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A Thesis Submitted to the School of Civil Engineering in Partial Fulfillment of the Requirements for the Degree of Masters in construction Technology and Management

Title: Investigating Challenges of Construction and Demolition Waste Management, in the Case of Mekelle, Tigray**"**

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Advisor: Mr. Tesfay Tsegay (MSc).

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Declaration

I, the undersigned declare that, this thesis is my original work performed under the supervision of my research advisor Mr. Tesfay Tsegay (MSc) and has not been presented as a thesis for a degree in any other university. All sources of materials that support to accomplish this thesis have also been referenced.

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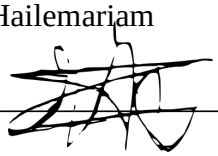
Signature: 

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ABSTRACT

With rapid urbanization and economic growth, All the activities, new construction, renovation, and demolition of buildings and structures generate huge amounts of waste, which require reduction in generation and proper management. Nevertheless, due to several barriers and constraints this could not be implemented. The purpose of this study was investigating challenges of construction and demolition waste management in Mekelle construction projects. Based on this objective, the factors that contribute waste, effects of C&DW, current construction waste management practice and major challenges of C&DW management have been investigated. The study used semi structured interview and questionnaire survey for data collecting techniques, and relative importance index for descriptive data analysis. The result of the study shown the improper material handling and storage, poor supervision, lack of skilled man power and late design changes are the most contributing factors to waste generation. Whereas, Project cost overrun, Environmental Pollution, Reduction in profit, Resources depletion and public health and safety risks are the main effect of C&DW. In the current construction waste management practices, the governing strategies i.e. waste reduction and proper management were not effectively implemented. Furthermore, *the following main challenges were identified in this research*. The challenges are; *Improper planning & waste management practice, Ineffective waste management plan, Insufficient waste management training programs, Poor supervision practice, Lack enforcement of regulations, Absence of training on waste minimization strategies for construction firms, insufficient legislation & regulation, Lack of Government incentives, Low Concern for socio-economic and environmental effect of wastage, Resistance to change traditional management practices, Poor coordination among construction stakeholders, Believing waste not a problem on site, High cost with low quality of recycled materials, Lack of demand for recycled materials, and High cost of waste disposal. The study also recommends that Managing C &D Waste needs a serious attention from all the stakeholders involved throughout the construction process.*

Key terms: Construction and Demolition Waste, Waste Management, Barriers of C&DWM

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Acronyms

RII = Relative Importance Index

LACS = Lack of Awareness of Construction Stakeholders

IGWMRP = Inefficient Government Waste Management Regulatory Policy

IRCHCWM = Insignificant Return Compared to High Costs of Waste Management

C&D = Construction and Demolition

SDGs = Sustainable Development Goals

NGOs = None Governmental Organizations

C&DW = Construction and Demolition waste

W = the weighting given to each factor by the respondent

A = the highest rate value;

N = the total number of samples

MSW = Municipal Solid Waste

SWMP = site waste management plan

DFD = design for deconstruction

CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Construction is a vital connection to the infrastructure and growth of industry in developing countries. In some areas, all or part of construction and demolition (C&D) waste is unlawfully deposited on land, or in natural drainage including water, contrary to regulations to protect human health, commerce, and the environment. The Construction industry, while contributing to overall socioeconomic development of any country, is a major exploiter of natural non-renewable resources and a polluter of the environment whereby it contributes to the environmental degradation through resource depletion, energy consumption air pollution and generation of waste in the acquisition of raw materials. Statistical data shows, construction and demolition (C&D) wastes frequently makes up 10–30% of the waste received at many landfill sites around the world [25] [47] (Fischbein, 1998).

The global ecological scenario and escalating demands on limited resources have brought waste management to attention, particularly in construction and demolition (C&D). Resource management is one of the biggest challenges in the performance of the Ethiopian construction sector [48]. The intricacies of this challenge are numerous and involve a diverse range of stakeholders, including but not limited to professionals in the construction industry, governmental agencies responsible for waste management, transportation companies, and various NGOs. The complex system of C&D waste handling involves allocating specific roles to each actor, with the added influence of socioeconomic and environmental factors that bear a significant impact. A very high level of waste is assumed to exist in construction. Though it is difficult to systematically measure all waste in construction, various studies from different countries have confirmed that waste represents a relatively large percentage of production cost [25][39]. So, the management of construction waste plays an important role in the cost of project and appropriate use of the construction waste is a solution to the fast degradation of virgin raw materials in the construction industry.

However, Ethiopia needs to improve in implementing legislative guidelines for C&D waste management, a lack of enforcement, insufficient collection, and disposal infrastructure. This study focuses on the obstacle dynamics of C&D waste management in Mekelle, Tigray.

Figure-1. 1: Accumulated Waste

1.2 STATEMENT OF THE PROBLEM

In most parts of the world, construction industry consumes huge amounts of natural resources and often generates large quantities of waste, and waste produced from the construction industry has a negative effect on the environment, cost, productivity, time, social and economy. According to the key findings of the United Nations, construction, and demolition waste accounts for approximately 40% of worldwide waste (United Nations, 2022). According to the Sustainable Development Goals (SDGs) of (United Nations, 2015), which refers to developing sustainable, secure, and resilient urban settlements, relies heavily on effectively managing C&D waste. However, many

obstacles to achieving sustainable C&D waste management exist, such as a lack of education, lax regulation enforcement, a negative perception of recycled goods, limited public awareness, and inadequate infrastructure.

In Ethiopia, the construction industry is the highest recipient of government budget in terms of government development program and these days the increased economic and urbanization has lead into extensive construction activities that generate large amount of waste materials. The excessive wastage of materials, improper management on site and low awareness of the need for waste reduction are also common in the construction sites of Tigray.

Construction waste can and should be managed in the same way as other home building operations. Reduce, reuse, and recycle construction waste may save money, reduce liability, keep job sites cleaner and safer, and conserve valuable landfill space.

Nowadays, Managing C&D waste is a critical and needs urgency in the present environmental context worldwide (Ma et al., 2020).

Thus, the paper is aimed at identifying the major challenges of construction and demolition waste management, and assessing the current waste management of construction projects in Mekelle. Besides the roles of different stakeholders would also be investigated in terms of their responsibility for construction waste management.

1.3 OBJECTIVE OF THE STUDY

The objective aims to understand the contemporary methodologies of Construction and Demolition (C&D) waste management and its challenges in the city of Mekelle. This includes an examination of the challenges of construction and demolition waste management; assessment of current practices of Mikelle's C&D Waste Management practices; analyzing factors contributing construction waste; and recommend remedial measures to sustainable management of construction and demolition waste in Mekelle, considering the potential opportunities and socio-political factors that may drive this shift by overcoming path dependency.

1.3.1 GENERAL OBJECTIVE

To identify the barriers of construction and demolition waste management, and to assess the current waste management in Construction Projects of Mekelle city. It also gives recommendations with respect to roles and responsibilities of different stakeholders in terms of their responsibility

for construction waste management in accordance with the outcome of the reviewed literature, and survey results.

1.3.2 SPECIFIC OBJECTIVE

a. To examine the factors that contribute construction and demolition wastes

b. To determine effects of waste in construction projects.

c. To assess the current waste management in the construction projects.

d. To identify the barriers of construction and demolition waste management practices.

e. To recommend construction stakeholders in terms of their roles and responsibilities towards construction waste management.

1.4 RESEARCH QUESTIONS

- ✧ What are the factors that contribute construction and demolition waste?
- ✧ What are the effects of waste on construction projects?
- ✧ What is the practice implemented for managing waste in the construction projects?
- ✧ What are the barriers of construction and demolition waste management?

1.5 SIGNIFICANCE OF THE STUDY

The research is significant because it refers to knowledge gaps about the existing state of C&D waste management systems and the barriers for better improvement. This research aims to improve the efficiency of Mekelle C&D waste management system by shedding light on these problems within a systemic framework and from the viewpoint of a resident. The results of this study help shape legislation and guidelines for managing C&D waste in the future.

This study intends to address a knowledge gap in the sector by investigating and analyzing the challenges and constraints of C&D waste management in Mekelle. The study's key findings serve as a springboard for creating viable strategies and interventions to address the problems pinpointed. It can also provide insights and help local officials, business leaders, and anyone interested in improving C&D waste management make more informed decisions. This research is crucial because it could lead to more ecofriendly and effective C&D waste management in Mekelle, positively impacting the city's ecology.

