JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION MATERIALS WASTE AND ITS MANAGEMENT PRACTICES:A CASE STUDY ON HOUSING CONSTRUCTION PROJECTS IN ADDIS ABABA

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(Id. No. MSc. 05953/05)

A Case Study Submitted to School of Graduate Studies in Partial fulfillment of the requirement for the Degree of Master of Engineering (M.Eng) in Civil Engineering (Construction Engineering and Management)

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DECLARATION OF WORK

I hereby declare that this case study paper is entirely my own work and appropriate credit has been given to the references of the work of others.

Name _Workneh Endale_____

Signature ________________

Date __June, 2016__________

Place _Jimma, Ethiopia_____

DEDICATION

To my loving parents, who are my greatest inspiration, and to Simret Tesfaye, who always brings out the best in me.

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EXECUTIVE SUMMARY

Construction is a vital connection to the infrastructure and growth of industry in developing countries. Ethiopia is among the fast growing developing nations where construction and demolition activities are undertaking at every corner of the country. Construction of roads, buildings, bridges and other constructed facilities play an important role in shaping society's future. However, the construction industry does not firmly take some common considerations such as design, finance, environment, energy, and other elements. Consequently, the construction industry produces a huge amount of waste which is environmentally unfriendly, and costly to project budgets. 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. 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. Furthermore, the environmental impacts of the construction industry can be reduced through sustainable waste management (SWM).As a developing country, Ethiopia is behind the developed countries in construction waste management. Thus the paper is aimed at review of literatures and to assess the factors that contribute to waste in construction; find out how much construction waste is costing project budgets; assess the practice of construction waste management; gain an understanding of C&D waste management planning concepts, frameworks, strategies, and components that are current and emerging in the field; besides the roles of different stakeholders such as owners, contractors and construction management community will also be investigated in terms of their responsibility for construction waste management. The study revealed that in Ethiopia, construction materials waste exists at high rates and its management is at an infant stage and construction companies do not adhere to international best practices. The study also recommends that Managing Waste need a serious attention from all the stakeholders involved throughout the construction process from planning to finishing stage of the works.

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ACRONYMS

BaTCoDA	Building and Transport Construction Design Authority
C&D	Construction and Demolition
CSA	Central Statistics Agency (of Ethiopia)
EACE	Ethiopian Association of Civil Engineers
EPA	Environmental Protection Authority (of Ethiopia)
ERA	Ethiopian Roads Authority
ETB	Ethiopian Birr
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
IWM	Integrated Waste Management
MoFED	Ministry of Finance and Economic Development
MoUDC	Ministry of Urban Development and Construction
MoWUD	Ministry of Works and Urban Development
SDGs	Sustainable Development Goals
SWM	Sustainable Waste Management
SWMP	Site Waste Management Plan

CHAPTERONE

1. INTRODUCTION

1.1. BACKGROUND TO THE STUDY

In general, 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 [3, 5& 43].

The Construction industry, while contributing to overall socio-economic 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 [36].

Construction activities have been known to generate large and diverse quantities of waste. According to the US Green Building Council, (2001), it accounts for up to 30% of total waste output in the United States alone, put at about 136 million tons per annum. In EC countries, about 200 to 300 million tons of construction and demolition waste is produced annually, which translates to roughly a 400 km^2area covered with demolition debris one meter high [36].

The construction and demolition industry annually produces three times the amount of waste generated by all UK households combined. The industry produced 91 million tons (t) of inert waste in England and Wales in 2003. Of this, 40 million t (44%) was used as recycled aggregate and a further six million t (6.5%) as recycled soil for landfill engineering or restoration. The remaining 45million t were spread on registered exempt sites, used to backfill quarry voids or disposed of at landfill sites. WRAP estimate that there is 15 – 20 million t of non-inert and mixed construction and demolition waste in addition to the 91 million t of inert waste. A further 13 million t of waste is created through material waste i.e. materials delivered to the site, unused and then sent away for disposal [5 &43].

Figure 1.1: C&D Waste generated in UK (by weight)

Waste in the construction industry is important not only from the perspective of efficiency, but also concern has been growing in recent years about the adverse effect of the waste of building materials on the environment. This kind of waste typically accounts for between 15 and 30% of urban waste [43].

The amounts of generated C&D waste are substantial. The absolute annual amount of C&D waste in different countries is reviewed by [42] and is presented in table below.

Table 1.1: C&D Waste as Percentage of All Solid Waste Entering Landfills in Various Countries

Country	C&D Waste (%By Weight)
The Netherlands	26
Australia	20-30
United States	20, 23, 24, 29
Germany	19
Finland	13-15

The term “construction and demolition waste” or “C&D waste” is commonly used to describe a large number of waste materials generated from the construction and demolition of buildings and civil infrastructure. While construction and demolition wastes are usually grouped together under the title “C&D waste”, these waste streams are produced by two different processes and the volume and type of materials produced can differ greatly. Demolition projects often produce 20-30 times as much waste material per square meter as construction projects. In addition, construction waste normally consists primarily of off-cuts from new construction materials and contains more modern building materials than demolition waste since new buildings are rarely torn down while demolition waste is often worn and contaminated with paint, adhesives and dirt and the materials can be securely fastened together making separation more difficult [15].

An estimated Annual volume of C&D wastes for Germany is demolition waste, 22.6 million tons (t); and Construction waste, 10 million t. Two years later, the volumes of C&D waste in Germany were; demolition waste, 30 million t; and Construction waste, 14 million t. In Western Europe, it was expected that the total amount of C&D waste generation will reach 215 million t, with about 175 million t coming from demolition work and 40 million t from construction [42].

These figures indicate that the weight of the generated demolition waste is more than twice the weight of generated construction waste. Though it seems that construction waste makes a smaller contribution to the generating of C&D waste than demolition waste, construction waste is an important topic to quantify and analyze despite the lower volumes in comparison with demolition waste because [42]:

- Construction waste is more difficult to recycle due to high levels of contamination and a large degree of heterogeneity.
- Prevention of construction waste is preferable to recycling of demolition waste “at the end of the pipeline.”
- A cost reduction caused by preventing the generation of construction waste is of direct benefit for most of the participants that work on a construction project.

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. However, material waste has been recognized as a major problem in the construction industry that has important implications both for the efficiency of the industry and for the environmental impact of construction projects [10&36].

Building materials waste is difficult to recycle due to high levels of contamination and a large degree of heterogeneity, and often there is insufficient space for its disposal in large cities [5]. Wyatt (1978) stressed the consequences of high levels of waste, both in reducing the future availability of materials and energy and in creating unnecessary demands on the transportation system. As a result, construction and demolition waste management has become one of the major environmental problems in many municipalities [43].

More than a few literatures have focused on material losses. Material is, indisputably, the most vital construction in put, around which the efficiency or inefficiency of labor, plant and equipment spin, and the need for efficient material usage and control is getting greater attention in the construction industry. A study made in India also confirms that the component of materials cost comprises highest portion of the project cost.

Table 1.2: Percentage Cost Distribution in Construction Industry of India, 2007 [6]

	Cost Distribution (%)						
	Materials	**Construction Equipment**	**Labor**	**Finance**	**Enabling Expenses (Overhead)**	**Admin. Expenses**	**Surplus (Profit)**
Building	58-60	4-5	11-13	7-8	5.5-6.5	3.5-4.5	5-6
Roads	42-45	21-23	10-12	7-8	5.5-6.5	3.5-4.5	
Bridges	46-48	16-18	11-13	7-8	5.5-6.5	3.5-4.5	5-6
Dams, etc	42-46	21-23	10-12	7-8	5.5-6.5	3.5-4.5	5-6
Power	41-43	21-24	10-12	7-8	5.5-6.5	3.5-4.5	5-6
Railway	51-53	6-8	16-18	7-8	5.5-6.5	3.5-4.5	5-6
Mineral Plant	41-44	20-22	12-14	7-8	5.5-6.5	3.5-4.5	5-6
Transmission	49-51	5-7	19-21	7-8	5.5-6.5	3.5-4.5	5-6

The above table shows the Distribution of cost among various modes of expenses in Indian Construction Industry. The importance of materials cost can be seen from the fact that the component of materials cost comprises nearly 40%–60% of the project cost. Other studies also indicate that the need for efficient use of construction materials is underpinned by the fact that material input constitutes as high as 60% of total project costs. Therefore material waste generation from construction activity is also huge in monetary terms. Thus economically evaluating cost benefits.

It is a known fact that, construction materials management in construction projects of Ethiopia is poor and is usually done by experience and using traditional methods. It is also viable that lack of proper construction materials management system in the country contributes to the high construction cost and poor quality of construction products in Ethiopia. Researchers have indicated that lack of proper materials management is one of the causes of claims in Ethiopia [14].

Therefore, the mentioned issues signify the need to develop an effective constructions materials management system in construction projects in Ethiopia.

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 construction waste and waste produced from the construction industry has a negative effect on the environment, cost, productivity, time, social and economy [10, 5, & 6].

The elimination of waste has been largely used as a driver for improvement in the manufacturing industries that have adopted the Lean Production philosophy. By contrast, it has not been strongly emphasized in the construction sector [3].

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 Ethiopia.

The buildup of the cost of construction projects (roads, buildings, bridges, railways, dams) significantly includes the cost of waste. Effective minimization of waste contributes to- reduced extraction of natural/ raw materials, reduced transportation and disposal cost, reduced environmental impact and improved profit [5].

Hence, construction waste management is essential to improve the performance of the industry in terms of economic quality and sustainability. One way of achieving this target is by reducing waste at all stages of the construction process. Managing building material waste can result in higher construction productivity, save time and assist sustainability.

Thus the paper is aimed at review of literatures to assess the factors that contribute to waste in construction; gain an understanding of C&D waste management planning concepts, frameworks, strategies, and components that are current and emerging in the field; besides the roles of different stakeholders will also be investigated in terms of their responsibility for construction waste management.

1.3. OBJECTIVE OF THE STUDY

1.3.1. General Objective

To assess and understand construction materials waste in construction and its management practices in Housing Construction Projects of Addis Ababa and give 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 literatures.

1.3.2. Specific Objective

a. To examine the factors that contributes to waste in housing construction projects.
b. To determine effects of waste to housing construction projects.
c. To assess the practice of waste management in the construction projects.
d. To identify the roles of different stakeholders in terms of their responsibility for construction waste management.

1.4. RESEARCH QUESTIONS

a. What are the factors that contribute to waste in housing construction projects?
b. What are the effects of waste on construction projects?
c. What is the practice implemented for managing waste in the construction projects?
d. What is the roles and responsibility of stakeholders in respect to construction waste management?

1.5. JUSTIFICATION/ RATIONALE

Construction is an important aspect of infrastructure and growth of industry in developing countries. In most parts of the world, construction industry consumes huge amount of raw materials/natural resources and often generates large amount of waste. Numerous studies from different countries have confirmed that waste represents a relatively large percentage of production costs. 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, reduced transportation cost and improved profit. Furthermore, the environmental impacts of the construction industry can be reduced through sustainable waste management (SWM).

