to both respondent use of prefabricated HCB are the top one waste management technics but recycling is the lowest degree of contribution and exercise for minimizing HCB waste on the site from nine waste management technics.

#### **4.7.5. Waste Minimization Techniques of Form work**

The effectiveness of the nine-building material waste minimization techniques chosen for lowering form work waste is shown in Table 4-31 below. The statistical examination of the minimization techniques showed that on material minimization practices for both respondents, reuse is the most important minimizing technics.

Table 4-31: The extent of waste minimization techniques for form work waste

No.	Waste minimization techniques	Consultant		Contractor	
		RW	Rank	RW	Rank
1	Use of Prefabrication on construction technology	1.46	9	2.16	7
2	Lean construction	3.62	6	3.66	5
3	Design management	4.23	4	3.61	6
4	Materials management	4.54	2	3.84	3
5	Develop site waste minimization plan	3.31	7	2.16	7
6	Proper material storage and handling	3.85	5	3.76	4
7	Waste reduction	4.46	3	3.90	2
8	Re-use	5.00	1	4.98	1
9	Recycling	1.54	8	2.16	7

#### **4.8. Case Study**

This case study is to assess material waste and its effect on project, and then to minimize the cost effect by implementing reuse and recycling waste minimization practice. To assess the actual quantities of material waste occurring on sites, sample blocks from two construction approaches are chosen and use total cost of blocks calculate for concrete work (used only casting on-site not prefabricated concrete elements), mortar and block works. These two sample sites are still under construction, no project has been fully finished as of yet and to show the actual levels of material wastage occurring on the sites and the respondents is willingness for giving documented data. Table 4-32 following is a summary of the projects' basic data.

Table 4-32: Sample projects basic data

Sample Project data	Sample Site 1	Sample Site 2
Project type	Prefabricated construction site	On-site construction site
Blocks	G+4	G+2 and G+4
No of blocks	7	8
Total cost of the blocks (Birr)	<b>50,477,729.40</b>	<b>161,887,656.48</b>

Cement, coarse aggregate, sand, reinforcement bar, hollow concrete block, and formwork (ply wood and eucalyptus tree) waste quantities were evaluated and estimated for this case study.

One can able to calculate the amount of wastage generated at these sites by comparing the actual quantities of the supplies with the quantities taken by the contractor during the construction work of concrete, mortar and block work. The information used to estimate this waste amount was derived from the quantity of actual building work as well as the payment and material requests made at the site's store. The results were then compared to the material waste, and evaluated reuse and recycling practices on the waste materials generated at these sites. Also, its side effects on project costs were assessed.

#### **4.8.1. Measured Construction Material Waste**

This section presents the amounts of material waste generated during the construction progress and calculated by wastage level given below the formulas, and this wastage calculated before reuse and recycling.

Table 4-33 gives percentage of wastage level of materials on prefabricated and on-site building construction on ECWC.

$$\text{Wastage Level (in \%)} = \frac{M_p - M_u}{M_p} \times 100\%$$

Where  $M_p$  = Purchased material or issued material and  
 $M_u$  = Material used for actual construction work.

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

Table 4-33: Percentage of wastage quantity on each case study sites

Material	Unit	Wastage level on each sample site						
		Sample site 1			Sample site 2			
		Issued material	Actual Material used	%	Issued material	Actual Material used	%	
<b>Cement</b>	Qtl	6,460.00	6,354.37	1.64	8,947.00	8,695.95	2.81	
<b>Coarse Aggregate</b>	M <sup>3</sup>	1,891.62	1,843.18	2.56	1,281.55	1,242.90	3.02	
<b>Sand</b>	M <sup>3</sup>	1,222.02	1,173.84	3.94	2,652.22	2,372.43	10.55	
<b>HCB 20*20*40</b>	Pcs	56,805.00	52,356.67	7.83	49,372.00	45,275.95	8.30	
<b>HCB 15*20*40</b>	Pcs	61,335.00	58,366.55	4.84	0	0	0	
<b>HCB 10*20*40</b>	Pcs	17,404.00	16,671.57	4.21	0	0	0	
<b>Re-bar</b>	Φ8	Kg	22,984.98	22,484.98	2.18	16,336.99	12,203.10	25.30
	Φ10	Kg	25,798.22	25,674.20	0.48	80,562.92	68,764.15	14.65
	Φ12	Kg	35,449.23	35,109.23	0.96	32,041.87	30,180.93	5.81
	Φ14	Kg	0	0	0	30,836.99	28,533.47	7.47
	Φ16	Kg	10,977.84	10,712.02	2.42	40,950.52	38,983.18	4.80
	Φ20	Kg	28,306.20	27,546.91	2.68	14,015.57	13,315.55	4.99
<b>Form work</b>	<b>Ply wood</b>	M <sup>2</sup>	0	0	0	4,414.42	3,408.38	1.05
	<b>Eucalyptus tree Φ 12</b>	Pcs	200	200	0.00	18,530.00	10,198.00	0.22
	<b>Eucalyptus tree Φ 10</b>	Pcs	200	200	0.00	5,477.00	4,735.00	0.11
	<b>Eucalyptus tree Φ 8</b>	Pcs	100	100	0.00	1,725.00	1,011.00	3.71

Above Table 4-33 shows that sand and HCB are highly wasted materials in prefabricated and on-site construction sites compare to other selected materials but formwork wastage is only showing on-site construction site.