1.6 SCOPE AND LIMITATIONS

This study focusses on the challenges of construction waste management in Mekelle, and it relies heavily on qualitative research methods, such as in-depth interviews with various stakeholders, field visits and questionnaire to the contactors and consultants at construction site. The study was in collaboration with Mekelle city municipalities, seven construction projects and others to gets more information for the study of construction and demolition waste management. This may not allow investigating critically as many projects as possible. This research focuses solely on seven construction projects in Mekelle and it does not include any regional or international comparison. Due to a scarcity of government records and statistics on trash management in Mekelle, the study does not include more quantitative data or extensive statistical analysis. Instead, the study aims to shed light on the difficulties and potential solutions in enhancing C&D waste management in Mekelle by analyzing the actions of the relevant players and their adherence to the law.

Several limitations are associated with this research on C&D waste handling in Mekelle. Firstly, the research was conducted in Mekelle; therefore, its results and interpretations may not apply outside that city or region. In addition, the study's generalize ability may be constrained by the fact that Mekelle has distinct characteristics and poor waste management system. Second, there is always the chance that the number of stakeholders participating in the study is too small to provide a representative sample or collect data from various perspectives. Third, self-reporting bias is risky when using qualitative data from in-person interviews since respondents may give answers colored by their preconceptions and preferences. Furthermore, the lack of official quantitative data on waste management in Mekelle constrains the scope of statistical research and quantitative insights. Finally, the study's depth and breadth may have been affected by time constraints during data collecting and processing.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, an extensive review of literature studied by different scholars relevant to "the challenges of C&D waste management in construction projects" has been analyzed and presented. A conceptual framework, scholars' empirical studies related to the specific objectives of this study, gaps, and summary are sub-sections of this chapter. Input variables for questionnaire survey for each specific objectives from existing studies are identified. Thus, a significant body of scholarly literature has been synthesized regarding this subject matter and, by critically analyzing a diverse array of perspectives and findings from prior research, this review contributes to the existing knowledge base on sustainable waste management.

2.2 GENERAL DEFINITION OF WASTE

Waste, according to Augustin (2007), is any resource utilized in a work process or non-value adding activity that does not benefit the stakeholders and can occur at any time in any work system. Other different groups of concepts on the definition of "waste" have been identified from review of literature [17]. Accordingly,

a). Waste is considered as debris that needs to be removed from building sites and is often concerned with the environmental impact produced by construction and demolition material waste (based on the amount of waste generated due to excessive material consumption);

b). Specific types of waste (rework resulting from quality deviation, modification orders, or unfinished jobs), of which the cost components are frequently not discussed;

c). Lean production theory defines waste as non-value, operations that take up time, resources, or space but do not contribute value from the standpoint of the consumer. The new production philosophy states that waste should be understood as any inefficiency that causes the use of more tools, materials, labor, or capital than are thought to be necessary for the product.

In construction, Waste is generated during site preparation, material use, and material damage during handling, material non-use, excess procurement, and human error. Construction waste is produced in large quantity by infrastructure projects, renovation, or demolition of structures, etc. There can also be non-hazardous by-products generated. Components of Construction waste debris typically include concrete, sand, aggregate, plastic, flooring material, rubber sealants, glass, metals

and metal alloys, wood and wood-based products, masonry material etc. Land clearing debris, such as weeds, rocks are also included in construction waste [9].

In Australia, waste is categorized into three main classes of Commercial and Industrial waste, Construction and Demolition waste (C&DW), and Municipal Solid Waste (MSW) [19]. C&DW fundamentally includes masonry wastes such as asphalt, concrete, plasterboard, and bricks, organics (such as timber), metals as steel and aluminum, plastics, glass, paper and cardboard, textiles, leather, rubber, and others [18,19,20].

2.3 CONCEPT OF CONSTRUCTION AND DEMOLITION WASTE

Construction and demolition waste lacks a universally accepted definition, and its interpretation varies across different nations. In Japan, C&D waste is not classified as waste but rather is regarded as a by-product of construction activities. Other studies, as cited in (Chen, 2016), define C&D waste as the waste generated by activities involving construction, renovation, and demolition.

[2] Lu, and Yuan (2011) described Construction and demolishing waste as the waste which arises from construction, renovation, and demolition activities. Construction of new buildings, demolition of old structures and roadways, and maintenance of existing buildings all generate Construction and demolishing waste on a regular basis in urban settings [3] According to the Hong Kong Environmental Protection Department (2013), construction waste is defined as "any substance, item, or thing generated as a result of construction work and abandoned, regardless of whether it has been processed or stored before being abandoned,"

Similarly, Construction and demolishing waste defined by the Environmental Protection Agency (2015), as "materials containing debris created during the construction, renovation, and demolition of buildings, roadways, and bridges."

Construction and Demolition waste is a complex waste stream, made up of a wide variety of materials which 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, roadwork, and building renovation. It also includes incidences of wastages in labour and energy used in construction works.

2.4 SOURCES AND CONTRIBUTORS OF WASTE IN CONSTRUCTION

C&D wastes are generated from a variety of sources on a construction site such as; Civil Works, fitting out new buildings, Renovation old Buildings, Construction New Building, Demolishing Old Buildings. C&D waste can be classified according to its source, or type of works from which it is generated. In general, there are two sources for generation of waste materials, namely, bulk generators and retail or small generators. The infrastructure development sector and real estate sector are the bulk generators of waste. Real estate sector consists of housing, industrial, and commercial building construction, demolition of unauthorized structures etc. Small commercial enterprises and individual house building teams are considered as retail or small generators. Construction and demolition waste includes but not limits the followings: Fill materials, Glass, plastic, Carpeting, Electrical wiring, Pipe and metals, plumbing fixtures, Roofing shingles and other roof coverings, Land clearing debris other than yard waste, Wood (including painted and treated wood, Drywall, plaster, and non-asbestos insulation, Wall coverings (including wallpapers, paneling, and tile) etc.

According to the survey on [1], the disposal of construction and demolition waste at landfills has caused major environmental concerns and, also there is an acute shortage of landfill space in Malaysia and the continuation of disposal of construction and demolition waste at landfills would risk to the strategic use of landfills for the disposal of the more demanding waste types such as domestic refuse and hazardous waste.

2.5 CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT

The reduction of construction waste and its management are now major and difficult environmental issues in developing cities all over the world. In lower-income countries, as well as poorer parts of middle-income nations such as Ethiopia, an estimated of 30 to 50% solid waste produced in urban areas is left uncollected [12].Due to the growing amount of demolition debris, the ongoing lack of disposal locations, the rise in transportation and disposal costs and most importantly, the growing worry about pollution and environmental deterioration, the management of construction and demolition waste is a serious challenge [5].

Dumping in landfills is the method of managing construction waste that is most frequently used. However, landfill capacity has resulted in rising, waste disposal expenses for the contractor [4]. The process of managing construction waste goes far beyond the disposal of the wastes itself. Alternative techniques and waste prevention strategies are now necessary. The "waste hierarchy approach" presented by a wide triangle at the top and becomes narrow down, is a common

foundation for current waste management techniques. Today, in most European countries, it is economically feasible to recycle up to 80–90% of the total amount of construction waste and most demolition and recycling technologies are generally easy to implement and control [15]. According to the study on [10] there are two fundamental reasons for reducing, reusing, and recycling waste: the economic advantages, and the environmental advantages. The environmental advantages include the minimization of the risk of immediate and future environmental pollution and harm to human health while the economic advantages include lower project costs, increased business patronage, lower risk of litigation regarding wastes amongst others.

According to scientific research, waste management tactics that emphasize minimizing, reusing, and recycling of C&D waste help to achieve sustainable waste management [6, 7].

Reduce, reuse, recycle, compost, incinerate, and landfill (Peng et al., 1997) is a hierarchy of disposal choices that categorizes environmental impacts into six stages, the "3Rs" are a collection of three key waste minimization strategies: reuse, recycling, and reduction.

Reusable materials are Materials in good shape include high-quality wood or steel structure and manufactured pieces of concrete blocks, bricks and tiles of both roofs and floors. In addition, excavated material and demolition concrete waste is suitable for sub-base material in road construction. Whereas Recyclable materials are, Materials such as glass, plastic, metals etc., can be reincorporated into the recycling process. Depending on the impurities, producing products that generate waste can use recycled raw materials.

The other strategy waste minimization is to use by- products materials such as; demolished Concrete, stones, precast elements, testing cubes, and ceramics are suitable sources for manufacturing secondary products, from which recycled aggregates are produced and used in the fabrication of fresh concrete.

The information from Department of the Environment and Transport in Nigeria, (2000) revealed that most effective environmental solution may often be to reduce the generation of waste. To reduce construction waste generated on site, coordination among all those involved in the design and construction process is essential.