Hence, studying on construction materials wastes will benefit the stakeholders of the construction industry such as contractors, consultants, project owners, financers, the general public and the environment at large. In addition, the paper also helps other researchers who want to work on this subject area by noticing the gaps and the sensitivity of the subject matter.

1.6. METHODS

The literature review involves reaching what others have written in the subject area of construction waste and its management practices. A set of specific journals with a high impact in the construction management research community are identified. These journals include: Architectural Engineering and Design Management; Journal of Architectural Engineering; Engineering, Construction and Architectural Management; Construction Management and Economics; Journal of Construction Engineering and Management; Journal of Management in Engineering. A particular focus is given to literatures which pertain to the management of C&D waste with a greater emphasis placed on papers that provided a discussion on the causes, measures, concepts, or preventive actions on construction waste were selected. Other sources like research papers, different reports and conference papers also reviewed.

1.7. SCOPE AND LIMITATIONS

The case study is carried out to identify causes of waste, waste management principles and roles of stakeholders for managing waste in the construction industry, specifically on building construction projects. The study is mainly constrained in terms of time in which this case study is supposed to be presented. This may not allow investigating critically as many projects as possible.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. CONSTRUCTION IN GENERAL

Construction as defined by the United Nations Statistics Division is “an economic activity directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature, and other such engineering construction as roads, bridges, dams and so forth”. It is a process that consists of the building or assembling of infrastructure in the fields of architecture and civil engineering. It comprises the building of new structures, including site preparation, as well as additions and modifications to existing ones. It also incorporates maintenance, repair, and improvements on these structures [1].

The construction industry has a great impact on the economy of all countries. It is a vital element of the economy and has a significant effect on the efficiency and productivity of other industry sectors. It provides crucial ingredients for the development of an economy. One cannot think of widespread investment in manufacturing, agriculture or service sectors unless the construction results of infrastructure facilities are in place. It not only provides the infrastructure for all other industries, but also constitutes one of the largest single sectors in the economy on its own and accounts for 12% to 25% of the GNP of both developed and developing countries [13].

Construction consumes higher percentage of the annual budget of many countries, nearly accounts for 6-9 percent of the GDP; and plays also an important role in social, economical, and political developments of a country. [4, 6, 13&14].Studies revealed that, investment in construction accounts for nearly 11 percent of India’s GDP in a year 2009[6& 11] and in the United Kingdom it contributes to 8.2 percent [16].In developing countries, the construction sector is a major stakeholder of the economy and is higher contributor to the GDP than manufacturing sectors[17].

Table 2.1:Construction industry contribution to GDP in some Southern African countries[20, 17]

S. No	Country	GDP (%) (Percentages of total GDP)	Year
1	Angola	4.8	1998
2	Botswana	10	1974/75
		6.4	1994/95
3	Malawi	16	1996
4	Mauritius and Seychelles	7.2	1991-96
5	Mozambique	11.3	1997
6	Namibia	11	1997
7	Tanzania	4.9	1996
8	Zimbabwe	3-5	1996

The boom in the economic growth of a country will also attribute to the development in the construction industry [11].From 2003 to 2004; the global construction industry grew by 6.6 percent. The largest international construction market is Europe; the second largest international construction market is Asia/ Australia with China being the single fastest growing market [13].

The sector is highly employment intensives and generates high employment opportunity. In UK it employs about 2.1 million people and in India, in a year 2005, it was reported that 31 million people were engaged in the construction industry [11 &16].Studies show that the total annual value of construction in the world ranges from 1 to 1.5 trillion dollars [14]; and in India, the total construction work for five years during 2006-2011 is about 847 billion dollars [6].

2.2. CONSTRUCTION INDUSTRY IN ETHIOPIA

2.2.1. Overview on History of Ethiopian Construction Industry

Ethiopia, a country with glorious ancient civilization symbolized by the remains of its marvelous architectural masterpieces [9], has a rich history of magnificent construction endeavors. The ruined palace of Queen Sheba at Yeha, the Obelisks of Axum, the rock-hewn churches of Lalibela, and the Fasilades Castles of Gondar are few examples of these expertises. With the advent of modern civilization, especially during the late $19^{th}$and early 20^{th}century, particularly during the reign of Emperor Menelik II (one of the most revered in Ethiopia's history), there have been some significant developments in this regard. The Addis- Djibouti railway line is one example where such a venture has been successfully carried out [23].

Half a century later, during the Italian Fascist occupation of the late 1930s, Mussolini plotted grand plans to recreate Addis and there were some construction activities, particularly in the development of long trunk roads. Even though the Italians didn't end up staying long enough in Ethiopia to transform the capital, they did contribute to its urban layout by developing the areas of Piassa, Mercato and Kasanchis, and building new roads to link them together. In the period that followed over the late 1950s and early 1960s, the all-powerful emperor Haile Sellasie, attracted some well-known international architects to help realize his dream of presenting Addis as the capital of a united Africa. Then Addis went through a massive urban makeover that proved extremely prolific architecturally and in a very short period of time, the face of Addis changed; the New Flower became a modern city with a unique architectural harmony [21].

After the Italian occupation and before the 1960s, expatriate contractors generally dominate most of the medium and small civil and building projects and the experience, as well as the financial benefits were almost exclusively in the hand of foreigners [23] though local experts have participated at large especially in the construction activities[9].Moreover, during this era, these foreign companies had the chance of deciding on the fate of the sector, its resources and even the management.

Gradually, the experience acquired by working along these foreign experts added to the academic training received both abroad and locally, has helped a lot in building local confidence in undertaking the design and construction tasks of major civil engineering works[9]. In 1967, Engineer Kassa Haile together with his friend, Engineer Abera Kassa, successfully organized and established a business entity "National Engineers and Contractors PLC" in Addis Ababa and has been acclaimed as the emerging unadulterated native company. This exemplified every native engineering professional to working together and remains dominant ownership of the sector within the shortest possible time. Therefore, the foreign construction companies could no more survive in the competitive local market and the story ended with the transfer of our own affairs to ourselves [33].

2.2.2. Construction Industry and National Economy of Ethiopia

In Ethiopia, the construction industry is the highest recipient of government budget in terms of government development program and shares a considerable amount of the country's scarce financial resources of total pro-poor capital and recurrent expenditure and accounts nearly **10** percent of the nation's GDP [2 &13]. Besides, about 58.2 percent of the federal capital budget of Ethiopia is channeled to the development of physical infrastructure [19].

National economic indices related to various industries reveal their corresponding economic role [20]. The registered economic growth (10.2% GDP at constant basic price) for 2007_{EFY} was obviously based on the contribution of wide range of economic activities. The contribution and the shares of the major sectors, agriculture, industry and services out of the total GDP for the years (2003 – $2007_{EFY,}$ Ethiopian Fiscal Year) is summarized and presented in table below.

Table 2.2: Percentage Distribution of GDP by economic activity and by Major Industrial Classification in Ethiopia for 2010/11-2014/15 (2003-2007_{EFY})[24]

1. Percentage Distribution of GDP by Economic Activity (2003_{EFY} Base Year Series) (A) at Constant Basic Prices and (B)at Current Prices;										
Industry*	Year									
	2003 2010/11		2004 2011/12		2005 2012/13		2006 2013/14		2007 2014/15	
	A	B	A	B	A	B	A	B	A	B
Agriculture	44.6	44.6	43.1	47.9	41.9	44.8	40.1	41.8	38.7	40.9
Manufacturing	4.0	4.0	4.1	3.7	4.4	4.0	4.6	4.3	4.8	4.1
Construction	**4.0**	**4.0**	**4.9**	**4.3**	**6.1**	**5.7**	**6.9**	**8.6**	**8.5**	**11.0**
Transport and Communications	4.2	4.2	4.3	4.3	4.6	4.8	4.7	4.7	4.8	4.6
Education	2.3	2.3	2.4	2.4	2.6	2.8	2.4	2.6	2.3	2.4
*Not all industries are listed to make looking for relevant data easier.										

2. Contribution to GDP Growth by Economic Activity at Constant Basic Prices (%) (2003$_{EFY}$ Base Year Series)					
Industry*	Year				
	2003 2010/11	2004 2011/12	2005 2012/13	2006 2013/14	2007 2014/15
Agriculture		2.2	3.0	2.2	2.5
Manufacturing		0.5	0.1	(0.0)	(0.3)
Construction		**1.3**	**1.9**	**1.5**	**2.5**
Transport and Communications		0.50	0.7	0.6	0.6
Education		0.1	0.2	0.1	0.1
*Not all industries are listed to make looking for relevant data easier.					

3.Contribution to GDP Growth by Major Industrial Classification At Constant Basic Prices (%)					
Industry	Year				
	2003 2010/11	2004 2011/12	2005 2012/13	2006 2013/14	2007 2014/15
Agriculture		2.2	3.1	2.3	2.5
Industry		**2.1**	**2.8**	**2.2**	**3.0**
Services		4.4	4.1	5.9	4.7
GVA at Constant Basic Prices		8.7	9.9	10.3	10.2

Construction industry is one of the foremost industries in any developing country whose upward activity is related to the economy of the country. It is also perhaps the first industry whose slump is closely inter-linked with the fall of an economy [20]. It means that the healthy performance of the construction industry fosters economic development. This accomplishment of an economy does not only signify the availability and demand for infrastructure and shelters in the country, but also is an indication of a growing economy [1].

In Ethiopia, to maintain the rapid and sustainable economic growth, 66.6 % of the federal recurrent and capital budget of the country is allocated to road, education, agriculture, water, health, and Universal Electrification Access Program for the year 2015/2016 (2008_{EFY}) which is summarized and presented under the table below.

Table 2.3: Amount and Distribution of Recurrent and Capital Expenditures of the Ethiopian Federal Government for the year 2015/16 (2008_{EFC}) [25]

1.Total Amount of Expenditures			
S.No.	**Type of Expenditure**	**Amount (Birr)**	
A	Federal Recurrent	50,288,442,092	
B	Federal Capital	84,300,732,449	
	Total	**134,589,175,351**	
2.Distribution of Expenditures			
S.No.	**Main Expenditures**	**Amount (Millions Birr)**	**Percentage (%)**
1	Roads	33,386.10	24.81
2	Education	32,927.50	24.47
3	Public Debts	11,903.70	8.84
4	National Defense	9,500.00	7.06
5	Agricultural and Rural Development	9,125.60	6.78
6	Water and Energy	6,771.50	5.03
7	Health	6,375.40	4.74
8	Justice and Public Order	5,450.10	4.05
9	Industrial Parks Development	3,000.00	2.23
10	Urban Development, Housing Construction*	2,726.10	2.02
11	Transport and Communication	1,197.20	0.89
12	Universal Electrification Access Program	1,000.00	0.74

13	Others**	11,226.00	8.34
	Total	**134,589.20**	**100**
** Does not include the budget background of roads*			
***Includes (Organs and State, Gender Service, Mining, Industry and Trade, Culture and Sport, Labour and Social Affairs, Prevention and Rehabilitation, and Provision).*			

From the above table, one can easily see that the budget allocation is toward to sustainable development, economy transformation and poverty reduction, and the development of physical infrastructures.