There is also a variation in waste percentage of the two sites for the same material. For instance, the wastage of reinforcement bar is almost above two times higher than at site 1. This is due to on prefabricated construction site reinforcement bar on site used for only for grade beams and slab mesh because other concrete structures are prefabricated in the production center.

Furthermore, a large variation of wastage was also found on formwork materials. Form work wastage only showing on site 2 but site 1 is not used timber form work because only assemble prefabricated elements or there is no casting on site.

**4.8.2. Impact on the Total Project Cost**

The cost spent as a result of extreme material usage at the two sites where the case study was conducted is shown in Table 4-34.

Table 4-34: Total cost of material wastage on each case study sites

Material	Unit	unit price (Birr)	Total wastage cost of a sample sites				
			Sample Site 1		Sample Site 2		
			Wastage quantity	Total cost	Wastage quantity	Total cost	
<b>Cement</b>	Qtl	559.36	739.41	413,596.38	2,008.40	1,123,418.39	
<b>Coarse Aggregate</b>	M <sup>3</sup>	565	339.08	191,580.20	309.2	174,698.00	
<b>Sand</b>	M <sup>3</sup>	630	337.26	212,473.80	2238.30	1,410,130.02	
<b>HCB 20*20*40</b>	Pcs	33.05	31,138.31	1,029,120.98	15034.72	496,897.50	
<b>HCB 15*20*40</b>	Pcs	28.5	20,779.17	592,206.33	-		
<b>HCB 10*20*40</b>	Pcs	36.48	5,127.01	187,033.32	-		
<b>Re-bar</b>	Φ8	Kg	37.33	3500	130,655.00	33071.15	1,234,546.12
	Φ10	Kg	37.33	868.14	32,407.67	94,390.16	3,523,584.85
	Φ12	Kg	37.33	2380	88,845.40	14887.53	555,751.38
	Φ14	Kg	37.33	-		18428.20	687,924.72
	Φ16	Kg	37.33	1860.74	69,461.42	15,738.72	587,526.45
	Φ20	Kg	37.33	5315.03	198,410.07	5600.18	209,054.57
<b>Form work</b>	<b>Ply wood</b>	M <sup>2</sup>	452.29	0	0	8048.35	3,640,189.13
	<b>Eucalyptus tree Φ 12</b>	Pcs	112	0	0	66656	7,465,472.00
	<b>Eucalyptus tree Φ 10</b>	Pcs	140	0	0	5936	831,040.00
	<b>Eucalyptus tree Φ 8</b>	Pcs	80	0	0	5712	456,960.00
<b>Total wastage cost</b>			<b>3,145,790.58</b>		<b>22,397,193.13</b>		
<b>Cost impact on the project (%) = Total wastage cost per Total cost of the blocks</b>			<b>6.23%</b>		<b>13.84%</b>		

The costs of waste generated at these two sites are 6.23% in prefabricated project site and 13.84% in on-site project site. From the result, in on-site project sites on average of above 45% extent cost of project due to material wastage compare to prefabricated sites. This suggests that using prefabrication construction techniques and minimization of material waste in the construction projects would reduce material waste and saving money on building materials overall.

**4.8.2.1. Cost of Reused and Recycled Waste Material**

The above discussion shows the amount of wastage at both project sites. The company collected reinforcement bar wastage for sell and reuse formwork materials wastage for additional small works and maintenance projects for saving cost or minimizing material wastage. The cost saving found by reuse formwork material from site 2 and selling of reinforcement bar from the two sample sites are shown in the table below. The cost benefit from reuse and recycled waste material are shown in Table 4-35 and 4-36 respectively.

Table 4-35: Cost benefit by recycled waste material

Sample site	Material	Unit	Unit price (Birr)	Recycled quantity	Cost benefit from recycled waste quantity	Cost benefit in (%)
Sample site 1	Reinforcement bar	kg	13	13,923.91	181,010.83	<b>5.75%</b>
Sample Site 2	Reinforcement bar	kg	13	182,115.94	2,367,507.24	<b>10.57%</b>

Table 4-36: Cost benefit by reused waste material

Material		Unit	Unit price (Birr)	Reused quantity	Cost benefit from reuse waste quantity
<b>Form work</b>	<b>Ply wood</b>	M <sup>2</sup>	452.28	797.72	360,792.80
	<b>Eucalyptus tree Φ 12</b>	Pcs	112	3200	358,400.00
	<b>Eucalyptus tree Φ 10</b>	Pcs	140	500	70,000.00
	<b>Eucalyptus tree Φ 8</b>	Pcs	80	150	12,000.00
<b>Cost benefit from reuse waste quantity</b>					<b>801,192.80</b>
<b>Cost benefit in (%)</b>					<b>3.58%</b>

## **5. CONCLUSIONS AND RECOMMENDATIONS**

### **5.1. Conclusions**

The general objective of this study is to assess the impact of materials wastage on the cost of a project in on-site construction method through comparing with prefabricated building construction. According to the purpose of this thesis's study, the following key findings have been concluded based on the results attained.