Where further reduction is not practicable, products and materials can sometimes be re-used, either for the same or a different purpose. Failing that, value should be recovered from waste, through recycling, composting or energy recovery from waste.

Only if none of these solutions is appropriate waste should be disposed, using the best practicable environmental option.

According to solid waste management in Ethiopia several legislations, proclamations, regulations, directives, and guidelines have been issued. In [12] Manuscripts that address solid waste management policy, education, and economic and environmental assessments, and information on solid waste generation, characterization, minimization, collection, separation, recycling, treatment, and disposal is presented and discussed in solid waste management.

A significant proclamation that covers solid waste management, especially the management of construction waste, is Solid Waste Management Proclamation (SWMP) No. 513 of 2007 which address the management of solid building waste. The declaration seeks to strengthen the ability to avert any negative effects and turn solid waste into assets that will benefit society and the economy. Another relevant proclamation is Environmental Pollution Control Proclamation (EPCP) No. 300/2002. The proclamation requires urban administrations to develop and put into place secure and reliable systems for managing, moving, and storing municipal waste. According to the proclamation under article 5, Management of Municipal Waste, Urban administrations are required to oversee the collection, transportation, and, where necessary, the recycling, treatment, or safe disposal of municipal garbage through an integrated municipal waste management system.

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes" [17]

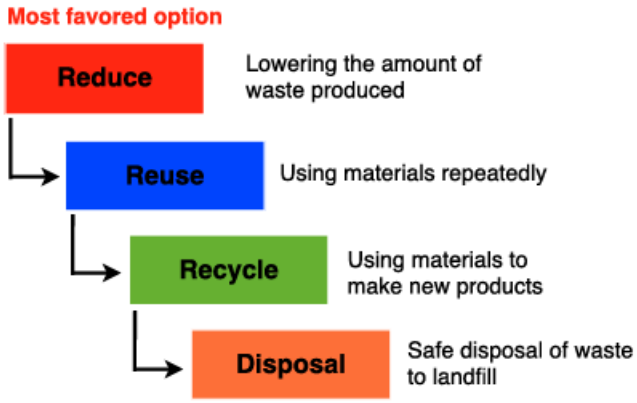

Figure-2. 1: Hierarchy of waste management

2.6 BENEFITS OF WASTE MANAGEMENT

Reducing waste will not only protect the environment but will also save on costs or reduce expenses for disposal. Waste Management in Construction activities has been promoted for the aim of increasing profit from project and protecting the environment [9]. The reported [8] revealed that the net benefit of reusing and recycling of waste materials is estimated at 2.5% of the total project budget. Recycling and/or reusing the waste that is produced benefits the environment by lessening the need to extract resources and lowers the potential for contamination. According to Authors [8, 10 & 12] also, there are two fundamental reasons for waste management, the economic and the environmental advantages. The environmental Advantages Reduced quantity of waste generated and hence, minimized amount of wastes disposed at landfills to extend the life span of landfills; Reduced Environmental effects (noise, pollution) and decreased global warming; Conserving natural resources due to recycled packaging. Whereas economic advantages reduced Transportation cost, Less Disposal Cost, Minimized Purchase quantity and raw materials, Reduced Purchase price of new materials (considering reuse and recycling), Increased returns by selling waste materials to be reused and recycled. Other than these, there are other Advantages of waste management namely enhanced Work Efficiency and Productivity; Improved Profit Margin; Improved image of the company; Competitiveness and Client Satisfaction; and Increased site safety.

2.7 REVIEW OF EMPIRICAL STUDIES.

Waste Generation Factors in Construction Life Cycle

Waste is generated at different stages of construction process and, also there are various factors that cause construction waste generation. Researches revealed that construction waste is effectively generated along the project from start until completion. Construction life cycle (CLC) is defined as the whole process from creating the construction intention to abolishing the project, which includes the project decision-making stage, implementation stage and operation stage. Life cycle of a project includes several phases which are conceptual planning and feasibility studies, design and engineering, construction, and operation and maintenance.

The most frequently occurring factors in construction phase that are very significant in generating waste during construction phase are Ordering error and poor workmanship. On the other hand, the most frequently occurring factors in design and finishing phases is “last minute client

requirement." In fact, clients may request any change or additional requirement and facility in their project; however, if work is in progress, this will require additional time, cost, and material. Similarly, in planning phase, the factor that contributes to waste is lack of waste management plan. A Study [9] shown that Waste disposal practices of most construction projects in the world is almost similar fashion. The trend is just like remove waste to privately owned site, low-lying land for a price purpose, or more commonly dumping it in unauthorized manner along roads or other public land or the region. In contrary, research revealed in countries like United States of America, Japan, United Kingdom, France, Germany, and Denmark etc. There is possibility of using construction waste to substitute new materials of recycling which may help in reducing cost of the project and avoid sustainable impact on the environment.

The results of a Study [22] in building construction projects dealt key measures to minimize construction material wastes. Such major measures are; employing waste management officers for this purpose, using prefabricated or off-site production of components, appropriate on-site waste management, and incorporating a policy of material waste minimization plan.

Effects of C&D wastes in construction projects

A study [21] was conducted on analysis of the socio-economic and environmental impacts of construction waste and management practices in Addis Ababa building construction projects. It used a questionnaire survey, in depth interview and review of literatures, and survey was sent to clients, consultants, and contractors using purposive sampling techniques. The result indicated that project cost overrun, pollution of the environment, reduction in profit and failure of construction firms, excessive consumption of raw materials, and public health and safety risks are ranked as the five major impacts of construction waste, respectively. And employing a waste management officer, using prefabricated or off-site components, implementing strong onsite management practices, reusing, and recycling materials leftover on the sites, and practicing green building codes and specifications are recommended measures to mitigate construction waste and its impacts.

Construction and Demolition Waste Management Barriers

Cochran, (2001) and Barnes, (2002), assessed the potential demand for construction and demolishing waste materials (recycled material and the barriers to use deconstruction and reuse/recycling materials. The result of his study in Canada shown that lack of knowledge about the value of reused material; the perception among industry professionals (demolishing costs is

more); The short deconstruction turnaround time; Poor waste management planning; lack of cooperation among subcontractors, and lack of a market for reused material were identified as major challenges. Similarly, his study in Germany revealed that construction stakeholders perceive the following; existing buildings are not designed to be dismantled, suitable deconstruction equipment is not available, disposal to landfills is often more cost effective, material separation can be time consuming, building codes may limit the reuse of some structural components, dismantling costs are uncertain, there are no "best practices," in place etc.

The research conducted by 14 found the following five main construction and demolition waste management hinders and their proposed solutions.

A research study of [15] identified most common practices of CDW management. Their study indicated that; indiscriminate dumping, dispose mixed waste of concrete, bricks, and soil in landfills, separate and sell most marketable materials, such as steel, metals, wood, and plastics to recyclers, and other CDW dump illegally are the common practices in Vietnam. The study announced the reduction of illegal dumping of CDW was a big challenge as recycling of CDW was not yet fully developed in Vietnam. On the top of this, the following Major Problems namely; illegal dumping, hazardous waste, and depletion of natural resources caused by insufficient CDW management were examined.

[13] Conducted research and he found the following barriers for adoption of construction and demolition waste management (Reduce, reuse, and recycle) system in India. Such challenges are; Lack of Awareness in the Industry (among local contractors, construction labor and architects about waste management techniques and approach); Lack of interest from clients (in imposing waste reduction and management practices into the projects); Lack of proper training and education: Lack of skilled labor(Major portion of construction labor in the industry is unskilled); Lack of market competition; Lack of Government Interventions (Regulations like landfill tax or tax incentives to incorporate this approach in the project might enforce industry to explore cost savings seriously); and Lack of waste reduction approach by architects.