2.2.3. Construction in Ethiopia these days (Where are we now?)

The construction industry in Ethiopia has been providing wide variety of buildings, ranging from houses to high rise buildings and from schools and hospitals to factories and shopping centres, and has been carrying out an equally wide variety of engineering construction projects, ranging from highways to hydro – electric dams and irrigation dams / canals [1]. Growth registered in the construction industry has not been adequate enough compared to the requirement in the sector. This is mainly due to absence of coordinated effort by all stakeholders to support the creation of competent capacity in the field. These include limited capacity of local contractors and consultants, and the absence of strong professional associations that can support the development of the sector [9]. Even though, the development of the construction industry in Ethiopia is slow, it plays a key role in the development of the national economy.

The demand for economic growth of Ethiopia is increasing from time to time and meeting the demand requires more construction works. Without the vibrancy of the sector, the expansion of urbanization, which is emphasized in the second Growth and Transformation Plan (GTPII), is impossible [22]. Hence, these days, construction is booming in Ethiopia, especially, its capital Addis Ababa in terms of both value and employment. It has continued to expand despite the high costs of inputs and a striking increase in the size and complexity of many individual projects has been recorded. For example, the housing boom saw the development of project housing /real estate/ condominium comprising hundreds of units of apartment buildings and complexes and of entire communities and the heavy and civil engineering construction saw the colossal hydro –

electric dams of Ethiopia[1]. The developments of high rise buildings in the capital Addis is also intensified when commercial and Financial Institutions have started fierce competitions along Meskel Square-Bole Square road and around Commerce School, Stadium, Lideta and Ethiopia Hotel areas.

Dominique Magada, an author and journalist, who is currently working on a book about Ethiopia, has mentioned on one of her article on a magazine that *"Living in Addis Ababa at the moment is like living amid an overgrown building site. Instead of airy parks, lush gardens or pleasant pedestrian alleyways, the city feels as though it is filled with cranes scaffolding, diggers, building fences and piles upon piles rubble. The shuffling of mechanical earth and beating of metal on metal have become the city's dominant sounds, and not a single area or street is spared by the construction frenzy. Addis has turned itself upside down to create the new New Flower"* [21]

Today, there are also thousands of local contractors engaged in road, building and other construction works and they have their own status from type one to ten with different experience, knowledge, machinery and construction capacity but only few of them are from type 1 to 5. The rest are in the lowest status [22].A reference from Ministry of Urban Development, Housing and Construction (formerly called MoUDC) shows that there are more than 4500 contractors registered and licensed in Ethiopia.

According to the directive of Ethiopia [26 &27] that, no company or professional, may carry out any design, supervision, and construction without getting certificate of competence from the Ministry, MoUDC. For the purpose of contracting an engineering Works with an Employer, though the principles of procurement may vary from country to country and from organization to organization, the basic principles are common in many cases. The common guiding principles of procurement include; encourage competition, consistency, efficiency and effectiveness, fair dealing, integrity, transparency, flexibility and conformity to legal requirements [17]. That is also followed during the formal construction contracting in Ethiopia.

In this regard, the consulting services are not utilized in an informal and self-build manner [13]. However, there is a practice that a government institution, a company or a household carry out a construction activity be it new construction or a major maintenance using its own force, without contracting it to a construction company or a company not registered at the Ministry. Therefore, there exist a separation between the design consultants and the contractors. This leads to generation of poor project management and wastage of materials in the construction process which in turn results in project cost overrun and environmental impact due to poor management of wastes.

2.3. WASTE IN GENERAL

2.3.1. Waste- Definition and Concept (Conceptual Framework)

Almost all human activities create waste in some form or another. Most individual items of waste, particularly wastes from homes and offices, are not themselves a direct threat for the public health. It is the way these wastes are or not handled, stored, collected, and disposed that can pose risks to public health. 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 [31].

Waste has become one of the major concern in many developed and some developing cities across the world. Waste has even been seen as a crisis in these cities because landfill spaces have been exhausted at a much faster rate; while sating new waste facilities is a long and painstaking process when tightened administrative procedure and the not-in-my-backyard (NIMBY) syndrome are in play. The rise of the materialism and a consumptive culture has driven up the generation of waste per-capita. With rising awareness for environmental protection, there has been a higher demand for state-of-art waste management facilities as well as integrated solutions to the waste problem [32].

Definitions of waste from different literature as:

- Waste is the unnecessary depletion of the natural resources, unnecessary costs and environmental damage which can be avoided through improved waste ethics [5].
- Waste is “any materials apart from earth materials, which needed to be transported elsewhere from the construction site itself other than the intended specific purpose of the

project due to damage, excess or non-use or which cannot be used due to noncompliance with the specification, or which is a by-product of the construction process" [5, 37].

- "Any losses produced by activities that generate direct or indirect costs but do not any value to the product from the point of view of the client" [35].
- "Any substance or object the holder discards, intend to discard or required to discard" 28].
- "Any non-value adding activity carried out in any work system at any time or any resource deployed in the work process which does not create utility for the stakeholders can be conceived as waste" [5].

Waste, according to the World Bank, is defined as any unwanted material intentionally thrown away for disposal. However, certain wastes may eventually become resources valuable to others once they are removed from the waste stream. Solid waste streams are characterized by their sources, by the types of wastes produced, as well as by generation rates [29, 30].

Once a material falls within this definition it will remain waste until it is fully recovered and is no longer a threat to the environment and human health [5].Waste is also defined in different terms or phrases to imply various meanings. The meanings are not extremely different, but variations are enough to cause confusion when the words or phrases are used.

Waste is one of the key concepts in the Lean Production philosophy. According to the new production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labour, or capital in large quantities than those considered as necessary to the product. Waste includes both the incidence of material losses and the execution of unnecessary work, which generates additional costs but do not add value to the product [35].

The elimination of waste has been largely used as driver for improvement in companies that have adopted the Lean Production philosophy, largely used in the manufacturing industry. This topic has also been the focus of investigation in the construction industry around the world in recent years. The three different groups of concepts identified from review of literatures are[3, 7&35]:

i. Waste as a material loss(based on the amount of debris generated due to excess consumption of materials) - often concerned with the environmental impact caused by construction and demolition material waste and waste is understood as debris that need to be removed from construction sites;

ii. Specific type of waste(rework from quality deviation, change orders or uncompleted tasks)- often do not discuss the cost components of this type of wastes;

iii. Waste as non-value-adding activities (activities that take time, resources or space but do not add value from the perspective of the customer) - conceptualization of waste in lean production philosophy.

2.3.2. Waste-Classification, Sources and Causes

Besides a clear understanding of the general concept of waste, it is helpful to use a classification of waste in different categories, in order to understand the wide range of possible corrective actions related to its prevention [35].

It is also necessary to characterize wastes by their sources, by type of wastes produced, as well as by generation rates and composition. Knowledge and accurate information in these three areas is necessary in order to monitor and control existing waste management systems, to design and operate appropriate solid waste management systems, and to make regulatory, financial, and institutional decisions [30].

There is an acceptable level of waste, which can only be reduced through a significant change in the level of technological development. From point of view of necessary investment and the possibility to control the incidence of waste, waste can be categorized as [7& 35]:

- **Avoidable Waste:** when the cost of waste is significantly higher than the cost of its prevention.
- **Unavoidable/ natural waste:** in which the investment necessary to its reduction is higher than the economy produced/ reduction of waste causes higher investment than economy produced.

The percentage of unavoidable waste in each process varies from company to company and from project to project, since it is related to the technological development.

Waste can also be classified according to its origin, i.e. the stage that the main root cause is related to. Although waste is usually identified during the production stage, it can be originated by processes that precede production, such as materials manufacturing, training of human resources, design, materials supply, and planning.

Mainly there are eight major classifications of solid waste generators: residential, industrial, commercial, institutional, construction and demolition, municipal services, process, and agricultural. Table below gives sources and types of waste generated according World Bank Study.

Table 2.4:Source and Types of Solid Waste [29&30]

Source	**Typical Waste Generators**	**Type of Solid Wastes**
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, hospitals, prisons, government centers	Same as commercial
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal Services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and waste water treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas, sludge

Source	Typical Waste Generators	Type of Solid Wastes
✓ All of the above should be included as municipal solid waste. Industrial, commercial, and institutional (ICI) wastes are often grouped together and usually represent more than 50%of MSW. ✓ C&D waste is often treated separately: if well managed it can be disposed separately. ✓ The items below are usually considered MSW if the municipality oversees their collection and disposal.		
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids),hazardous wastes (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes(e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous wastes(e.g., pesticides)

According to [5], waste is also classified on the basis of:

- **Waste Resources**: Material resources based on physical state like solids, liquids, and gases; Energy resources like physical, human and solar energy; Time resources waste of waiting and idle time of workers.
- **Property**: materials wasted are either hazardous or non-hazardous.
- **Recoverability**: Recoverable or non-recoverable

The other classification of waste is by its nature. There are seven categories of waste: (1) overproduction of goods not needed;(2) waiting by employees for process equipment to finish its work or an upstream activity;(3) excessive handling (unnecessary transport) of goods; (4) unnecessary processing;(5) inventories of goods awaiting further processing or consumption; (6) unnecessary/ inefficient movement of people (including waste of human energy);and (7) defects in products. It is basically identified in the Toyota production system which can Waste can be equally applied to the construction industry and are defined below [3, 7&35]:

- **Overproduction**: related to the production of a quantity greater than required or earlier than necessary. This may cause waste of materials, man-hours or equipment usage. It usually produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate. An example of this kind of waste is the overproduction of mortar that cannot be used on time.

- **Waiting time**: related to the idle time caused by lack of synchronization and levelling of material flows, and pace of work by different groups or equipment. One example is the idle time caused by the lack of material or by lack of workplace available for a gang.
- **Transportation**: concerned with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways can cause this kind of waste. It is usually related to poor layout, and the lack of planning of material flows. Its main consequences are: waste of man-hours, waste of energy, waste of space on site, and the possibility of material waste during transportation.
- **Processing**: related to the nature of the processing (conversion) activity, which could only be avoided by changing the construction technology. For instance, a percentage of mortar is usually wasted when a ceiling is being plastered.
- **Inventories**: related to excessive or unnecessary inventories which lead to material waste (by deterioration, losses due to inadequate stock conditions on site, robbery, vandalism), and monetary losses due to the capital that is tied up. It might be a result of lack of resource planning or uncertainty on the estimation of quantities.
- **Movement**: concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.
- **Production of defective products**: it occurs when the final or intermediate product does not fit the quality specifications. This may lead to rework or to the incorporation of unnecessary materials to the building (indirect waste), such as the excessive thickness of plastering. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification of the team work, lack of integration between design and production, etc.
- **Substitution**: is monetary waste caused by the substitution of a material by a more expensive one (with an unnecessary better performance); the execution of simple tasks by an over-qualified worker; or the use of highly sophisticated equipment where a much simpler one would be enough.