- a) According to both group of respondents and from site observation the results obtained indicate that lack of onsite material control and equipment malfunctioning are the main reasons of concrete wastage in the sites. Similarly, modifications made to the design while work is still being done, lack of onsite material control and material damage resulting from storage and handling are the main three identifying reasons of mortar waste in ECWC prefabricated and on-site construction sites.
- b) Selection of the material's type and dimensions without considering wastage and design changes are the main reasons of reinforcement bar wastage according to the contractor respondents, also from the consultant respondents, ordering error and material damage resulting from storage and handling are the main reasons.
- c) The main reasons from both respondents of hollow concrete block wastage proved to be modifications made to the design while work is still being done, material damage resulting from storage and handling, lack of onsite material control and errors by trades men. Modifications made to the design while work is still being done, rework, consuming an extreme amount of materials than required and lack of onsite material control are also main reasons of formwork on both respondents.
- d) The case study's findings show that the cost of material waste generation impact on the total project cost in ECWC prefabricated and on-site building construction projects were 6.23% and 13.84%, respectively. This shows that the proportion of waste for all of the evaluated construction materials was genuinely high for on-site building construction projects. So, this amount of costs could possibly be saved, increasing the profit for the contractors by this amount, and provided suitable waste minimization procedures and particularly employing prefabricated construction material like concrete.
- e) Sand and HCB are highly wasted materials in both sites but formwork wastage is only showing on-site construction site. On the prefabrication building construction site, there is no wastage amount of formwork material.
- f) Also, this study offered empirical information regarding the application of waste minimization techniques for each of the five materials mentioned above in ECWC construction sites. Among nine waste minimization techniques, more

prefabricated elements are utilized for concrete work on prefabrication sites, and recycling of reinforcement bar is used in both sites and reuse formwork is more frequently used on on-site. The other techniques for reducing waste are, however, less frequently used.

## **5.2. Recommendations**

Based on the study's findings, the following recommendations are provided to reduce material waste at ECWC building construction sites.

- a) A construction site shall practice use of prefabricated construction element (prefabricated concrete like footing, stair, column, slab and beam and partition walls).
- b) In order to increase the prefabrication production capacity of the company by employing updated technologies available in the market, increasing number of molds and expansion of production shop and empowering the available man power.
- c) Proper detailing during designing and to show design to be completed for minimize waste caused by design problems in construction sites.
- d) Lean construction (just-in-time delivery system) should be enhanced to reduce waste resulting from unnecessary quantities of material ordering and purchased product with completed specification and ensure that the products provided on site fit the specifications are in order to minimize waste produced by procurement issues.
- e) Develop site waste minimization plans used to know detail about material waste problem and provide solutions to reduce this problem. In addition, from other country experience they will be start to providing a training and having a department on waste management.
- f) Determine the extent to which recycled and reused waste contributes to reducing cost overruns.
- g) Additional investigate should be conducted to study the connection between construction waste and project cost overrun in the construction industry.

## **5.3. The Research's Knowledge Contribution**

Given the lack of awareness regarding wasteful use of construction materials and project cost overruns, the research has added to the body of knowledge in this field. The following contributions are suggested in this regard:

- a) Effective construction waste management and its connection to cost overruns in the building sector are now well understood theoretically according to the research.

- b) The study has improved knowledge of how construction waste reduced by using different minimization technics on the prefabricated and on-site construction projects.
- c) The study has improved knowledge of how recovering waste construction materials reduce cost overruns in the construction project and for society, the environment and the financial benefits.
- d) The study has improved knowledge how to calculate the quantity of construction waste and its cost.

With its limitations, this study looked into material waste in prefabricated and on-site construction projects. However, the following problems are noted and optional for future studies.

- a) To develop a full document for estimating waste quantities on the construction sites.
- b) To develop empirical checklist for assessing waste quantity and project cost profitability on the construction sites.
- c) Employing laboratory testing to evaluate the quality of material like sand and hollow concrete blocks delivered to the site.