Similar study [22] which adopted combine site visits, and semi-structured interviews was identified challenges of construction and waste management. The identified results are;(1) unstable source of C&D waste for recycling, (2) absence of subsidies for recycling activities and high cost for land use, (3) insufficient attention paid to design for waste minimization, absence of regulations on on-site sorting, (5) unregulated landfill activities, (6) a lack of coordination among different

government administration departments, (7) a lack of accurate estimation of waste quantity and distribution, and (8) a lack of an effective waste tracing system

Summary of the literature review

In this chapter, an extensive review of various scholars has been presented. From the literature review, it is observed that most of the studies were carried out on the factors that generate waste, effects of waste, and the impacts of ineffective waste management in construction projects. In addition to that, in some studies experiences of current construction projects and the roles and responsibilities of their stakeholders has been identified. However, various studies revealed that there are limited studies on challenges of construction and demolition waste management globally, and specifically in Mekelle. Further from the literature review, it is observed that, research work on challenges and current practices of construction and demolition waste management is scanty. In the present research study, an attempt has been made to evaluate the current practices of seven Mekelle construction projects and the challenges towards effective construction waste management.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research plays a critical role in resolving a variety of operational and strategic issues. This chapter's major purpose is to detail the research procedure followed. It explains the methodology used, the data-gathering methods and tools used, the analysis techniques followed. By raising awareness of construction and demolition waste management, this research will identify the major challenges on proper management of construction and demolition waste. A review of the literature on the subject was conducted first, based on the description of the problem. Following the literature review, the research employs both semi structured interview and questionnaire survey to collect data from construction industry of the seven sub cities of Mekelle and Mekelle municipality. Construction Stakeholders were asked to complete and answer questionnaires and interviews for this purpose. Finally, the data were analyzed to determine their level of importance and ranking.

3.2 THE RESEARCH TYPE.

The class of the research used in this study was exploratory research which identify the barriers of implementing proper construction and demolition waste management practice and recommend solutions by categorizing in to the roles and responsibilities of each construction stakeholders.

3.3 RESEARCH APPROACH

The research involves a combination of qualitative and quantitative approaches. Qualitative research is an approach for exploring and understanding the meaning individuals or groups describe to a social or human problem. Whereas quantitative research is an approach for analyzing numbered data using statistical procedures. Mixed methods research is an approach to inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data. The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone.

3.4 RESEARCH DESIGN AND METHODS

3.4.1 *RESEARCH* DESIGN

The approach utilized in constructing the framework of research is known as research design, and its major goal is to successfully answer research questions to satisfy the research objectives [28]. In this research, the design was created based on analysis of literature review, semi structured interview, and questionnaire survey. Based on the respondents' responses from interview and literature review a questionnaire were prepared and distributed to assess current practice and identify major challenges of construction and demolition waste management. And then the collected data were analyzed to identify the main challenges of proper construction and demolition waste management practice. Data analysis was made based on the relative importance index of the Likert scale RII. Then the main challenges of C&D waste management were identified. Generally, to fulfill the research aims, questions were designed using information acquired from literature, data were collected for each specific objectives, data were processed and analyzed then interpretations and discussions on the findings were drawn.

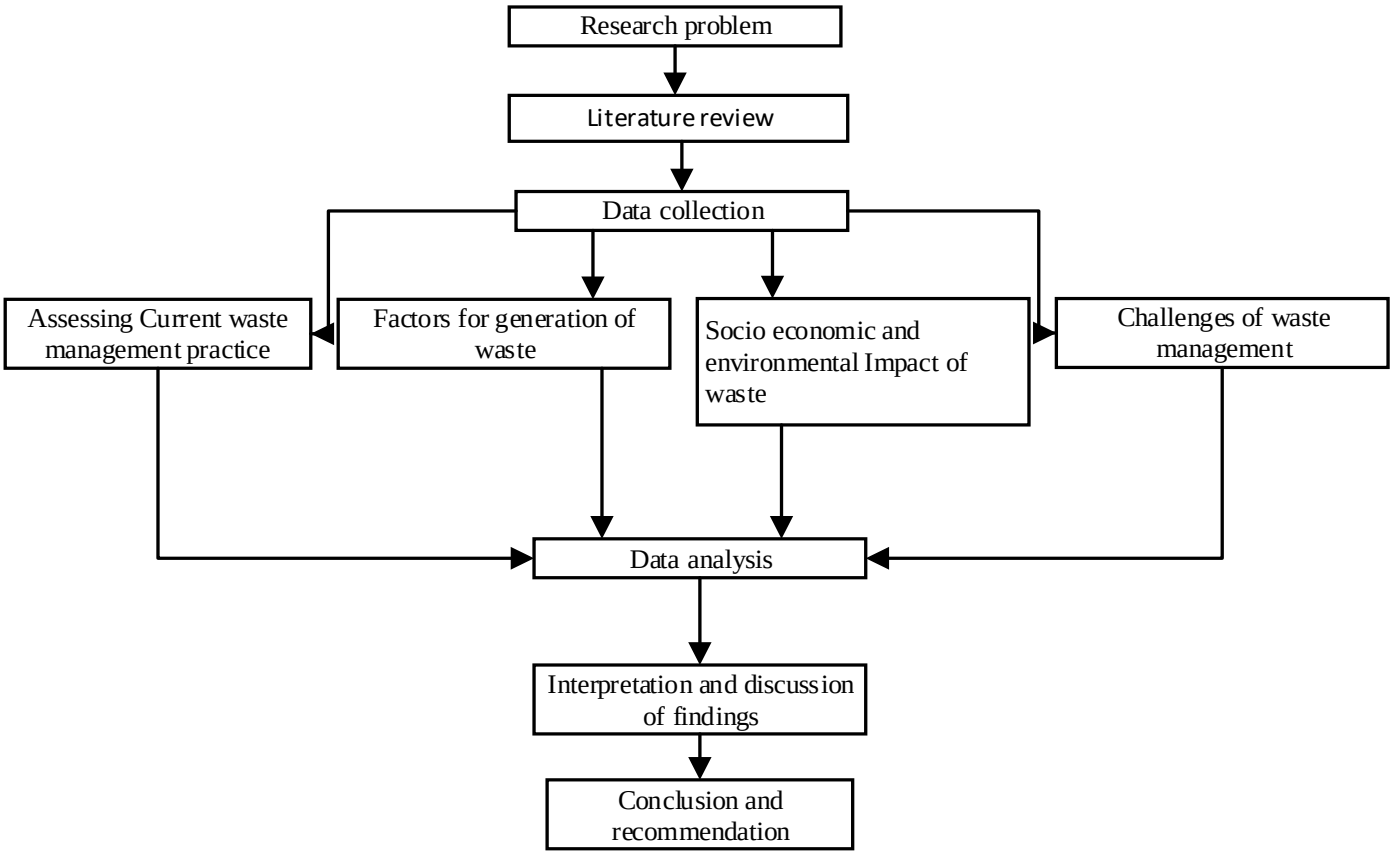

Figure-3. 1: Research structure flow chart

3.4.2 RESEARCH METHODS

3.4.2.1 DATA COLLECTION METHOD

This research uses a combination of literature review, survey questionnaire and interview, to identify the factors that contribute waste, effects of waste and challenges of construction and demolition waste management. Data are both primary and secondary sources of information.

Primary Data: In the present study, data were primarily obtained through semi structured interview which was conducted with the construction stakeholders i.e. construction industry of the seven sub cities of Mekelle and Mekelle municipality and individual having contribution in C&D waste management. The conducted interviews aimed at assessing the current practice and major challenges on construction and demolition waste management. The methodology entailed conducting face-to-face interviews' field visits and personal communication.

Secondary Data: Secondary sources, like scholarly articles, reports, policy documents, and public records, were used to gather information for literature review of C&D waste management.

This study was carried out by semi structured interview and a closed ended questionnaire with key construction stakeholders. First, the respondents were interviewed by asking background, their profession, organization, years of experience, what are the primary causes of waste, social and environmental impacts of waste, strategies and technologies adopted to reduce waste, challenges in implementing proper waste management. Based on the respondent answer from interview and literature review, questionnaire was prepared and distributed based on a 5-point Likert scale.

The questionnaire was designed in such a manner to produce responses that could be easily analyzed using closed ended questions with suggested answers on ordinal scales. A questionnaire to a total of thirty-five (35) respondents were distributed and thirty (30) of them were returned.

In addition, the opinions of the respondents were also gathered with relevant closed ended interview questions to find suitable recommendations on the findings of the research.

3.4.2.2 RESEARCH POPULATION AND SAMPLING

The targeted population for this study is all contactors and consultants in the construction projects and some selected municipality professionals in Mekelle city. It was selected purposively. A sample is derived from the target population to identify information-rich participants whose understanding was important for the study. The samples were all professionals in the construction project from the seven sub cities of Mekelle and Mekelle municipality, i.e. consultants, contractor, and construction bureau of Mekelle.