- **Others**: waste of any nature different from the previous ones, such as theft, burglary, vandalism, inclement weather, accidents, etc.

Those categories were based on problems observed in the car industry and shall be remembered that, construction industry processes are not confined, as in the case of mechanical industry. Hence applying 'Zero waste' concept to the construction industry seems impractical and uneconomical.

Waste generation rates are also affected by socioeconomic development, degree of industrialization, and climate. Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced and MSW generation levels are expected to double by 2025 [30].

2.4. WASTE IN CONSTRUCTION

Construction is a vital connection to the infrastructure and growth of industry in a country. Building roads, bridges and other constructed facilities play an important role in shaping society's future. Consequently, the construction Industry produces a vast quantity of waste which is environmentally unfriendly, and costly to project budgets [5, 10 &34].

There are differing views held by researchers as to what constitutes construction waste [36]. According to [5] construction waste can be closely defined as debris of construction and demolition. Specifically, construction waste refers to solid waste containing no liquids and hazardous substances, largely inert waste, resulting from the process of construction of structures, including building of all types (both residential and non-residential) as well as roads and bridges.

Building Research Establishment [5, &37]) define waste as "any materials apart from earth materials, which needed to be transported elsewhere from the construction site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to noncompliance with the specification, or which is a by-product of the construction process".

Researchers often adopt the definitions used by regional institutions and government departments for material waste and waste is understood as debris that needs to be removed from construction sites. Material waste is defined as "the by-products generated and removed from construction, renovation and demolition workplaces or sites of building and civil engineering structures" [3].

Several research projects around the world have been conducted in recent years on waste in the construction industry. According to Formoso, et al. [35], the two main aspects based on the impacts of the construction waste are:

A. Studies concerned with Impact on environment due to generation of material waste: include

- Wyatt (1978) - stressed consequences of high levels of waste in both reducing the future availability of materials and energy, and creating unnecessary demands on the transportation system.

- The Hong Kong Polytechnic and the Hong Kong Construction Association Ltd. (1993) - aimed to reduce the generation of waste at source, and to proposed alternative methods for treatment of construction waste in order to reduce the demand for final disposal areas.

- Brossik and Brouwers in the Netherlands (1996) - concerned with the measurement and prevention of construction waste, regarding sustainability requirements stated by Dutch environmental policies.

B. Studies concerned with the economic aspect of waste in the construction industry:

- Skoyles in UK (1976) - monitored material wastes in 114 building sites, and concluded that there was a considerable amount of waste that can be avoided by adopting relatively simple prevention procedures. In addition, storage and handling were pointed out as major causes of waste. Most of the problems concerning waste on building sites are related to flaws in the management system, and have very little to do with the lack of qualification of workers. Furthermore, waste is usually caused by a combination of events, and not due to an isolated factor.

- Pinto in Brazil (1989) - developed a study based on one site only; pointing out for the fact that indirect waste (materials unnecessarily incorporated in the building) can be higher than direct waste (rubbish that should be disposed in other areas).

2.4.1. C&D Waste- History

C&D wastes have been a quiet aspect of construction throughout the industry's history. However, the last hundred years have brought the most change in the waste philosophy of the construction industry. Throughout the early 1900's labor was inexpensive, so building materials accounted for most of construction costs. This meant that contractors could not afford to discard materials, but they could afford more labor to cut and trim leftover materials for later use. After World War II, many technologies began to change the way construction materials were manufactured. Products required less preparation time for installation, and many were produced in the controlled environment of factories. This did two things for construction materials:

- It provided consistent quality, and
- It allowed for mass production.

The panelization of materials such as plywood and gypsum board were two such innovative improvements which helped change the focus of construction costs. The effect was a higher quality product at a lower price. This transformed the construction industry by placing less emphasis on material wastes, and putting more efforts towards reducing labor costs. As labor costs have increased, due to rising insurance, health, and worker's compensation fees, there has been less emphasis on reducing material wastes and more focus on labor efficiency.

The fundamental change in philosophy towards material wastes has led to the concept that the C&D waste stream is closely related to the material flow during construction- this can be best illustrated in figure below [34]. There are various consumable and non-consumable materials on a construction site. The consumables are those which are physically used and left in the constructed facility. Some materials can be reused on later projects, while others are leftover and must be returned to the supplier or kept for later use. Non-consumables are materials that aid in the construction, but do not end up in the completed structure.

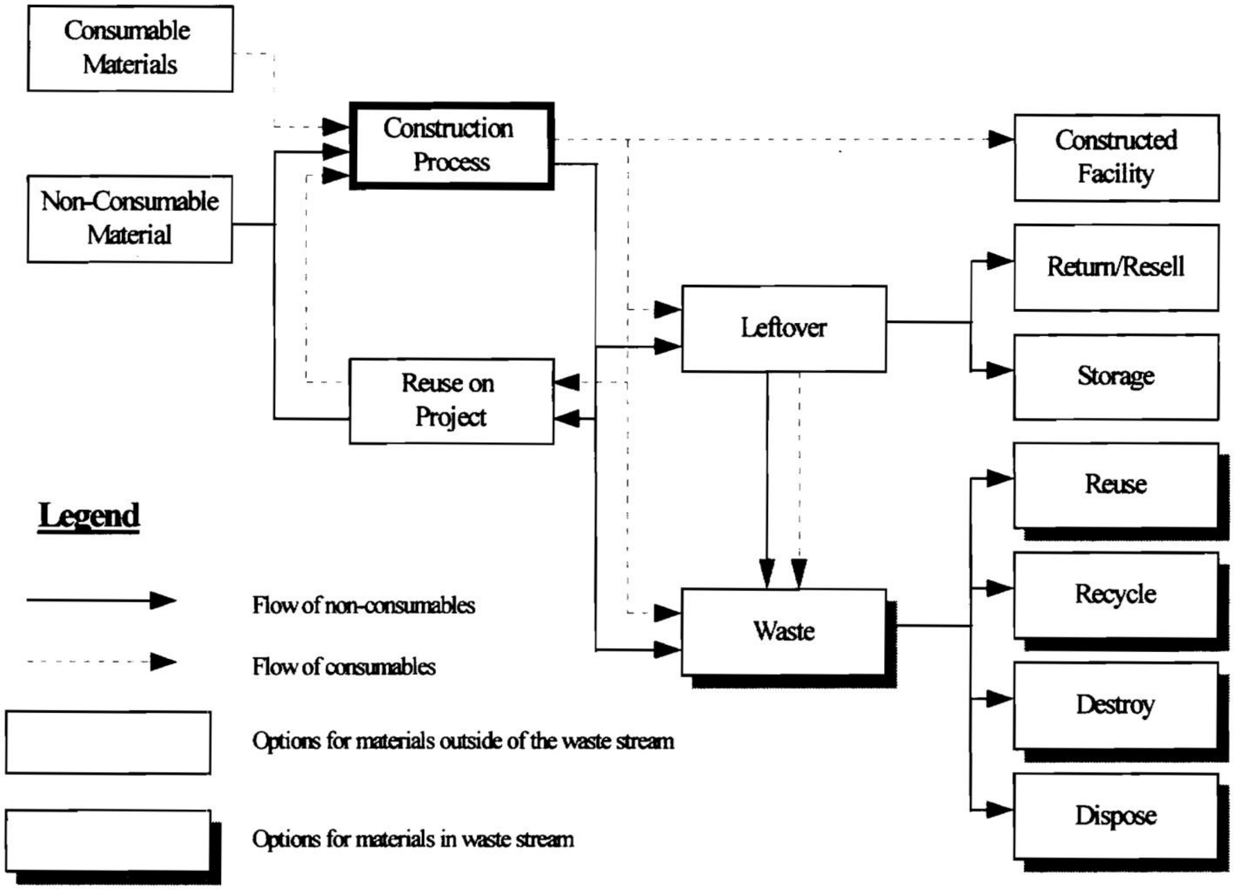

Figure2.1: Generic flow of construction materials on site

2.5. QUANTIFICATION OF WASTE IN CONSTRUCTION

C&D wastes are quantifiable when comparing various construction projects, but they are very inconsistent when comparisons are made between localities and regions. Many of the factors that affect C&D disposal rates are beyond the control of the builder. These include [34]:

- Season and Climate
- Strength of national economy (growth of construction)
- Decisions on repairs of municipal infrastructure (roads, bridges, utilities)
- Development of Urban Renewal Projects
- Catastrophic events such as earthquakes, fires, floods, tornadoes, and hurricanes

The level of waste at construction sites is considerable. Now days, the industry faces many challenges with issues related to construction waste and Construction waste has become a serious problem in many countries. Waste which has negative impact on the environment, cost, productivity, time, social and economy. Production of construction waste in huge amount due to increasing demand of infrastructure; commercial buildings and housing development projects which has generated large amount of construction waste [10].

A waste diagnostic survey was carried out on a sample of 35 top contractors by three researchers at a national level recently. The contractors' selection was based on their size of capital and experience according to the classification of the Egyptian Union for Building and Construction Contractors. The survey focused on the waste rates and causes of the most dominant materials influencing the projects' costs. The survey revealed that the existence of material waste was unquestionable and found to be range from 4.5%to 13%.Researches in Ethiopia also revealed that all respondents of a questionnaire survey strongly agreed up on the existence of material wastage [37].

Studies below shows different waste level from different countries:

United Kingdom: The first extensive investigation of material waste in the building industry was carried out in U.K. This study was based on data obtained from 114 building sites. Thirty seven materials had their direct waste measured and the percentage of wasted materials ranged from 2% to 15% [43].

Hong Kong: The Hong Kong Polytechnic and Hong Kong Construction Association conducted a study from June 1992 to February 1993 on 14 construction sites. The waste of premixed concrete ranges from 2.4 to 26.5%; the average was 11% [43].

The Netherlands: Study was conducted from April 1993 to June 1994. Waste from seven materials from five housing construction projects (a total of 184 homes) the amount of waste for each building material lies between 1% and 10% of the amount purchased. The average amount of the purchased construction materials that end up as a construction waste is 9% by weight [42].

Australia: Data was collected in 15 house-building sites for six materials and resulted with waste of materials ranged from 2.5 to 22% [43].

Brazil: The total waste was 18% of the weight of all materials purchased and the waste percentage include both direct and indirect waste. In other study which is carried out between 1986 and 1987 at residential building revealed that the percentage of waste was estimated to be between 11 and 17%[43]. The other study in Brazil also conducted by other researchers and the result described construction industry is about 20-30% of the weight of total materials on site[42].