## REFERENCES

- Abdul Kadir, M., Lee, W., Jaafar, M., Sapuan, S., & Ali, A. (2006). Construction Performance Comparison between Conventional and Industrialized Building Systems in Malaysia. vol. 24, pp. 412-424.
- Abdul-Rahman, I., Memon, A.H., & Abd-Karim, A.T. (2013). Significant factors causing cost overruns in large construction projects in Malaysia. *Journal of Applied Sciences*, 13(2), 286-293.
- Adewuyi, T.O., & Oтали, M. (2013). Evaluation of Causes of Construction Material Waste: Case of River State, Nigeria. *Ethiopian Journal of Environmental Studies and Management* 6, 746-753.
- Al-Moghany, S.S. (2006). *Managing and Minimizing Construction Waste in Gaza Strip*. A thesis submitted to the Islamic University of Gaza- Palestine.
- Ameh, J.O., & Itodo, E.D. (2013). Professionals' views of material wastage on construction sites. *Organization, Technology and Management in Construction*. An International Journal, 5(1), 747-757.
- Andualem, E., Yadeta., Akililu, M., & Eshetie. (2019). Causes of materials wastage in building construction projects. *International journal of scientific & engineering research* vol 10, issue 10.
- Augustine, S. (2011). *Managing Waste and Cost in the Construction Industry: A case Study of the Road Construction Industry*," M.BA. Thesis, Kwame Nkrumah University of Science and Technology, Ghana.
- Begum, R.A., Siwar, C., Pereira, J.J., & Jaafar, A.H. (2007). Implementation of waste management and minimization in the construction industry of Malaysia. *Resources, Conservation and Recycling*, 51(1), 190-202.
- Birhanu Muluken Tessera. (2020). Review on the practicing of prefabricated building construction technology in Ethiopia vs world experiences. Federal TVET Institute, Bahir Dar Satellite Campus, Faculty of Civil Technology, Department of Construction Technology, Bahir Dar, Ethiopia.
- Boafo, F., Kim, J.H., & Kim, J.T. (2016). Performance of modular prefabricated architecture: case study-based review and future pathways. *Sustainability* 8(6).
- Cao, X., Li, X., Zhu, Y., & Zhang, Z. (2015). A comparative study of environmental performance between prefabricated and traditional residential buildings in China. *J Clean Prod* 109:131–143.
- Carlos, T., Foromos., Lucio S., Eduwardo, L., Isato., Claudia, M., & De, C. (2002). Material Waste in Building Industry: Main Causes and Prevention *journal of construction engineering and management* 128(4).

- Chitkara, K.K. (2011). *Construction Project Management-Planning, Scheduling and Controlling*. 2nd Edition, Tata Mc Graw Hills.
- Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: techniques and procedures for developing grounded theory*. 3<sup>rd</sup> edition, thousand oaks, CA: Sage.
- Crawford, R.H., Mathur, D., & Gerritsen, R. (2017). Barriers to Improving the Environmental Performance of Construction Waste Management in Remote Communities *Procedia Eng*, 196 830–7.
- Dajadian, S.A., & Koch, D.C. (2014). Waste Management Models and Their Applications on Construction Sites *Int. J. Constr. Eng. Manag.* 3 (3) 91–8.
- Dennis, S., & Macozoma. (2002). *Construction site waste management and minimization*. International council for research and innovation in building and construction.
- Deribsa, A. (2018). *Research methodology handbook for research students and practitioners*, first edition, pp 22.
- Dr. Subash, T., Galeta, C., Kidist, M., & Woyesa, A. (2021). Research finding on impact of material wastage on building construction project. pp 472-481.
- Ekanayake, L.L., & Ofori, G. (2000). Construction material waste source evaluation, *Proceedings of the 2nd South African Conference on Sustainable Development in the Built Environment*, Pretoria, South Africa. pp 35–36.
- Ekanayake., & Ofori. (2004). Building waste assessment score: Design-based tool. pp 851-861.
- Ektewan Manowong. (2010). *Investigating factors influencing construction waste management efforts in developing countries: an experience from Thailand*.
- Eskeदार Girma. (2016). *Study on material wastage of 40/60 condominium construction sites*. Addis Ababa University construction technology and management.
- Fitri, L., Hatmoko, J.U.D., & Hermawan, F. (2019). *Managing Construction Waste in Developed Countries: Lessons Learned for Indonesia* IOP conference series earth and environment science 366(1).
- Francois buys. (2015) *Five Causes of Project Delay and Cost Overrun, and Their Mitigation Measures*.
- Ganesan, S. (2000). *Employment, Technology and Construction Development* Ashgate Publishing Company, Aldershot.
- Gangoells, M., Casals, M., Forcada, N., & Macarulla, M. (2014). Resources, Conservation and Recycling Analysis of the Implementation of Effective Waste Management Practices in Construction Projects and Sites, *Resources, Conserv. Recycl* 93, 99–111.

- Gopang, R.K.M., Imran, Q.B.A., & Nagapan, S. (2020). Assessment of delay factors in Saudi Arabia railway/metro construction projects. *Int. J. Sustain. Constr. Eng. Technol.*, 11, 225–233.
- Ibn-Homid, N.T. (2002). A Comparative Evaluation of Construction and Manufacturing Materials Management, *International Journal of Project Management* 20,263-270.
- Ingrao, C., Giudice, A. L., Tricase, C., Mbohwa, C., & Rana, R. (2014). The use of basalt aggregates in the production of concrete for the prefabrication industry: environmental impact assessment, interpretation and improvement. *Journal of Cleaner Production*, 75, 195-204.
- Kasim, N.B., Anumba, C.J., & Dainty, A.R.J. (2005). Improving materials management practices on fast-track construction projects. In: Khosrowshahi, F. (Ed.). *Proceedings of the 21st Annual ARCOM Conference, 7-9 September, University of London: SOAS.* pp 793-802.
- Keal. (2007). Reduction material wastage in construction <http://www.wrap.org.UK/construction>.
- Kibirt Bayou. (2017). *Precast Construction in Ethiopia-An In-Depth Look at the PBPPE Precast Plant.* Addis Ababa University construction technology and management.
- Kofoworola, O. F., & Gheewal, S. H. (2009). Estimation of Construction Waste Generation and Management in Thailand. *Journal of Waste Management*, vol. 29, 731-738.
- Lara., Jaillon., & Poon, C.S. (2009). The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector. vol 18 issues 3, pp 239-248.
- Lingard, H., Graham, P., & Smithers, G. (2000). Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. *Construction Management and Economics*, vol. 18, no. 4, pp. 383–393.
- Li, Z., Shen, G.Q., & Alshawi, M. (2014). Measuring the impact of prefabrication on construction waste reduction: An empirical study in China. *Resour Conserv Recycl* 91, 27–39.
- Lu, W., & Tam, V. W. Y. (2013). Construction Waste Management Policies and Their Effectiveness in Hong Kong: A Longitudinal Review *Renew Sustain Energy Rev.* 23, 214–23.
- Ma, U. (2011). *No waste: Managing sustainability in construction.* Surrey, Farnham: Gower Publishing Limited.