3.4.2.3 DATA ANALYSIS METHOD

The analysis had combined all responses from, groups of respondents (consultants, and contractors, and municipal professionals) to obtain significant results. Data were analyzed by calculating frequencies and Relative Importance Index (RII) then ranked. To identify factors, and effects of waste, and the main challenges of construction and demolition waste management, the ranking and analysis were made. Relative importance index (RII) was used for generating an index and used to show the level as perceived by research respondent [29] [30]. To determine the relative ranking of factors, the scores were transformed into important indices based on the following equation [31];

$$RII = \frac{\sum w}{A*N}$$

Were

W = r*n

r = is the weighting given to each factor by the respondent, ranging from 1 to 5 in which '1' is very low importance and '5' is very high importance;

n = the frequency of respondent for each factor

A is the highest weight, in this study r = 5

N is the total number of samples, 30 for this study, and RII the relative important index, $0 \leq RII \leq 1$. Low value $RII < 0.5$ have less influence, medium value $0.5 < RII < 0.7$ have medium influence, high value of $RII > 0.7$ have large influence

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 RESULTS

This chapter describes the analysis and results of the questionnaire survey and interviews conducted in Mekelle construction projects. The chapter consists of two main sections namely the results and the discussions. The sub sections include the questionnaire results and analysis of respondents' background information, the factors, effects, the Companies' Current waste management practices and barriers of construction and demolition waste management**.**

Table 4.1. 1: Background Information of Respondents

Characteristics of respondents	Frequency	Percentage (%)	Characteristics of respondents	Frequency	Percentage (%)
Company			Position		
Contractor	15	50%	Project manager	4	13.33%
Consultant	8	26.67%	Site engineer	8	26.67%
Local authorities	7	23.33%	Office engineer	5	16.67%
Academic rank			Quantity surveyor	2	6.67%
Diploma	5	16.67%	Site supervisor	3	10%
Degree	17	56.67%	General Forman	6	20%
Master and above	8	26.67%	Designer	-	0%
Work experience			Architect	-	0%
1–5year	12	40%	Resident engineer		
6–10year	13	43.33%	Contract Administrator	2	6.67%
11–15year	3	10%			
>= 16year	2	6.67%			

As indicated in the table, the respondents for this study are professionals from contractors (50%), consultants (26.67%), and municipalities (23.33%). Contractors have taken the largest portion of this study in which construction and demolition waste management is highly concerned. Respondents from the consultant side take the second largest portion next to contractors, and respondents from municipality have the smallest portion in the present study.

Respondents were also asked to fill out their academic rank, accordingly 56.67% (17) of the respondents are degree, 26.67% (8) masters and above, and those 16.67% (5) have an academic rank of diploma. This shows that most of the respondents involved in this study have an academic status of degree and master. It was also required that the respondents' experiences in the organization, and provided as most of the respondents, as shown in the table, are fallen in the range of 6 to 10 years. It indicates that the questionnaire was filled out by experienced professionals and is reliable data. The study was also intended to know the position of respondents who filled out the questioner, and it was found that most of them were from site engineers (26.67%) and general Forman (20%). Project managers (13.33%) and office engineers (16.67%) covered the third and second portion of the total respondents respectively.

Table 4.1. 2: Factors contributing to waste generation in construction project

Factors contributing to waste generation	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
Improper material Handling and storage	126	0.84	1
Poor Supervision	124	0.83	2
Lack of skilled man power	118	0.79	3
Design (late) Changes	108	0.72	4
Material Deterioration	90	0.41	5
Manufacturing defects	86	0.38	6
Over ordering of a quantity greater than required or earlier than necessary	**79**	0.33	**7**
Overestimated quantity	**73**	0.33	**8**

Legend: Very high effect =5, High effect =4, mid effect =3, little effect =2, Very little effect =1

The factors that contribute to construction wastes are ranked based on respondents' rate and the RII of the eight (8) factors are shown in Table 4.1.2. The respondents stated that the improper material handling and storage, poor supervision, lack of skilled man power and design changes, with RII values of 0.84, 0.83, 0.79 and 0.72 respectively, were the most contributing factors at their organization. These factors may have essential impact on the construction waste generation. On the other hand, material deterioration, manufacturing defects, over ordering of a quantity, and

overestimated quantity have less contribution for the construction and demolition waste generation.

Table 4.1. 3: Impact of waste on construction project

Effect of waste in construction project	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
Project cost overrun	128	0.85	1
Environmental Pollution	126	0.84	2
Reduction in profit	124	0.83	3
Resources depletion	122	0.81	4
Public health and safety risks	122	0.81	5
Delay of project completion time	115	0.56	6
Land occupancy or land consumption for dumping waste	105	0.52	7
Disagreement between construction parties.	108	0.41	8

Legend: Strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1

Table 4.1.3 shows the RII ranks of the eight (8) effects of waste. The result indicates that Project cost, environmental pollution, reduction in profit and resources depletion, with RII value of 0.85, 0.84, 0.83 and 0.81 respectively, have significant negative impact on C&D waste management. Whereas, the effects of delay project completion time, land consumption for dumping waste and disagreement among construction parties, have less impact compare to the above factors which have higher RII.

Table 4.1. 4: Challenges for proper construction and waste management practice

Improper planning and waste management practice (IPWMP)	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
Ineffective waste management plan	134	0.91	1
Insufficient waste management training programs	121	0.86	2

Poor supervision practice	119	0.82	3
No waste minimization motivation	116	0.52	4
Poor waste segregation practice	111	0.51	5
Limited waste recycling facilities	110	0.47	6
No adoption to recycling technology	99	0.43	7

Legend: Strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1

Table 4.1.4: shows the rank of seven (7) construction waste management challenges based on RII values. Result of the respondents at the organization revealed that the ineffective waste management plan, insufficient waste management training programs, poor supervision practice, with RII value of 0.91, 86, and 0.82 respectively, are the most challenging factors for construction and demolition waste management, However those with lower RII values, No waste minimization motivation, poor waste segregation practice, limited waste recycling facilities and no adoption to recycling technology are less challenging factors compare to the above with higher RII values.

Table 4.1. 5: Inefficient Government waste management regulatory policy (IGWMRP)

Inefficient Government waste management regulatory policy (IGWMRP)	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
Lack enforcement of regulations	129	0.87	1
Absence of training on waste minimization strategies for construction firms	123	0.82	2
Insufficient legislation and regulation	117	0.78	3
Lack of Government incentives	114	0.76	4

Legend: Strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1

Table 4.1.5: also shows the RII ranks of the four (4) challenges that are grouped under the IGWMRP. Almost all factors i.e. Lack enforcement of regulations, absence of training on waste minimization strategies for construction firms, insufficient legislation and regulation and lack of Government incentives are factors with high degree of challenge for construction and demolition waste management.

Table 4.1. 6: Lack of awareness of construction stakeholders (LACS)

Lack of awareness of construction stakeholders (LACS)	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
Low Concern for socio-economic and environmental effect of wastage	139	0.93	1
Resistance to change traditional practices	132	0.88	2
Poor coordination among construction stakeholders	125	0.83	3
Believing waste not a problem on site	115	0.77	4

Legend: Strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1

Table 4.1.6: shows the RII and ranks of the four (4) challenges that are grouped under the LACS. In this group almost all factors i.e. Low Concern for socio-economic and environmental effect of wastage, resistance to change traditional practices, poor coordination among construction stakeholders and believing waste not a problem on site are factors with high degree of challenge for construction and demolition waste management.

Table 4.1. 7: Insignificant return compared to High Costs of waste management (IRCHCWM)

Insignificant return compared to High Costs of waste management (IRCHCWM)	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
High cost and low quality of recycled materials	129	0.86	1
Lack of demand for recycled materials	126	0.84	2
High cost of waste disposal	123	0.82	3
Lack of supplies recyclable waste	113	0.59	4
Lack of available landfill	112	0.51	5

Legend: Strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1

Table 4.1.7: shows the RII and ranks of the five (5) challenges that are grouped under the IRCHCWM. The High cost and low quality of recycled materials, lack of demand for recycled materials and high cost of waste disposal are the most challenging factor for construction and

demolition waste management. But the Lack of supplies recyclable waste and Lack of available landfill were less challenging factors.

Table 4.1. 8: Major Challenges of construction and demolition waste management

MAJORE CHALLENGES	Total Weight $\sum W$	RII $RII = \frac{\sum W}{A * N}$	RANK
Lack of awareness of stakeholders	140	0.93	1
Improper planning and waste management practice	134	0.91	2
In efficient government waste management regulatory policy	131	0.87	3
Insignificant return compared to high costs of waste management	127	0.85	4

Legend: Strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1

Table 4.1.8: also shows the RII and ranks of the five (5) major challenging groups. Lack of awareness is the most challenging group with RII value 0.93 whereas the improper planning and waste management practice is the second challenging group with RII value of 0.91. The in efficient government waste management regulatory policy is ranked as the third challenging group with RII value of 0.87and Insignificant return compared to high costs of waste management is third challenging group with RII value of 0.85.