Table2.5: Construction Waste as % of Total Amount of Purchased Construction Material (Brazil)

Reference	Construction waste (%by Weight)
Pinto and Agopayan(1994)	20-30
Hamassaki and Neto(1994)	25
Formoso et al. 1993	20

- To gain an insight in the percentage of generated waste during construction operations for **specific** materials for different countries is presented below:

Table 2.6: Construction Waste of **Specific** Material as Percentage of Total Purchased Amount of **Specific** Construction Material in Brazil.

Construction Material	**Researchers** [42])		
	Pinto (1989)	**Solbeiman et al. (1994)**	**Pinto and Agopayan (1994)**
Steel	21%	16%	26%
Cement	25	46	33
Concrete	1	12	2
Sand	28	31	28
Mortar	50	48	46
Ceramic Block	-	21	-
Brick	11	23	12
Timber	-	-	32
Hydrated Lime	-	-	51
Wall Ceramic Tile	-	-	9
Floor Ceramic Tile	-	-	7

Table 2.7: Construction Waste of Fraction as Percentage of Total Purchased Amount of **Specific** Construction Material in The Netherlands [42].

Application of Construction Material	Construction Waste % (By Weight)
Stone Tablets	9
Piles	5
Concrete	3
Sand- lime elements	1
Roof Tiles	10
Mortar	10
Packing	Not Applicable
Sand-lime Bricks	6
Remainder (mainly small fractions of metal and wood)	-

Table 2.8: Construction Waste of Fraction as Percentage of Total Purchased Amount of **Specific** Construction Material in Ethiopia [13 &37]

Construction Materials	Construction Waste % (By Weight)				
	Asmare Seyoum (2015) [13]				Merid, M. et al. (2012) [37]
	Site A	Site B	Site C	Average	
Cement	19.1	8.91	12.90	13.64	15
Sand	17.48	9.92	15.37	14.26	16.67
Steel Reinforcement	14.75	6.17	11.00	10.64	15
Hollow Concrete Block	12.82	9.10	13.01	11.64	9.3
Coarse Aggregate	9.48	9.75	12.43	10.55	5.12
Ceramics	-	-	-	-	13

Table 2.9: Average Waste Percentage of Construction Material in Different Countries [44]

Material	Palestine			Egypt	Australia	Korea	Netherlands	Hong Kong		UK	USA
	Al Mogany 2006	Enshassi 1996	Dahman 2004	Garas 2003	Ekanayake and Ofrie 2004	Chen et al. 2002	Bassink and Brauwers 1996	Poon et al. 2001		Poon et al. 2004	Chen et al. 2002
								Public	Private		
Concrete	5.4	-	4.7	4	-	1.5	3	4-5	3-5	5	7.5
Steel Reinforcement	5.4	3.6	5.4	5	-	-	-	1-8	3-5	5	-
Timber Board	8.7	-	10.4	13	13.8	16.7	-	15	5	-	10
Block	5.4	-	4.6	6	-	3	-	4-8	6		3.5
Tile	4.4	-	3.8	5	-	2.5	-	4-10	6-8	2	6.5
Cement	4.4	-	5.3	5	19.6	-	10	4-20	1-7	10	-
Sand	10.5	-	8.8	9	-	-	10	-	-	-	-
Aggregate	8.9	-	5.7	-	-	-	-	-	-	-	-
Paints	4	-	-	-	-	-	-	-	-	2	-
Gypsum	4	-	-	-	-	-	-	6-10	5-	-	-
Water Pipes	1.7	-	-	-	-	-	-	1-5	1	-	-
Sewage Pipes	2.1	-	-	-	-	-	-	1-5	2	-	-
Crushed Rock	8.5	-	-	-	-	-	-	-	-	-	-

The result of the researches proofed the existence of material wastage at significant rates and the amount of construction materials wasted on site cannot be neglected. However, there exists big disparity in waste indices at different sites for the same material. Thus high variability of construction performance exists for a specific material between different sites. However, waste rates in one country may not also be directly comparable to those from other countries in consequence of differences in used construction techniques, culture, work procedures and common practices between the countries under study. It is also reported that the real average loss of material has a big variation interval, and is located between 0.85 and eight times the usual admitted waste.

Besides, Foromso and his co-authors [35] have also documented some extensive studies and surveys done in Brazil which mainly focus towards identifying the types of material wastes, causes and waste measurement. For example,

- The first research project on construction waste developed at the Federal University of Rio Grande do Sul (UFRGS) started April 1992. The main objective of that study was to analyse the main causes of material waste in the building industry in order to propose guidelines for controlling it in small sized firms. Seven building materials were monitored in five different sites during a period ranging from five to six months.
- The Brazilian Institute for Technology and Quality in Construction (ITQC) more recently coordinated a much more ambitious research project on material waste measurement, which was developed for the Brazilian construction industry, involving 15 universities (including UFRGS) and more than one hundred building sites. For over 2 years, eighteen materials had their waste monitored by using a data collection method similar to the projects carried out at the Federal University of Rio Grande do Sul (UFRGS) in 1992.

The main conclusions drawn from those two studies are:

1. The waste of building materials far higher than the nominal figures assumed by the companies in their cost estimates.
2. There is a very high variability of waste indices from site to site. Furthermore, similar sites might present different levels of wastes for the same material. This indicates that a considerable portion of this wastage can be avoided.

3. Some companies do not seem to be concerned about material waste, since they do not apply relatively simple procedures to avoid waste on site. None of them had a well-defined material management policy, neither a systematic control of material usage.
4. The lack of knowledge was an important cause of waste. Most building firms did not know the amount of waste they had before the development of the study.
5. Most causes of waste are related to flaws in the management system, and have very little to do with the lack of qualification and motivation of workers. Also, waste is usually the result of a combination of factors, rather than originated by an isolated incident.
6. A significant portion of waste is caused by problems, which occur in stages that precede production, such as inadequate design, lack of planning, flaws in the material supply system, etc.

Waste in construction is important not only from the perspective of productivity but also from the environmental considerations. Many times actual percentage of waste generation is much higher than envisaged initially causing needless utilization of resources. It means there is a plenty of scope for enhancing project productivity simply by taking waste out of construction [7].

As construction codes have come into effect in recent years, new construction technologies and methods have emerged. The newest methods of construction improve efficiency, performance and reduce construction waste [1].Although some residual level of construction waste seems unavoidable, the potential cost reduction by preventing generation of construction waste on site is substantial and can be an incentive for participants in construction projects to put efforts in minimizing construction waste. Furthermore, construction companies benefit from reduced waste generation by lower deposition costs and lower purchasing costs of virgin materials [42].

2.6. CLASSIFICATIONAND COMPOSITION OF CONSTRUCTION WASTE

Construction activity leads to generation of different kinds of solid wastes. Construction waste varies worldwide depending on the structure being built, materials used and construction methods employed [15 &4].Waste in construction falls into different categories. The causes that contribute to the generation of construction waste are various and culminate as a result of different causes and situations. A number of criteria are usually employed to classify wastes into types including their sources, physical state, material composition and the level of risk associated with waste substances. Such classification of waste provides a basis for the development of appropriate waste management practice [5 &29].

2.10.1. Classification of Construction Waste

Waste is, to a certain extent, inevitable on building sites and this is generally recognized by everybody in the construction industry[5].All those activities that produce costs, direct or indirect, and take time, resources or require storage but do not add value or progress to the product can be called non-value – adding activities or waste [13].

Distinct types of wastes have been measured in those studies, indicating that waste in construction has been understood in several different ways. As a consequence, a wide range of measures have been, such as excess consumption of materials, non-value adding activities, rework, and quality deviation. Those measures have been used to assess the performance of projects or production systems, since they usually allow areas of potential improvements to be pointed out, and the main causes of inefficiency to be identified [3].

Waste in construction can be classified into two main types; waste of materials and waste of time. Construction material wastes refer to materials from construction sites that are unusable for the purpose of construction and have to be discarded for whatever reason. The time waste is from the concept that the duration of construction tasks consists of process (and reprocess or rework) time, inspection time, move time, and wait time from which only process time is considered value-adding activity. The value adding activity is defined as the activity that converts material and/or information towards that which is required by the customer; non value adding activity (also called waste) as the activity that takes time, resources or space but does not add value. However, all value adding time belongs to process time, not all process time is value adding. Processes are also subject to wastes resulting from overproduction, wrong construction method, defects, and poor optimization in performance tasks [13].

According to resource consumed, waste can be categorized into physical and financial waste. This classification includes [5]:

- **Physical waste of materials**: Additional amount of materials relative to those specified in the project.
- **Physical Waste of man-hours**: Man hours increased by delay in the arrival of materials and overproduction.
- **Physical Waste of Equipment**: Equipment hours increased infunction of the problem quoted for the manpower.
- **Financial waste as a result of physical waste**: Determine the costs associated with physical waste.
- **Financial waste in result of material purchase**: Relative additional cost for the use of material with superior value to the specified one.

According to its nature, waste is also categorized in to two as[5, 7, 13 &37]:

- **Direct Waste**: include damaged material which could not be repaired and subsequently used, or which were lost during the building process.
- **Indirect waste**: represents monetary losses only and not the physical loss of material. Such loses arise principally from substitution of materials, unnecessary use of costlier material, excess use of material than estimated and allowed under the contract, from errors etc.

”Indirect Waste” is distinguished from “direct waste” in that the materials are not usually lost physically, but the payment for part or whole of the value is lost. This is the waste, which can be prevented, and involves the actual loss. Table below summarizes the various forms in which direct and indirect waste can occur.

Table 2.10: Types and forms of material waste [5,13 &37]

Principal Types	Forms of the Principal Types
Direct Waste	**Deliveries waste**: comprises all losses in transit to the site, unloading and placing into the initial storage.
	Site storage and internal site transit waste: comprise losses due to bad stacking and initial storage, including movement and unloading around the site, to stack at the workplace or placing into position.
	Conversion waste: comprises losses due to cutting uneconomical shapes, e.g. timber, sheeted goods.

	Fixing waste: comprises materials dropped, spoiled or discarded during the fixing operation.
	Cutting waste: includes losses caused by cutting materials to size and to irregular shapes.
	Application waste: includes materials such as mortar for brickwork and paint spilled or dropped during application, similarly, materials left in containers or cans which are not sealed and mixed materials like mortar and plaster left to harden at the end of the day.
	Waste due to the uneconomical use of the plant: this covers plant running when not in use, or not employed to its optimal use.
	Management waste: includes losses arising from an incorrect decision and not related to anything other than poor organization or lack of supervision.
	Waste caused by other trades: This includes losses arising from events such as "borrowing" by trades for purposes other than work, and not returning the plant or material or damage by succeeding trades.
	Criminal waste: covers pilfering, theft from the site and vandalism.
	Waste due to incorrect type or quality of materials: This includes waste stemming from materials wrongly specified and waste due to errors, particularly in the bills of quantities and specification.
	Learning Waste: Waste that is usually caused by apprentices, unskilled tradesmen, and tradesmen on new operations.
Indirect Waste	**Substitution**: where materials are used for purposes other than those specified
	Production waste: where materials are used in excess of those indicated or not clearly defined in contract documents, e.g. additional concrete in trenches, which are extracted wider than designed because no appropriately sized digger bucket was available.
	Operational waste: where materials are used for temporary site work for

	which no quantity or other allowances have been made in the contract documentation, e.g. tower crane bases, site paths, temporary protection.
	Negligent waste: where materials are used in addition to the amount required by the physical waste financial waste materials man-hour Equipment material purchase Due physical waste. Waste according to the type of resource consumed contract, owing to the construction contractor's own negligence.