- Macmillan, J.H. & Schumacher, S. (2001). *Research in Education. A conceptual introduction*. 5<sup>th</sup> edition, Longman, Boston.
- Muhwezi, L., Chamuriho, L., & Lema, N. (2012). An investigation into materials wastes on building construction projects in Kampala-Uganda. *Scholarly Journal of Engineering Research*, vol. 1, no. 1, pp. 11–18.
- Nagapan, S., Abdul-Rahman, I., Asim, A., & Hameed, A. (2012a). Identifying Causes of Construction Waste-Case of Central Region Peninsula Malaysia. *International Journal of Integrated Engineering*, 4(2), 22-28.
- Narimah, B.K. (2008). *Improving materials management on construction projects*. A Doctoral Thesis Submitted in partial fulfillment of the requirements for the award of Doctor of Philosophy of Loughborough University.
- Nathaniel, O.O., Omololu, D.O., Abiodun, O.O. (2023). Construction and demolition waste management in a developing country: A Nigeria scenario.
- Neill, O., & Organ, S. (2016). A literature review of the evolution of British prefabricated low-rise housing. *Structural Surveys*, Vol. 34 Issue:2, 191-214.
- Nikolaos Legmpelos. (2013). *On-site Construction Versus Prefabrication*. Submitted to the Department of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Civil and Environmental Engineering at the Massachusetts Institute of Technology.
- Oyedele, L.O., Ajayi, S.O., & Kadiri, K.O. (2014). Resources, Conservation and Recycling Use of Recycled Products in UK Construction Industry: An empirical Investigation in to Critical Impediments and Strategies for Improvement Resources, *Conserv. Recycl.* 93, 23–31.
- Page, IC., & Norman, D. (2014). *Prefabrication and standardization potential in buildings*. BuildingResearch Association of New Zealand, Wellington, New Zealand.
- Poon, C. S., Yu, A. T. W., & Jaillon, L. (2004). Reducing Building Waste at Construction Sites in Hong Kong. *Journal of Construction Management and Economics*, 22, 461– 470.
- Poon, C. S. (2007). Reducing Construction Waste. *Journal of Waste Management*. vol. 27, 1715-1716.
- Rahim, M., Kasim, N., Mohamed, I., Zainal, R., Sarpin, N., & Saikah, M. (2017). Construction Waste Generation in Malaysia Construction Industry: Illegal Dumping Activities IOP Conf. Series: Mater. Sci. Eng., 271.
- Saidu, I., & Shakantu, W.M.W. (2015). A Relationship between Quality-of Estimating, Construction Material Waste and Cost Overruns in Abuja, Nigeria. Fourth Construction Management Conference, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa. Edited Emuze, F.A., 95-104.

- Saidu, I., & Shakantu, W.M.W. (2016a). A Study of the Relationship between Material Waste and Cost Overruns in the Construction Industry. The 9th cidb Postgraduate Conference Cape Town, South Africa. Emerging trends in construction organizational practices and project management knowledge area. Edited Windapo, A.O., 124-134.
- Sardénk, Y. & Engström, S. (2010). Modern Methods of Construction: A Solution for an Industry Characterized by Uncertainty. in Procs 26th Annual ARCOM Conference, pp. 6-8.
- Shahzad, W.M. (2016). Comparative analysis of the productivity levels achieved through the use of panelized prefabrication technology with those of traditional building system. Doctoral thesis, Massey University, New Zealand
- Shen, L. Y., & Tam, V. W. Y. (2002). Implementation of environmental management in the Hong Kong construction industry. *International Journal of Project Management*, vol. 20, no. 7, 535–543.
- Shen, L.Y., Tam, V.W.Y., Tam, C.M., & Drew, D. (2004). Mapping Approach for Examining Waste Management on Construction Sites. *Journal of Construction Engineering and Management* 130, 472–81.
- Sin, T. J., Chen, G. K., Long, K. S., & Hwang, G. H. (2012). Current Practice of Waste Management System in Malaysia: Towards Sustainable Waste Management Current Practices for Malaysia Available at: <http://eprints.uthm.edu.my/5381/1/FPTP>.
- Sin, T. J., Chen, G. K., Long, K. S., Goh, I & Hwang, G. H. (2013). Current practice of waste management system in Malaysia: Towards sustainable waste management Current Practices for Malaysia. *UTHM J.*, vol. 1, no. 1, 538.
- Tadesse Ayalew., Zakaria, D., & Zoubeir, L. (2016). Assessment on performance and challenges of Ethiopian construction industry. *Journal of Architecture and Civil Engineering* 2(11): 01-11.
- Tam, V. W. Y., Tam, C. M., Chan, J. K. W., & William, C. Y. (2006). *International Journal of Construction Cutting Construction Wastes by Prefabrication*.
- Tam, V. W.Y., Tam, C.M., Zeng, S.X., & Ng, W.C. Y. (2007). Towards adoption of prefabrication in construction. *Build Environment* 12(10), 3642–3654.
- Tam, V. W. Y., & Tam, C. M. (2008). Waste Reduction through Incentives. A Case Study, *Building Research and Information Journal*, vol. 36, 37-43.
- Vivian., Tam, W.Y., & Jianli, H. (2014). Prefabrication as a mean of minimizing construction waste on site. *international journal of construction management* 14(2), 113-121.
- Yemane, Taro. (1967). *Statistics: An introductory analysis*, 2<sup>nd</sup> edition, New York: Harper and Row.