Table 4.1. 9: Companies' responses of C and D waste implementation practices

Company's Responses	Frequency	Percent (%)
Yes	11	36.67
No	19	63.33
Total	30	100

Table 4.1.9: Represents data from the questionnaire related to seven construction projects in Mekel C&DW management practices from 30 stakeholders' perspectives. C&DW management satisfaction in Mekelle generated a range of responses among the participants in this survey. Most respondents (63.33%) stated that no specific construction and demolition waste management

practices were in place at their organization. Whereas, 36.67% (11) of construction companies implemented waste management strategies capable of mitigating construction waste.

Participants who answered "yes" (36.67%) were asked to express their experience with waste management practices used in construction projects via closed and an open-ended questionnaire, interviews, and the result of closed ended questionnaire is as follow.

Table 4.1.10: Companies' Current waste management strategy practices

Table 4.1. 10: Companies' Current waste management strategy practiced

Sn.	**Aspects related to companies' current waste management practice**	ΣW	RII=ΣW/N*5	Rank
1	Use prefabricated or off-site production of components	97	0.808	1
2	Resource optimization practice	91	0.758	2
3	Sufficient legislation	87	0.725	3
4	Use recent plants and machinery	86	0.717	4
5	Considering for environment effect of waste	78	0.650	5
6	Incorporate waste minimization plan	72	0.600	6
7	Concern for Public health and safety issues	68	0.567	7
8	Create awareness among the construction work members	71	0.592	8
9	waste Segregation and sorting process	67	0.558	9
10	Implementing proper waste disposal	66	0.550	10
11	Strong coordination among stakeholders throughout project life.	61	0.508	11
12	Practice 4R waste management techniques	57	0.475	12
13	Adopt recycling technology to recycle waste materials left-over on site	57	0.475	12
14	Proper Storage and materials handling	46	0.383	13
15	Provide Waste management training for workers	44	0.367	14
16	Strict Supervision and penalty on WM	44	0.367	14
17	Establish strategies and guidelines for use of recycled material	44	0.367	14
18	Government incentive and training related to waste minimization to construction firms	36	0.300	15

19	Offer incentives and tender premiums related to waste management (by client)	36	0.300	15
20	Employ waste management officer	33	0.275	16
21	Conduct waste audits	33	0.275	16

Legend: Not practiced = 1, minimal practice = 2, practiced =3, Highly practice = 4

From Table 4.1.10: it is observed that construction projects performed waste management through aspects; Use prefabricated or off-site production of components; Resource optimization practice; Sufficient legislation; Use recent plants and machinery, and considering for environment. It also indicates that the level of waste management and its degree of practice is rank by the variables' relative importance index, which indicated by highest value at the top for i.e. Use prefabricated or off-site production of components, and lower going down i.e. considering for environment. In this present study revealed that construction companies commonly exercise those waste management strategies with highest RII and less or not exercised with those lower and least RII. Hence, respondents stated that the construction projects were a little use or didn't use the strategies with the RII values 0.275 (for Conduct waste audits and Employ waste management officer), 0.3000 (for Offer incentives and tender premiums for waste management and Government incentive and training), 0.367 (for Establish strategies and guidelines for recycled material, Strict Supervision and penalty, Provide Waste management training for workers) , and 0.383 (for Proper Storage and materials handling) at their organization.

4.1.1 Interview Survey Results on current Construction Waste Management Practices

The survey responses indicate significant dissatisfaction and lack of engagement with construction and demolition waste (C&DW) management practices. They have no an effective recycling policy in the construction industry and waste segregation is not being practiced, leading to mixed waste disposal. Recycling initiatives are either absent or poorly executed in practice and the contract clause did not include the use of recycled materials. In addition, the existing waste disposal methods are perceived as inefficient or unsustainable. They believe that government bodies do not play an active role in waste treatment. They perceive lack of regulatory enforcement or support from authorities in managing C&DW. The policy may be seen as ineffective, poorly enforced, or impractical.

4.2 DISCUSSION OF RESULTS

This section contains a complete discussion, interpretation, and evaluation of the results from the literature review, interviews, and questionnaire survey. Where the output from the interviews and the results/findings from the questionnaire survey were triangulated to answer research questions. A detailed discussion was carried out on the four key terms in this research: the factors and effects of construction waste, the investigated challenges of waste management; the companies' current waste management implementations; and the roles of stakeholders towards construction waste management.

4.2.1 Discussion on Factors Contributing to Waste generation in Construction Project

Several factors rated by the survey respondents with respect to their effect on construction waste generation have been identified and ranked according to their relative importance index RII as shown on Table 4.1.1. The three factors with the highest RII were improper material handling and storage, poor supervision, lack of skilled man power and late design changes.

Improper material Handling and storage is ranked the first highest key cause of construction waste generation with relative importance index value of RII = 0.84. This problem highly affects brittle and corrosive materials which end up as waste if not properly handled and stored .in Mekelle there are construction material here and there which are not properly handled and stored and that's why this factor is the highest contributor to waste. A very comprehensive and good storage technique should be adopted for better protection of materials at site.

Poor supervision is the second factor which contribute to generation of waste with RII = 0.83. Supervision plays an important role in waste generation. Less control paid to workers during material transportation, handling, and usage on site causes generation of waste [49] The project managers need to assign a good dedication supervisor at the site. The poor supervision lead to poor workmanships and improper material handling done by workers generating construction waste. Thus, strong supervision is the key controlling mechanism that should be used to be effective in eliminating these waste causes.

Lack of skilled man power is the third highest factor with RII = 0.79. Construction is a labor-intensive industry in which workers' behaviors, skill and work attitude are likely important in

successful construction waste management, and controlling or reducing waste generation. The workers mistake occurs due to untrained laborers, lack of skills and poor working attitude always generated material waste [49] The mistakes can be avoided by selecting a competent worker for site works. Workers should have a good working culture and must responsible to their daily works. If these steps taken positively by the workers, the waste generating can be minimized during construction.

The Late design changes was found the fourth factor for generating construction waste with relative importance index RII value of 0.72. This factor happened because of late client's need changes during the construction activities. The main sources of this problem is lack of timely communication between designers and the clients during design work. Whenever changes occurs after the construction starts, it may require rebuild according to new drawings need, it may be a must to change a construction material with new one, a lot of rework and material change may be required to substitute the previously purchased material which leads to waste. Therefore, to overcome this problem, more attention should be given in waste reduction during design phase. The parties, who involve in any construction projects, should always have a good communication with clients to avoid the last minutes changes.

4.2.2 Discussion on Impact of Waste on Construction Project

Several factors rated by the survey respondents with respect to the effect of waste on construction project have been identified and ranked according to their relative importance index RII as shown on Table 4.1.2. The five effects of waste with the highest RII value project cost overrun, environmental pollution, reduction in profit and resources depletion and public health and safety risks.

Project cost overrun is ranked the first impact caused by construction waste with relative importance index of RII = 0.85. Ones if construction waste occurs on construction sites, there will be a need to replace and rework, transport, and dispose of waste materials that require extra costs. In this regard, waste has been noted as a negative economic impact by contributing additional costs [32] [33].

Environmental Pollution ranked second impact of waste with RII = 0.84. Waste generated on construction sites pollutes the environment by releasing chemicals and other materials into it. . The

construction industry generates a significant amount of waste that causes environmental pollution [34] [35] [36] by contributing more than 33% of global CO2 emissions [37]. In Ethiopia, especially in Mekelle there are no policy implications, characterization, or methods of separating harmful construction waste and disposing of them. The reduction of construction waste means reducing the amount of hazardous waste and, in turn, reducing the impact of waste on the environment [38].

Reduction in profit that causes the failure of construction firms is the third impact due increased generation of construction waste with RII = 0.84. The profit of construction companies depends on the proper use of material resources or resource efficiency. Construction waste results in financial loss causing a reduction of the profit and failure of the construction sector [39] [40]. Nowadays, construction waste is a critical issue faced in many countries of construction projects. For example, [32], demonstrated that construction waste is one of the leading causes of business failure among building stakeholders in developing countries.

Depletion of natural resources due to excessive consumption of raw material is the fourth impact one with relative importance value of RII = 0.81. The main sources of construction materials are nonrenewable and are increasingly degraded and depleted. The construction project consumes bulk non-renewable resources and raw materials, along with generating great quantity waste [41] [42]. Improper management of waste resulted in the depletion of natural resources [43].