2.10.2. Constituents and Composition of C&D Waste

The waste in construction is consisted of numerous types of materials. In new construction, the materials are easier to quantify and identify. Roadwork is an example of this, because there are two or three main materials utilized on the project- this also holds true for earthwork projects. In new building construction, there is a wider variety of material wastes compared to the road work and earthwork projects. Renovation projects also show a greater variety of C&D wastes. This can be attributed to the fact that the quantities and types of materials are more difficult to estimate when they are hidden behind obstructions or within structures. Demolition waste is more difficult to estimate because there are so many unknown materials. This means that there are still a few main waste sources, but there will also be more constituents overall [34].

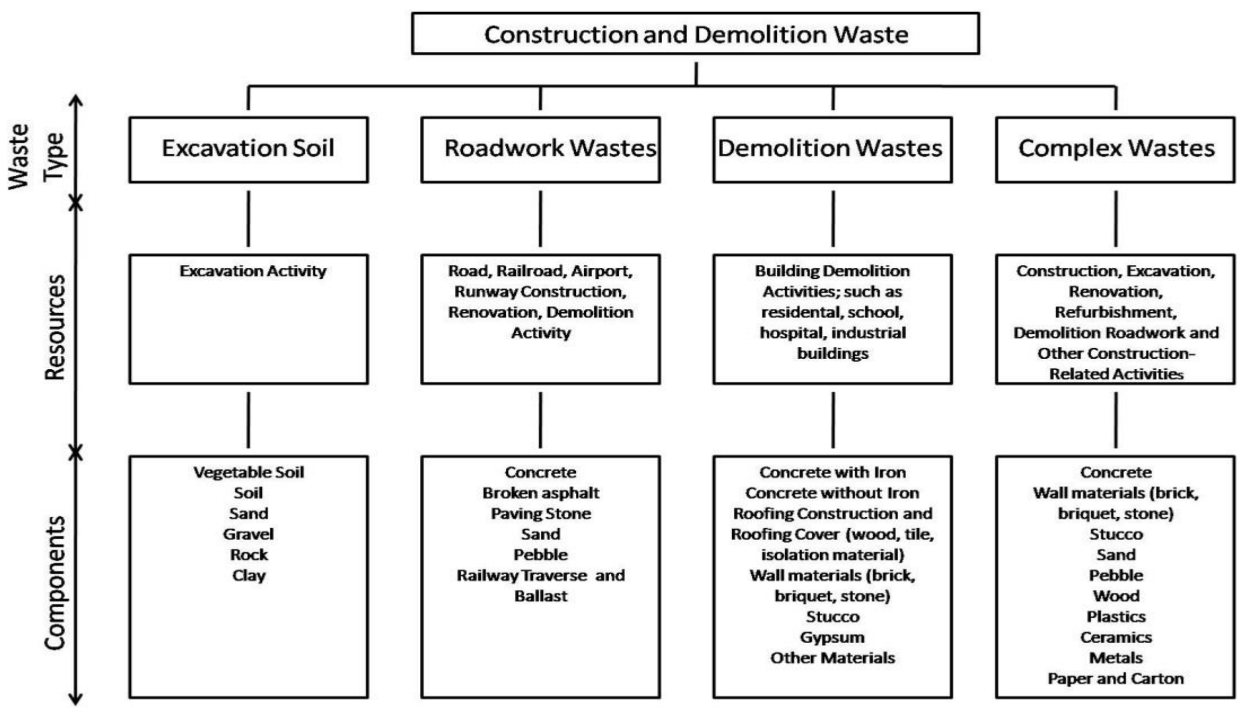

Figure 2.2: Type, Resources and Components of C&D waste

In order to simplify and generalize the treatment of wastes, the European Union has introduced a classification of the waste which is represented by the European Waste Catalogue EWC, breaking down the wastes into a 6digitcode. It is formed as follows [38]:

- 20 main groups ordered by origin of the waste, indicated by the 2firstdigits of the6digitcode
- Sub-groups, ordered according to their main physical feature, represented by the4first digits of the code
- And finally the waste types, which are represented by the whole 6digitcode.

C&DW, which interests us most in this context, is the number 17 in the catalogue. It embraces all the types of waste which can be expected to occur in construction and demolition activities, including excavated soil from contaminated sites.

Table 2.11: Classification of C&D Waste in Switzerland. *[S]: Hazardous waste, [ak]: waste which could be or become hazardous and therefore requires specific treatment*.

17	Construction and Demolition Waste including Excavation Material						
	17	01	Mineral Construction and Demolition Waste				
			17	01	01		Concrete
			17	01	07		Mixture of mineral construction and demolition waste
			17	01	98		Fraction from road demolition
	17	02	Wood, Glass, and Plastic				
			17	02	01		Untreated wood from construction sites
			17	02	02		Glass
			17	02	03		Plastics
			17	02	04	[s]	Glass and plastics containing hazardous residues
			17	02	97	[ak]	Scrap wood from renovation and demolition activities
			17	02	98	[ak]	Scrap wood containing hazardous components
	17	03	Bituminous mixtures, classified according to content of PAH*				
	17	04	Metals Including Alloys				
			17	04	01		Copper, bronze, brass
			17	04	02		Aluminum
			17	04	03		Lead
			17	04	04		Zinc
			17	04	05		Steel
			17	04	06		Tin
			17	04	07		Mixed metals
			17	04	09	[ak]	Scrap metal contaminated with hazardous substances
			17	04	10	[ak]	Cables containing oil, tar, or other hazardous substances

			17	04	11	[ak]	Cables other than those mentioned in 17 04 10
	17	05	Excavated Soil, Spoil and Gravel, classified according to Contamination				
	17	06	Insulation Material and Asbestos-containing material				
			17	06	01	[s]	Insulation material containing asbestos
			17	06	03	[s]	Other insulation material consisting of, or containing hazardous substances
			17	06	04		Insulation material not classified under 17 06 01 or 17 06 03
			17	06	05	[s]	Construction material containing unbound asbestos fibres
			17	06	98		Construction material containing asbestos other than classified under 17 06 05
	17	08	Gypsum based Construction material				
			17	08	01	[s]	Gypsum based construction material contaminated with hazardous substances
			17	08	02		Gypsum based construction material other than listed under 17 08 01
	17	09	Other Construction and Demolition Waste				
			17	09	01	[s]	Construction and demolition waste containing mercury
			17	09	02	[s]	Construction and demolition waste containing PCB
			17	09	03	[s]	Mixed construction and demolition waste containing hazardous substances
			17	09	04	[ak]	Mixed construction and demolition waste
			17	09	97	[ak]	Fine-grained fraction from C&D Waste separation
			17	09	98		Mixed combustible construction and demolition waste

The system is flexible enough to accommodate variations desired by certain countries; thus Switzerland, which is not member of the EU, has upon adoption of the EWC system, implemented adaptions favorable to its legislation and local situation. For instance the number 17 01 02 (bricks) has been omitted in the Swiss adaption, whereas the additional number 17 01 98 (fraction from road demolition, such as asphalt) has been introduced.

The table below also indicates the typical breakdown of material wastes for a variety construction projects. The survey was taken in Hong Kong, but it was also confirmed that the waste stream is virtually identical to the waste stream of similar construction projects in the United States.

Table 2.12: Composition of C&D Wastes in Hong Kong (%Volume)[34]

Constituent	Roadwork Material	Excavated Material	Building Demo Waste	Renovation Waste	Mixed Site Clearance	Total
Asphalt	23.4	0.0	1.6	0.0	0.1	2.22
Concrete	46.4	3.2	20.0	0.8	9.2	14.67
Reinforced Concrete	1.6	3.0	33.1	8.3	8.3	16.46
Dirt, Soil, Mud	16.8	48.9	11.8	16.1	30.6	23.84
Rock	7.1	31.1	6.8	7.8	9.7	11.53
Rubble	0.0	1.4	4.9	15.3	14.1	7.72
Wood	0.1	1.1	7.1	18.2	10.5	7.9
Sand	4.6	9.5	1.4	3.2	1.7	3.17
Metal (ferrous)	0.0	0.5	3.4	6.1	4.4	3.29
Block Concrete	0.0	0.0	1.1	1.1	0.9	0.08
Brick	0.0	0.3	6.2	11.9	5.0	5.18
Glass	0.0	0.0	0.2	0.8	0.6	0.32
Other Organics	0.0	0.3	1.3	2.6	3.1	1.71
Plastic Pipe	0.0	0.0	0.6	0.4	1.1	0.60
Trees	0.0	0.7	0.0	0.0	0.1	0.15
Fixtures	0.0	0.0	0.1	0.0	0.1	0.02
Miscellaneous	0.0	0.0	0.1	0.1	0.2	0.11
Bamboo	0.0	0.0	0.3	0.1	0.2	0.21
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

According to a study conducted in Malaysia in 1995, twelve (12) sub-categories of waste constitute the bulk of C&D waste received at landfills. The table below shows the composition of each category by weight.

Table 2.13: Composition of C&D Wastes in Malaysia[41]

Component	Composition of each Category of Construction & Demolition waste received at Landfill Sites (% by weight)				
	Road Work Material	**Excavated Soil**	**Demolition Waste**	**Site Clearance**	**Renovation waste**
Soil/sand	23.0	73.8	21.5	33.0	19.4
Concrete/mortar	16.9	1.2	10.8	4.6	7.4
Rock/Rubble	14.4	12.5	27.7	15.0	38.8
Reinforced concrete	14.2	0.4	5.8	0.9	7.0
Bricks/tiles	0.8	0.4	12.1	1.4	9.6
Slurry &mud	1.8	9.7	1.5	1.0	3.1
Asphalt	24.7	0.0	0.0	0.2	0.0
Cement contaminated	1.7	0.4	3.2	15.6	3.3
Wood	0.6	0.9	10.5	13.3	7.1
Ferrous metals	0.5	0.0	0.6	1.0	1.3
Non-ferrous metals	0.0	0.0	0.7	0.2	0.1
Others(include bamboo, trees, glass, plastics, bulky waste/fixtures, organics & garbage	1.4	0.7	5.6	13.8	2.9
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Percentage of total quantity of C & D waste landfill	**5.2**	**59.4**	**8.5**	**14.6**	**12.3**

A Study was conducted in The Netherlands which was conducted from April 1993 to June 1994 on five housing construction projects (a total of 184 homes). The result was a complete inventory of the amounts of the various waste fractions and is presented below [42].