Zeb, A., Malik, S., Nauman, S., Hanif, H. & Amin, O.S. (2015). Factors affecting material procurement, supply and management in building projects of Pakistan. A contractor's perspective. In: Proceedings of the International Conference on Innovations in Civil and Structural Engineering (ICICSE'15), 3-4, 170-175.

**ANNEX**

**Annex 1: Questionnaire for the Contractor**

**QUESTIONNAIRE**

**FOR ECWC CONSTRUCTION PROJECT**

**ON CONTRACTOR SIDE**

**Comparative Study on the Impact of Materials Wastage on Project Cost  
between Prefabricated and On-site Building Construction Methods:  
The Case of ECWC**

Dear respondent, this questionnaire's objective is to collect the information required for Addis Ababa University's MSc thesis in Construction Technology and Management. This study's goal is to compare the construction of prefabricated buildings on ECWC construction sites with on-site construction methods to determine the effect of material waste on project costs. You are kindly asked to participate in this research project by answering the following questionnaire. The respondent's identity as well as the name of the site you represent must remain secret, and all survey results will only be utilized for academic research. I want to express my appreciation for taking the time to answer this questionnaire.

Meseret Asefa

Email: [messiiasefa@gmail.com](mailto:messiiasefa@gmail.com)

**Section One: Overall Data of respondents**

1. Name of your companies \_\_\_\_\_

2. Your current position on this site

- Project manager
- Project team leader
- Site engineer
- Office engineer

3. Your educational Background

- Graduate (MSC)                       Undergraduate (BSC)
- Diploma

4. Work experience in the construction industry in years

- < 1 year                       1 - 3 years                       3 - 5 years                       5 - 10 years
- 10 - 15 years                       15 - 20 years                       > 20 years

5. Work experience in the prefabrication construction site in years

- < 1 year                       1 - 3 years                       3 - 5 years                       5 - 10 years
- 10 - 15 years                       15 - 20 years                       > 20 years                       there is no experience

**Section Two: Reason of Material Waste**

The given below are source and reasons of material waste and grades on a scale of 1-5.

No.	Grades for the reasons of waste
1	Not a waste reason
2	Insignificant waste reason
3	Moderately a waste reason
4	Significant waste reason
5	Extremely a waste reason





**Section Three: Relation between the reasons of material waste and project cost overruns**

Reasons of material waste found in the causes of cost overruns at the pre-contract stage of a project.

Rate of influence for material waste generation and cost overrun	
1	Very low influence
2	Low influence
3	Medium influence
4	High influence
5	Very high influence

No.	Reasons of cost overruns at the pre-contract stage of a project.	Level of influence for material waste generation					Level of influence for project cost overrun				
		1	2	3	4	5	1	2	3	4	5
1	<b>The quality of planning</b>										
1.1	Poor field investigation										
1.2	inadequate project information										
1.3	bad cost estimates										
1.4	lack of experience										
1.5	inadequate project formulation and feasibility analysis										
1.6	poor project appraisal leading to incorrect investment decisions										
1.7	inadequate resource plan										
1.8	inadequate equipment supply plan										
1.9	poor organization										
1.10	Poor cost planning.										
1.11	Improper pre-contract actions										
1.12	Poor post-award contract management.										
2	<b>The quality of design management</b>										
2.1	Design errors										
2.2	change order										

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

2.3	extra works													
2.4	revision of scope of work													
2.5	Design changes													
2.6	Labor skill level													
3	<b>The complexity of design</b>													
3.1	Designing uneconomical shapes and outlines													
3.2	Sophisticated systems and components/complexity													
3.3	Difficulties in interpreting specification													
3.4	Designing irregular shapes and forms													
3.5	Designing non-standard dimensions													
3.6	Allowing cutting and chiseling													
3.7	Lack of experience													
3.8	Incomplete drawings													
4	<b>The quality of estimating</b>													
4.1	Over or under estimation and allowance													
4.2	Inaccurate quantity takeoff													
4.3	Insufficient time for estimate													
4.4	Different methods used in estimation													
4.5	Late engagement of estimator													

Reasons of material waste found in the causes of cost overruns at the post-contract stage of a project.