Public health and safety risks is the fifth affected by construction waste with RII=0.81. Improper waste disposal contributes to air and water pollution, both of which are harmful to human health and have serious consequences for the welfare of the communities [44] [45] [46]. The negative impacts caused by construction waste include; aesthetically unattractive surroundings, loss of land, increase in the spread of diseases, community health suffers in the vicinity of waste accumulation, and air and water pollution [47]. This study has indicated construction waste has a potential impact on the health and wellbeing of society as it is mostly disposed of near residences and significantly pollutes the environment.

4.2.3 Discussion on companies' current practices of C & D waste management

This present study indicated that the most widely adopted methods at construction projects were; Use prefabricated or off-site production of components, Resource optimization practice, sufficient legislation, and use recent plants and machinery, which grouped under practiced and advanced

practice Likert scales. Interviewees suggested that low-waste construction technologies could help reduce, reuse, or recycle C&D waste. Such technologies include prefabrication, innovative formwork and false work, and low-waste structures which in lined to the present study

The result demonstrated that Resources optimization is highly practiced at their organizations. As cited in [30] awareness of resource saving and environment protection is a vital driver for C&D waste minimization. Nonetheless, during the interviews, we observed that both managers and constructors have little awareness of saving resources and protecting the environment through WM. Interviewees perceived that conducting C&D WM usually means increased project costs and therefore a reduction of company profits. They made it very clear that they care more about cost, time, and the quality specified in the contract than C&D waste reduction.

The responses from construction members shown that there are sufficient legislations at their organization for construction and demolition waste management. Nevertheless, interviewees suggested that a change of the current C&DW Management mindset can be enhanced not only by the development of sufficient legislations on C&DWM systems within companies but also by the enforcement of these government policies and legislations. Interviewees reflected that current policies for C&D WM are generally ineffective, although the promulgation of various C&D WM laws and regulations has improved the situation. The biggest problem is that most current policies are not detailed enough for guiding and enforcing C&D WM.

In fact, these are interesting practices towards the management of construction wastes, but many of the respondents showed a poor adoption of different methods of managing construction wastes. So, the construction Professionals' understanding of construction waste management was found to be deficient, and the adoption and practice further hampered by the following methods of managing construction wastes. Such methods are shown in table 4.1.10. Based on the responses on current waste management practices at construction sites. The result of respondents revealed that lack of enforcement sufficient legislation, absence of waste management officer, offer incentives and tender premiums related to waste management (by client), Government incentives and training towards waste minimization, establish strategies and guidelines for use of recycled material, Strict Supervision, and penalty etc. are the waste management methods missed at their organizations.

4.2.4 Discussion on Barriers of Construction and Demolition Waste Management

The other key term studied in this research is the barriers of construction and demolition waste management. The following are the top major challenges found in this present study.

- Ineffective waste management plan
- Insufficient waste management training programs
- Poor supervision practice
- Lack enforcement of regulations
- Absence of training on waste minimization strategies for construction firms
- Low Concern for socio-economic and environmental effect of wastage
- Resistance to change traditional practices
- Poor coordination among construction stakeholders
- High cost and low quality of recycled materials
- Lack of demand for recycled materials
- High cost of waste disposal

The listed barriers are only those having highly and moderately significant difficulties on Construction and demolition waste management efforts. Other factors having significant challenges, but at a lower level, can be observed based on their RII values in Table 4.1.4 to 4.1.9. For the sake of discussion, these challenges are grouped in to four.

Improper planning and waste management practice: Ineffective waste management plan, insufficient waste training programs and Poor supervision practice.

The literature review [26] revealed that formal C&D WM plans are developed in accordance with government regulations and organizational WM policies, and need to be monitored, reviewed and updated throughout a project. The plan typically covers waste sorting, waste streams, waste clearance schedule, waste collection and transportation, waste reuse, recycling, and disposal.

It was further stated that C&D WM can be embedded in the training courses provided by government departments, universities, and research institutions. Giving Vocational training on C&DWM to construction workers improve workers' skill to sort and reduce waste on site, and enhance their awareness of environmental benefits as well as foster their attitude towards C&D waste management. In this similar study it was cited that the government super vision is crucial to assure the enforcement of several regulations and reduce illegal dumping. However, there are

arguments that government should impose on strict supervision on WM for a better result, but recycling companies and contractors argued government intervention and supervision gradually decrease as the C&D waste recycling become mature. The present findings demonstrated majority of the respondents agreed that Ineffective waste management plan, insufficient waste training programs and Poor supervision practice are the challenges that could be seen at their organization, and this is in line with the literature in [26].

Inefficient government waste management and regulatory policy: Lack enforcement of regulations and Absence of training on waste minimization strategies for construction firms

The result of this study indicated that Lack enforcement of regulations and Absence of training on waste minimization strategies for construction firms ranked at highest level of the other factors. This shows government should not only formulate legislations, regulations, and even policies and guidelines it should follow and supervise strictly its implementation as well as assist construction firms through scheduled training programs, financial incentives, and increased landfill levies till the firms aware and practiced waste management. This result is consistent with literature works cited in [24, 27] that implementing different waste minimization regulations and strategies helps to improve sustainable construction and efficient environment. Effective site management like material logistic waste segregation, maximization of material reuse, and contractual provision are crucial strategies in reducing the quantity of material sent to landfills. Hence, Providing scheduled training on how to prevent and minimize wastes for construction firms helps to reduce the amount of material wastes generated from construction sites by creating awareness among site workers regarding the prevention method and severity associated with material wastes.

Lack of awareness of construction stakeholders: Low Concern for socio-economic and environmental effect of wastage, Resistance to change traditional practices and Poor coordination among construction stakeholders. These are the challenges of construction waste management fail into high and moderate significant barriers.

As previous studies [21] revealed, societies suffer because of construction wastes. it has potential impact on the health and wellbeing of the societies as it commonly disposes near residents and significantly pollutes the environment. Construction waste has also negative economic impact as it needs to replace and rework, transport, and dispose waste materials that require extra costs.

Environmental pollution has also been reported as one of the most significant impacts of construction waste as it pollutes the environment by releasing chemicals and other materials. It is not only this excessive consumption of raw material and depletion of natural resources are adverse effect on the environment.

Poor coordination among construction stakeholders is another challenge which identified in this research. This can enhance mutual trust and reduce conflicts, positively change attitudes, and play an important role for effective C&D WM in different project phases. All the relevant WM policies should be clearly communicated among project participants. Precious study [25] suggested that communication and coordination between designers and clients during design phase of the project can reduce design errors, changes, and reworks; and reduce construction wastes in general. Generally, it was cleared that communication and coordination among construction actors at different phases of the project i.e. Design phase, tendering phase, construction phase is crucial to prevent and mange construction and demolition wastes.

Insignificant return compared to cost of waste management: High cost and low quality of recycled materials, Lack of demand for recycled materials and High cost of waste disposal.

The most significant barrier that waste producers refuse to engage in waste management systems because they think it will increase project cost and they faced a reduction in business when selling products resulting from recycled construction waste due to quality problems, and there was lack of interest on the part of beneficiary of the service. The literature review [14] cited that the five market barriers of construction and demolition waste management. These includes; lack of an established market for reused construction materials; limited demand for second-hand building materials; negative stakeholder attitudes and behavior; costs being higher than alternative disposal methods; and contractors who pay little attention to CDW reduction, resulting in irresponsible behavior. This may happen due to lack of awareness in construction and demolition waste management and or unaware or not concern by the environmental impact of C&D waste generation as stated in [11]. This is also in agreement with the responses for Low Concern for socio-economic and environmental effect of waste, and Resistance to change traditional practices are challenging factors in the present study. In addition, this is also confirmed by the respondents in this present study and they agreed that high cost and low quality, lack of demand of recycled materials, and high cost of waste disposal were major challenges at their project sites. Therefore, the construction

stakeholders including the government should work to improve the awareness of every one working in the construction industry towards the current situation and its significant environmental impacts.

5. CONCLUSIONS and RECOMMENDATIONS

5.1 CONCLUSIONS

Construction projects in Mekelle, which produce large amount of C&DW and having poor waste reduction and management, are severely affected their sustainability due to many barriers to its successful waste management implementation. In this present study, the factors that contribute C&DW, effects of C&DW in construction projects, current C&DW management practice, and major challenges of C&DW management have been investigated through questionnaire survey and an in-depth interview among the construction stakeholders; contractors, consultants, and municipalities. Based on the findings the following conclusions were drawn.