Table 2.14: Composition of Construction waste (fractions as % of total amount of construction waste) in The Netherlands.

Application of Construction Material	Construction Waste % by Weight
Stone Tablets	29
Piles	17
Concrete	13
Sand- lime elements	11
Roof Tiles	10
Mortar	8
Packing	7
Sand-lime Bricks	3
Remainder (mainly small fractions of metal and wood)	2
Total	**100.0**

I Ethiopia, it was difficult to find in literatures and researches conducted that show the composition of wastes in construction projects. Although these examples do not constitute the entire construction industry, they are good indicators of the quantities and varieties of waste materials which are prevalent during construction and demolition projects.

2.7. SOURCES AND CONTRIBUTORS OF WASTE IN CONSTRUCTION

C&D wastes are generated from a variety of sources on a construction site. 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. Construction and repair of roads, bridges, flyovers etc. are classified under infrastructure development sector. 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. The classification of sources is shown in figure below [11].

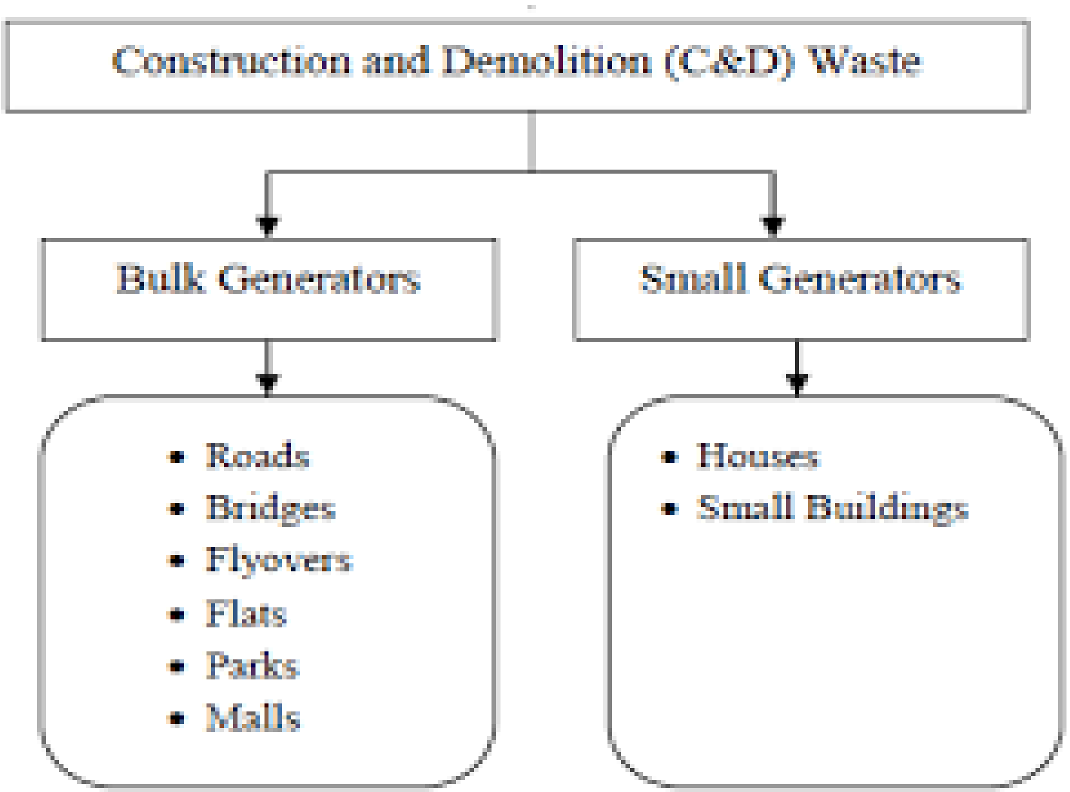

Figure 2.3: Sources of C&D waste generators

The contributors of C&D waste include Owner, Designer, Contractor, Manufacturer, Supplier, Logistics, Procurement and Site management as depicted and given in figure below[11].

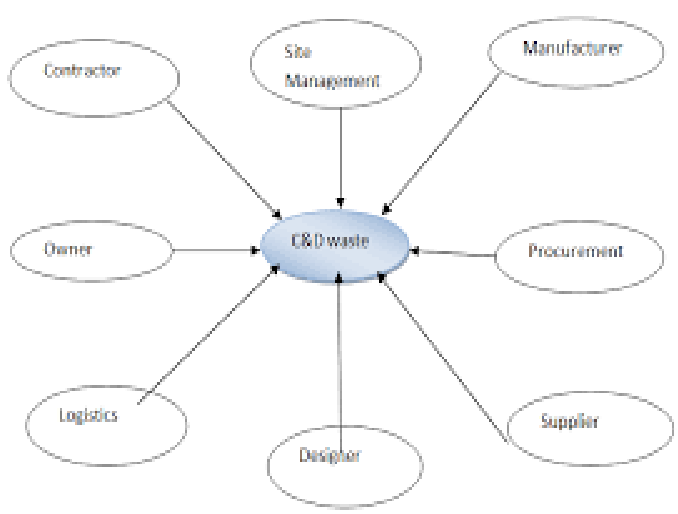

Figure 2.4: Contributors of C&D waste in a project

C&D waste can be classified according to its source, or type of works from which it is generated. On a Survey conducted in Malaysia [41], nature and proportions of C&D material delivered to public filling areas and landfills also vary for private projects and public projects.

Table 2.15: Sources of C&D Waste and Material Generation rates in Malaysia

<table>
<tr><th rowspan="3"></th><th colspan="4">C & D Material
100%</th></tr>
<tr><th colspan="2">C & D Waste
16.5%</th><th colspan="2">Public Fill
83.5%</th></tr>
<tr><th>Private Projects
8.7%</th><th>Public Projects
7.8%</th><th>Private Projects
44.6%</th><th>Public Projects
38.8%</th></tr>
<tr><td>Civil Works</td><td>0.4%</td><td>1.5%</td><td>31.9%</td><td>26.9%</td></tr>
<tr><td>Fitting out new buildings</td><td>0.6%</td><td>0.2%</td><td>1.4%</td><td>1.5%</td></tr>
<tr><td>Renovation old Buildings</td><td>2.9%</td><td>0.7%</td><td>2.1%</td><td>1.2%</td></tr>
<tr><td>Construction New Building</td><td>4.3%</td><td>5.1%</td><td rowspan="2">9.2%</td><td rowspan="2">9.2%</td></tr>
<tr><td>Demolishing Old Buildings</td><td>0.6%</td><td>0.3%</td></tr>
</table>

According to the survey, 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.

2.8. 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 at different stages of project. Researches revealed that construction waste is effectively generated along the project from start until completion of construction work. It can be emanated during design, operational, material handling and procurement [12].

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. Figure below is a diagram that shows the phases of construction project life cycle.

Figure 2.5: Phases of Construction Lifecycle (CLC)

Akhir, et al. [12] in their research by conducting extensive literature review, identified a total of 46 common factors of construction waste generation throughout CLC, classified in 7 groups as Information and Communication (ICT), Equipment, Project and Contract Management, Material, Delivery/Procurement, External/Unpredictable and Human Resources/Manpower have confirmed that:

- Construction phase is most critical phase where majority of the identified factors occurred in this phase. It is followed by design phase and finishing phase. However, in planning phase the chances of waste generation are minimum. This is due to the fact that waste is primarily produced during site operation and rarely occurred during at the early stage.
- The most frequently occurring factors in construction phase that are very significant in generating waste during construction phase are Ordering error and poor workmanship.
    - **Ordering error** causes over or shortage of ordering. Over ordering may cause excessive materials and result to material waste. While shortage of ordering may cause insufficient material availability which will lead to stoppage of construction work at site. The material need to reorder and cause longer of waiting time to receive materials from supplier.
    - **Poor workmanship** may be caused by unskilled labour, inadequate tools and equipment and/or poor working conditions. Incompetent supervisor and project manager also lead to poor workmanship. The effects of poor workmanship are abandoned work especially during construction/renovation stage and also may cause to conflict between workers due to deviation from the original intent.
- 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 the request happens during the construction work is in progress, this may result in demolishing and rework activities. This will require additional time, cost and material.
- On the contrary, construction waste factors are less commonly occurring in planning and finishing phase. In planning phase, the factor that contributes to waste is lack of waste management plan.

❖ By identifying the crucial occurrence phase of factors which contribute to waste generation and this will help the construction community to avoid or lessen the construction waste generation. Therefore, the project activities need to be planned at every stage by every personnel, who are involved, to minimize the overall waste generation [12].

C&D wastes are generated from a variety of sources on a construction site. According to researches, C&D wastes are organized into six categories: design, procurement, handling of materials, operation, residual, and other sources. The sources of waste for each category do vary depending on the materials utilized in each project. Table below provides details for typical sources of waste for each category [34].

Table 2.16: Identification of C&D waste sources

S.No.	Waste	Cause/ Source of Waste
1	Design	Blue Print Error
		Detail Error
		Design Changes
2	Procurement	Shipping Error
		Ordering Error
3	Handling of Material	Improper Storage/ Deterioration
		Improper Handling (on and off site)
4	Operation	Human Error (by craftsmen or other laborers
		Equipment Malfunctions
		Acts of God (catastrophes, accidents, weather)
5	Residual	Leftover scrap
		Un-reclaimable non-consumables
6	Other Sources	

Design errors with blueprints or change orders can cause waste for a builder. Improperly handled material off the construction site causes excess waste as materials are brought to the site already damaged. Communication problems also account for many sources of error in C&D wastes. Ordering too much, too little, or wrong material can cause waste. Many times, human error is the cause of waste, as wrong dimensions or poor cuts are made on a material. Other sources of waste may come from losing, reordering, then discovering the misplaced material, or even nighttime dumping of wastes by local authorities.

If we consider wastes that arise during the construction phase, According to Nagapan et al[39], there are about 63 waste factors existed in construction activities. The common causes of construction waste identified from past research papers are grouped into seven categories: Design, Handling, Worker, Management, Site Condition, Procurement and External. The frequency of the causative factor in each category was determined based on the deduction from past research works that were considered and the severity of each factor is identified. Table below shows the mapping of the causative factors taken from research articles around the world.