No.	Reasons of cost overruns at the post-contract stage of a project.	Level of influence for material waste generation					cost overrun							
		1	2	3	4	5	1	2	3	4	5			
1	<b>Procurement management quality</b>													
1.1	Inappropriate and inadequate procurement													
1.2	faulty contractual management system													
1.3	slowness in decision making													
1.4	lack of experience													
1.5	inadequate project formulation and feasibility analysis													
1.6	late procurement of materials													
1.7	delay in approving design documents													
1.8	Errors in shipping/supply													
1.9	Damage of material during transportation													

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

1.10	Non-standard sizes of materials																			
2	<b>The standard of construction management</b>																			
2.1	change in material price and changes in exchange rates																			
2.2	client's cash flow problems/delays in contractor's payment,																			
2.3	contractor's financial difficulties																			
2.4	poor site organization and coordination between various parties																			
2.5	Lack of contractor experience																			
2.6	Poor building techniques																			
2.7	Shortage of skilled workers																			
2.8	inappropriate use of materials and equipment,																			
2.9	Damage caused by workers																			
3	<b>The quality of site management</b>																			
3.1	Slow closeout																			
3.2	unresolved disputes linked with client acceptance																			
3.3	change order issues not resolved																			
3.4	final change orders not issued,																			
3.5	poor documentation of project success and lessons learnt																			
3.6	slow client acceptance and failing to close the work order																			
3.7	Wrong material storage																			
3.8	Transfer of materials from storage to application																			
3.9	Damage of materials by other trades																			
3.10	Poor site storage area																			
3.11	Long distance from storage to application point																			
3.12	Damage by weather																			
3.13	Insufficient and ineffective working																			
3.14	Delays																			
3.15	changes in scope of work and location																			
3.16	law and order																			
3.17	Late engagement of estimator																			

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

Please explain if there are any other reasons of material waste found in cause of cost overruns at the pre-contract and post-contract stage of a project in your ECWC construction site.

---

**Section Four: Waste Management Techniques**

Grade on a scale of 1-5 for minimization of material wastage in ECWC construction sites.

Level of exercise	
1	Not exercise
2	Unusually experienced
3	experience
4	Commonly experienced
5	Most commonly experienced

No.	Waste management technics	Level of practice to this site																													
		Concrete					mortal					Reinforcement bar					Hollow concrete block					Form work									
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5					
1	Use Prefabrication construction technology																														
2	Lean construction or just-in time delivery strategy																														
3	Design management																														
4	Materials management																														
5	Develop site waste minimization plan (SWMP)																														
6	Proper storage and																														



## **Annex 2: Questionnaire for the Consultant**

### **QUESTIONNAIRE**

#### **FOR ECWC CONSTRUCTION PROJECT**

#### **CONSTRUCTION SUPERVISION CONSULTANTS**

### **Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

Dear respondent, this questionnaire's objective is to collect the information required for Addis Abeba University's MSc thesis in Construction Technology and Management. This study's goal is to compare the construction of prefabricated buildings on ECWC construction sites with on-site construction methods to determine the effect of material waste on project costs. You are kindly asked to participate in this research project by answering the following questionnaire. The respondent's identity as well as the name of the site you represent must remain secret, and all survey results will only be utilized for academic research. I want to express my appreciation for taking the time to answer this questionnaire.

Meseret Asefa

Email: [messiiasefa@gmail.com](mailto:messiiasefa@gmail.com)

**Section One: Overall data of respondent**

1. Name of your companies \_\_\_\_\_

2. Your current position on this site

Project Coordinator

Resident Engineer

Site Supervisor

3. Your educational Background

Graduate (MSC)

Undergraduate (BSC)

Diploma

4. Work experience in the construction industry in years

< 1 year

1 - 3 years

3 - 5 years

5 - 10 years

10 – 15 years

15 - 20 years

> 20 years

5. Work experience in the prefabrication construction site in years

< 1 year

1 - 3 years

3 - 5 years

5 - 10 years

11 – 15 years  
experience

15 - 20 years

> 20 year

there is no

**Section Two: Reason of Material Waste**

The given below are source and reasons of material waste and grades on a scale of 1-5.

No.	Grades for the reasons of waste
1	Not a waste reason
2	Insignificant waste reason
3	Moderately a waste reason
4	Significant waste reason
5	Extremely a waste reason

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

Source	Reason	concrete					Mortar					Reinforce ment bar					Hollow concrete block					Formwork				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Design phase	• Disregard for the product's dimensional coordination																									
	• Modifications made to the design while work is still being done																									
	• Inexperience of designers with building sequence and methods																									
	• Lack of consideration for the available standard sizes																									
	• Designers unfamiliarity with alternative products																									
	• Selection of the material's type and dimensions without considering wastage																									
Procurement phase	• Error in contract document																									
	• Lack of trades skill																									
	• Ordering more or less material																									
Material	• Purchased products that do not meet the specification																									
	• Unfriendly attitudes of project team and laborers																									
	• Damages during transportation																									



**Section Three: Relationship between the causes of material waste and project cost overruns**

Reasons of material waste found in the causes of cost overruns at the pre-contract stage of a project.