From the investigation of factors contribute to waste, it can be concluded that the improper material handling and storage, poor supervision, lack of skilled man power and late design changes respectively are the most factors that contribute waste generation. Similarly, the study shown that the Project cost overrun, Environmental Pollution, Reduction in profit, Resources depletion, and public health and safety risks are also the major negative effects of C&DW.

On the other hand, the result of respondents on current practices revealed that enforcement of legislation, employ waste management officer, offer incentives and tender premiums related to waste management (by client), Government incentives and training towards waste minimization, establish strategies and guidelines for use of recycled material, Strict Supervision, and penalty, are the waste management methods missed at their organizations which are the governing activities for reduction and proper management of waste.

From the investigation on challenges of construction waste management, the Improper planning & waste management practice, Ineffective waste management plan, Insufficient waste training programs, Poor supervision practice group under management related challenges; and Lack enforcement of regulations, Absence of training on waste minimization strategies for construction firms, insufficient legislation & regulation, Lack of Government incentives grouped under government regulatory policy related challenges; were found the most challenging conditions.

Additionally, Low Concern for socio-economic and environmental effect of wastage, Resistance to change traditional practices, Poor coordination among construction stakeholders grouped under awareness related challenges; and High cost with low quality of recycled materials, Lack of demand for recycled materials, High cost of waste disposal grouped under low return compared to cost of managing waste were found the most challenging practices.

5.2 RECOMMENDATIONS

Effective construction and demolition waste (CDW) management requires collaboration among all stakeholders. Each party has distinct responsibilities to ensure waste is minimized, recycled, and disposed of sustainably. Based on the findings and the current difficulties of C&D waste management observed on project site, the following recommendations were forwarded to construction stakeholders.

Government & Regulatory Bodies

Government should develop Policy, establish laws, regulations, guidelines for CDW management like mandatory waste sorting, promote circular economy principles (reduce, reuse, recycle, recover) and Monitor compliance with waste disposal laws and penalize violations. Conduct audits and inspections on construction sites. In addition, government should provide Incentives, tax benefits, subsidies, or grants for recycling and sustainable practices and Fund research on innovative waste reduction techniques. Facilitate recycling plants, landfills, and waste collection systems.

Clients/Project Owners

From client it is expected to include waste reduction clauses in contracts, ensure funds are allocated for proper waste handling, define waste management goals in project briefs, hire contractors with proven waste management plans, Approve budgets for recycling and proper disposal and Monitor waste reports from contractors.

Contractors & Construction Firms

Contractors should Implement sorting, recycling, and disposal procedures, follow local and national waste laws, develop a site waste management plan (SWMP) before construction begins, train workers on waste segregation, provide labeled waste bins and ensure proper disposal, track waste generation and report to authorities and partner with licensed waste collectors and recyclers.

Architects & Designers

Architects & Designers should design for waste minimization use modular construction, prefabrication, and reversible design, apply design for deconstruction (DFD) principles, and optimize material usage to reduce offcuts, collaborate with contractors on waste-efficient construction methods.

Suppliers & Material Manufacturers

Suppliers should Provide recyclable, low-waste, or reusable materials, Reclaim excess materials for reuse, offer materials with minimal packaging, provide guidance on recycling/disposal of their products, Participate in Extended Producer Responsibility (EPR) programs.

Waste Management Companies & Recyclers

Waste Management Companies should implement Efficient Waste Collection & Processing, Sort, recycle, and dispose of CDW responsibly, Operate licensed recycling facilities, ensure hazardous waste (asbestos, chemicals) is handled safely, Offer waste tracking documentation for compliance.

Workers & Subcontractors

Follow waste sorting and disposal protocols, minimize material wastage during construction, Separate waste into designated bins (metal, wood, and concrete, hazardous), Report improper waste handling to supervisors, avoid over ordering materials to reduce surplus waste.

Future works: The present study can be extended by determining reliable data on rates of generation and composition of C&DW waste require for sustainable waste management.

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APPENDIX

5.3 APPENDIX –A Interview Survey Format

Questions	Yes	No
Are you satisfied with the current landfill process in the construction industry?		
Do you believe government bodies plays an active part in the waste treatment process?		
Do you think the government made the right decision by obliging contractors to provide containers to separate the Construction and Demolition Waste (CDW)?		
Are you applying waste sorting identification on the site?		
Should there be a contract clause that requires the contractor to use recycled materials?		
In your experience, have you observed that a policy of recycling materials has been implemented in the construction industry?		
Do you think the construction sector is encouraged by incentives for recycling CDW?		

5.4 APPENDIX –B: Factors contribute to generation of waste

Factors contribute to generation of waste	Strongly disagree	Disagree	Neutral	Agree	Strongly disagree	weight	RII	RANK
	r =1	r =2	r =3	r=4	r=5	$\sum W = \sum r * n$	$RII = \frac{\sum W}{A * N}$	
Improper material Handling and storage	0	0	0	24	6	126	0.84	1
Poor Supervision	0	0	4	18	8	124	0.83	2
Lack of skilled man power	0	2	5	16	7	118	0.79	3
Design(late) Changes	1	4	7	12	6	108	0.72	4
Material Deterioration	9	12	5	2	1	61	0.41	5
Manufacturing defects	13	11	3	2	1	57	0.38	6
over ordering of a quantity greater than required or earlier than necessary	16	10	3	1	0	49	0.33	7
Overestimated quantity	13	15	1	1	0	50	0.33	8

5.5 APPENDIX –C: Effect of waste on construction project

Effect of waste on construction project	Very little effect	Little effect	Moderate effect	High effect	Very high effect	weight	RII	RANK
	r =1	r =2	r =3	r=4	r=5	$\sum W = \sum r * n$	$RII = \frac{\sum W}{A * N}$	
Project cost overrun	0	0	0	22	8	128	0.85	1
Environmental Pollution	0	0	0	24	6	126	0.84	2
Reduction in profit	0	0	3	20	7	124	0.83	3
Resources depletion	0	0	5	18	7	122	0.81	4
Public health and safety risks	0	0	8	17	6	122	0.81	5
Delay of project completion time	5	7	9	7	2	84	0.56	6
Landfill overload	3	9	15	3	0	78	0.52	7
Increase in illegal dumping.	9	11	9	1	0	62	0.41	8

5.6 APPENDIX –D: Factor Hindering the Practice of Construction Waste Management

Factor Hindering the Practice of Construction Waste Management	Strongly disagree	Disagree	Neutral	Agree	Strongly agree			
	r =1	r =2	r =3	r=4	r=5	weight	RII	RANK
Improper planning and waste management practice						$\sum W = \sum r * n$	$RII = \frac{\sum W}{A * N}$	
Ineffective waste management plan	n= 0	n=0	n= 0	n= 13	n= 17	137	0.91	1
Insufficient waste management training programs	0	0	4	13	13	129	0.86	2
Poor supervision practice	0	1	6	12	11	123	0.82	3

No waste minimization motivation	5	9	4	7	3	78	0.52	4
Poor waste segregation practice	6	10	8	4	2	76	0.51	5
Limited waste recycling facilities	5	13	10	1	1	70	0.47	6
No adoption to recycling technology	7	15	5	2	1	65	0.43	7
In efficient Government waste management regulatory policy						0	0.00	
Lack enforcement of regulations	0	0	2	17	11	129	0.86	1
Absence of training on waste minimization strategies for construction firms	0	1	3	18	8	123	0.82	2
Insufficient legislation and regulation	0	5	4	10	11	117	0.78	3
Lack of Government incentives	0	0	8	20	2	114	0.76	4
Lack of awareness of stakeholders								
Low Concern for socio_economic and environmental effect of wastage	0	0	0	11	19	139	0.93	1
Resistance to change traditional practices	0	0	4	10	16	132	0.88	2
Poor coordination among construction stakeholders	0	2	3	13	12	125	0.83	3
Waste not a problem on site	1	3	5	12	9	115	0.77	4
Insignificant return compared to High Costs of waste management								
High cost and low quality of recycled materials	0	0	2	17	11	129	0.86	1

Lack of demand for recycled materials	0	0	3	18	9	126	0.84	2
High cost of waste disposal	0	2	3	15	10	123	0.82	3
Lack of supplies recyclable waste	6	5	7	8	4	89	0.59	4
Lack of available landfill	9	7	5	7	2	76	0.51	5
MAJORE CHALLENGES								
Lack of awareness of stakeholders	0	0	0	10	20	140	0.93	1
Improper planning and waste management practice	0	0	0	16	14	134	0.89	2
In efficient Government waste management regulatory policy	0	0	2	15	13	131	0.87	3
Insignificant return compared to High Costs of waste management	0	0	3	17	10	127	0.85	4