Rate of influence for material waste generation and cost overrun	
1	Very low influence
2	Low influence
3	Medium influence
4	High influence
5	Very high influence

No.	Reasons of cost overruns at the pre-contract stage of a project.	Level of influence for material waste generation					Level of influence for project cost overrun					
		1	2	3	4	5	1	2	3	4	5	
1	<b>The quality of planning</b>											
1.1	Poor field investigation											
1.2	inadequate project information											
1.3	bad cost estimates											
1.4	lack of experience											
1.5	inadequate project formulation and feasibility analysis											
1.6	poor project appraisal leading to incorrect investment decisions											
1.7	inadequate resource plan											
1.8	inadequate equipment supply plan											
1.9	poor organization											
1.10	Poor cost planning.											
1.11	Improper pre-contract actions											
1.12	Poor post-award contract management.											
2	<b>The quality of design management</b>											
2.1	Design errors											
2.2	change order											

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

2.3	extra works												
2.4	revision of scope of work												
2.5	Design changes												
2.6	Labor skill level												
3	<b>The complexity of design</b>												
3.1	Designing uneconomical shapes and outlines												
3.2	Sophisticated systems and components/complexity												
3.3	Difficulties in interpreting specification												
3.4	Designing irregular shapes and forms												
3.5	Designing non-standard dimensions												
3.6	Allowing cutting and chiseling												
3.7	Lack of experience												
3.8	Incomplete drawings												
4	<b>The quality of estimating</b>												
4.1	Over or under estimation and allowance												
4.2	Inaccurate quantity takeoff												
4.3	Insufficient time for estimate												
4.4	Different methods used in estimation												
4.5	Late engagement of estimator												

Reasons of material waste found in the causes of cost overruns at the post-contract stage of a project.

No.	Reasons of cost overruns at the post-contract stage of a project.	Level of influence for material waste generation					cost overrun						
		1	2	3	4	5	1	2	3	4	5		
1	<b>Procurement management quality</b>												
1.1	Inappropriate and inadequate procurement												
1.2	faulty contractual management system												
1.3	slowness in decision making												
1.4	lack of experience												

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

1.5	inadequate project formulation and feasibility analysis																			
1.6	late procurement of materials																			
1.7	delay in approving design documents																			
1.8	Errors in shipping/supply																			
1.9	Damage of material during transportation																			
1.10	Non-standard sizes of materials																			
2	<b>The standard of construction management</b>																			
2.1	change in material price and changes in exchange rates																			
2.2	client's cash flow problems/delays in contractor's payment,																			
2.3	contractor's financial difficulties																			
2.4	poor site organization and coordination between various parties																			
2.5	Lack of contractor experience																			
2.6	Poor building techniques																			
2.7	Shortage of skilled workers																			
2.8	inappropriate use of materials and equipment,																			
2.9	Damage caused by workers																			
3	<b>The quality of site management</b>																			
3.1	Slow closeout																			
3.2	unresolved disputes linked with client acceptance																			
3.3	change order issues not resolved																			
3.4	final change orders not issued,																			
3.5	poor documentation of project success and lessons learnt																			
3.6	slow client acceptance and failing to close the work order																			
3.7	Wrong material storage																			
3.8	Transfer of materials from storage to application																			
3.9	Damage of materials by other trades																			
3.10	Poor site storage area																			
3.11	Long distance from storage to																			

**Comparative Study on the Impact of Materials Wastage on Project Cost between Prefabricated and On-site Building Construction Methods: The Case of ECWC**

---

	application point																			
3.12	Damage by weather																			
3.13	Insufficient and ineffective working																			
3.14	Delays																			
3.15	changes in scope of work and location																			
3.16	law and order																			
3.17	Late engagement of estimator																			

Please explain if there are any other reasons of material waste found in cause of cost overruns at the pre-contract and post-contract stage of a project in your ECWC construction site.

---

**Section Four: Waste Management Techniques**

Grade on a scale of 1-5 for minimization of material wastage in ECWC construction sites.

Level of exercise	
1	Not exercise
2	Unusually experienced
3	Experienced
4	Commonly experienced
5	Most commonly experienced

No.	Waste management technics	Level of practice to this site																													
		Concrete					mortal					Reinforcem ent bar					Hollow concrete block					Formwork									
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5					
1	Use Prefabrication construction technology																														
2	Lean construction or just-in time delivery strategy																														



### Annex 3: Construction site observation checklist

Company name: \_\_\_\_\_

Site name: \_\_\_\_\_

Date: \_\_\_\_\_

Area: \_\_\_\_\_

Criteria	Yes	No	Comment
Are building materials stored within the confines of work area?			
Are building materials properly used on time?			
Are their building material waste show on the site?			
Are their material waste control methods practiced on the site?			
Are the site using any method to show material wastage impact on the project?			
Is the profession for material waste control designated?			
Is the supervisor designated?			
Are the relevant office document gain from the office?			
Are the office document organized by softcopy?			
Are the relevant document organized by hardcopy?			

*This page is blank intentionally!*

---