Table 2.17: Matrix of the Causes of Construction Waste

GROUP	CAUSES OF CONSTRUCTION WASTE	%
DESIGN	Frequent design changes	1.6
	Design errors	0.9
	Lack of design information	0.6
	Poor design quality	0.4
	Slow drawing distribution	0.3
	Complicated design	0.2
	Inexperience designer	0.2
	Interaction between various specialists	0.2
	∑	**4.2**
HANDLING	Wrong material storage	1.1
	Poor material handling	1.0
	Damage during transportation	0.6
	Poor quality of materials	0.6
	Equipment failure	0.5
	Delay during delivery	0.4
	Tools not suitable	0.2
	∑	**4.5**
WORKER	Workers' mistakes	0.8
	Incompetent worker	0.5
	Poor attitudes of workers	0.4

	Damage caused by workers	0.3
	Insufficient training for workers	0.2
	Lack of experience	0.2
	Shortage of skilled workers	0.2
	Inappropriate use of materials	0.2
	Poor workmanship	0.2
	Worker's no enthusiasm	0.2
	Abnormal wear of equipment	0.1
	Too much overtime for workers	0.1
	∑	**3.4**
MANAGEMENT	Poor planning	0.9
	Poor site management	0.7
	Poor controlling	0.7
	Poor supervision	0.6
	Inappropriate construction methods	0.6
	Lack of coordination among parties	0.6
	Poor information quality	0.6
	Late information flow among parties	0.5
	Scarcity of equipment	0.5
	Resources problem	0.3
	Rework	0.3
	Waiting periods	0.3
	Communication problems	0.2
	Outdated equipment	0.2
	Lack of waste management plans	0.2
	Non availability of equipment	0.2
	Lack of environmental awareness	0.1
	∑	**7.4**
SITE CONDITION	Leftover materials on site	0.4
	Poor site condition	0.3

	Waste resulting from packaging	0.2
	Congestion of the site	0.2
	Lighting problem	0.1
	Crews interference	0.1
	∑	**1.3**
PROCUREMENT	Ordering errors	0.9
	Error in shipping	0.2
	Mistakes in quantity surveys	0.2
	Ignorance of specifications	0.2
	Waiting for replacement	0.1
	∑	**1.3**
EXTERNAL	Effect of weather	1.0
	Accidents	0.5
	Pilferage	0.3
	Vandalism	0.2
	damages caused by third parties	0.2
	Festivities	0.1
	Unpredictable local conditions	0.1
	Lack of legatitive enforcement	0.1
	∑	**2.3**

Based on the above table, the highest frequency as indicated by most researchers is a frequent design change that contributes to large generation of construction waste. The significant factors for other categories are also presented below.

Table 2.18: Significant factors that contribute to construction waste generation based on category

Category of factors	Significant factor determined	Rank
Design	Frequent design changes	1
Handling	Wrong material storage	2
External	Effect of weather	3

Management	Poor planning	4
Procurement	Ordering errors	5
Worker	Workers' mistakes	6
Site condition	Leftover materials on site	7

Seyoum, A. [13] in his research identified 81 factors which cause material waste in construction, and those factors were distributed into five groups namely, Design and Documentation; Materials handling and storage; Operation (onsite Equipment); Site Management and Practices; Site Supervision. Table below shows the results of his research and illustrates the mean and ranking of each group.

Table 2.19: Weighted average and ranking over-all causes of construction materials wastage (Ethiopia)

Main Group	**Weighted average (all groups)**	**Rank**
Site Supervision	0.69	1
Materials handling and storage	0.60	2
Design and Documentation	0.55	3
Site Management and Practices	0.54	4
Operation	0.53	5

These waste generation activities consume time and effort without adding values to the client thus resulting losses in material, delay in meeting the stipulated time and effort without adding values to client thus resulting losses in material, delay in meeting the stipulated time and execution of unnecessary work [10].

C&D wastes are as much a part of construction as schedules, estimates, hammers, or nails. The failure to recognize and record waste from such causes makes accounting for materials meaningless. A simple measure of waste on site would be the difference between that used as specified and the quantity of material delivered to site as a percentage of such deliveries [13]. Therefore to avoid overrun the cost of the project it is necessary to avoid the waste generation and apply proper waste management.

2.9. IMPACT OF CONSTRUCTION WASTE ON PROJECTS AND THE ENVIRONMENT

Construction waste becomes a global issue facing by practitioners and researchers around the world. In most parts of the world, construction industry consumes huge amount of natural resources and often generates large quantities of construction waste. Construction waste gives a negative impact to the environment, costs, time, productivity and social of country [3, 5, 6, 7, 13&39].

The large volume of waste in the construction industry contributes to the rapid depletion of natural resources and production of high volumes of air pollution caused during processing. Water pollution will also result from the processing of materials. According to [13] the construction industry is the biggest consumer of raw material in the UK, 90% of non-energy minerals extracted in Great Britain are used to supply the construction industry with materials 260m tones of material are extracted for use as aggregate and other construction material. The construction of buildings, their materials and the occupant's use of services is responsible for 50% of the UK CO_2 emissions.

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

Considering enormous increase in amount of waste generation owing to the growth in construction industry can also lead to wastage of materials which has its economic value. Waste has direct impact on the productivity, material loss and completion time of project which resulting in loss of a significant amount of revenue.

A research in The Netherlands was conducted on five residential building projects and percentage of the total waste costs (purchasing costs plus transport costs plus waste-management costs) caused by the use of a particular building materials is shown in table below[42]:

Table 2.20: **Costs** of Waste of Fraction as Percentage of Total Waste Costs- Netherlands

Application of Construction Material	Costs of Waste (%)
Stone Tablets	26
Piles	13
Concrete	7
Sand-lime elements	8
Roof-tiles	13
Mortar	5
Sand-lime bricks	3

The research project indicates that the main amount of solid waste in a construction project is caused by the use of a small variety of construction materials and is reached 75% of total waste costs.

A research in Ethiopia which is conducted on six projects also confirmed that the net economic impacts caused by the material wastage are so extensive and is found to be 6.89% of the project cost[37].

Table 2.21: Net Economic Effect of Material wastage on the Project- Ethiopia

Construction Materials	Wastage % by Weight	Material Pre-output in line with Project Cost	Net Effect % By Weight
HCB	9.3	0.0231	0.22
Cement in Block Works	14.5	0.0033	0.05
Sand in Block Works	15.2	0.0011	0.02
Cement in Plastering	15	0.0200	0.30
Sand in Plastering	16.67	0.0072	0.12

Ceramics	13.91	0.0424	0.59
Steel in C - 25 Concrete	15	0.3690	5.54
Cement in C - 25 Concrete	5	0.0088	0.04
Sand in C – 25 Concrete	5.5	0.0019	0.01
Coarse Aggregate in C-25 Concrete	5.12	0.0019	0.01
		Total net Effect	**6.89%**

Evidences of **waste and value loss** due to quality of works, material management, non-productive time, safety and constructability are also found important and there is strong empirical evidence showing that a considerable amount of waste and loss of value exists in construction apart from the conventional understanding of physical waste or material waste. A large part of these wastes has been hidden, and it has not been perceived as actionable [5].

When material ends up as waste it has the potential to be reused or recycled thereby minimizing its impact on the environment through less processing. Therefore, to reduce the negative impacts of waste to the environment, costs, time, productivity and social of country, it needs a comprehensive understanding of the construction waste generation and management.

2.10. CONSTRUCTION WASTE MANAGEMENT

2.10.1. Definition/ Concept:

Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial producers [32].

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" [31].

Responsible management of waste is an essential aspect of sustainable building. In this context, managing waste means eliminating waste where ever possible; minimizing waste whenever feasible and reusing materials which could otherwise become waste. Construction waste management practices have known the reduction, recycling and utilize of wastes as essential for property management of resources [10].

Construction waste minimization and its management has become a serious and challenging environmental issue in the developing cities all over the world today. The management of construction and demolition waste is a major concern due to the increasing quantum of demolition's rubble, continuing shortage of dumping sites, increase in transportation and disposal cost and above all growing concern about pollution and environmental deterioration [4]. Construction waste once generated is difficult to recycle and reuse due to high level of contamination and heterogeneity. Hence its prevention and minimization gets an importance in project management scope. Depleting natural resources, increasing pollution, scarcity of dumping yards, destruction to the natural environment and habitat leading to ecological imbalance etc. are some of the negative impacts of construction and demolition (C&D) waste.

In solid waste management there is no throwing 'away'. When 'throwing away' waste, system complexities and the integrated nature of materials and pollution are quickly apparent. Failing to take immediate efforts in its reduction and management will lead to exhaust of the natural resources and land fill spaces. Though some amount of construction waste can't be avoided, the potential cost reduction by preventing generation of construction waste on site is substantial [7].

2.10.2. Approaches to Construction Waste Management

The first appearance for the need of waste management was for health and hygienic reasons. Waste management was primarily about waste disposal, in other words, how to transport waste away from where people lived. For many decades waste management was seen predominately as an engineering topic. Efforts have been made to explore waste treatment and disposal methods such as biological processing, state-of-art landfills and waste-to-energy incinerators, in order to reduce the adverse impacts to humans and the environment [32].

There are several approaches to construction waste management. The process of managing construction waste goes far beyond the disposal of the wastes itself. It is an all-encompassing strategy to effectively utilize construction resources, with the view to reducing the quantity of waste and also utilizing the generated waste in the most effective manner. The most common approach to management of construction waste is dumping in landfill sites. However, decreasing landfill space has led to increasing costs of landfill disposal to the contractor. Also, a relatively large amount of materials is being wasted because of poor material control on building sites. This has prompted the need for alternatives for waste prevention and the initiatives to reduce, reuse and or recycle waste produced which are referred to as the **three R's** of construction waste management [36].

A waste hierarchy has been widely adopted as a guide for construction managers, in line with the principles of sustainable construction.

Fig. 2.6: The Waste Hierarchy

(Source:http://www.acceleratio.eu/wp-content/uploads/2014/10/Waste_Hierarchy.gif)

The Waste hierarchy suggests that [36]:

i. The most effective environmental solution may often be to **reduce** the generation of waste.

ii. Where further reduction is not practicable, products and materials can sometimes be **re-used**, either for the same or a different purpose.

iii. Failing that, value should be recovered from waste, through **recycling**, composting or energy recovery from waste.

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

For managing the waste, there must be efficient waste management system which can control the waste at source and manage the waste at every stage or phase of construction project. Furthermore, Construction waste can be **controlled** by various ways such as [10]:

- ✓ Practicing Attitude towards Zero Wastage,
- ✓ Proper decisions at design stage,
- ✓ Site management,
- ✓ Proper Standardization of Construction Materials, and Codification of the same,
- ✓ Using Waste Management System on Project,
- ✓ Plan the project activities at every stage by every construction personnel, who are involved in minimizing the overall waste generation at project.

Local practices in the management and disposal of construction and demolition wastes often are shaped by the availability of suitable disposal sites, economic conditions, societal priorities, availability of markets for recycling and reuse, transportation options, and the capabilities of local workforces and construction business to adapt demolition processes for management of wastes [45].

2.10.3. Benefits of Waste Management

The practice of waste management for construction activities has been promoted with the **aim** of protecting the environment and the recognition that wastes from construction and demolition works contribute significantly to the polluted environment. This increasing awareness of environmental impacts from construction wastes has led to the development of waste management as an important function of construction project management [36].

Waste Management in Construction activities has been promoted for the aim of increasing profit from project and protecting the environment [10]. According to Authors [36, 7, & 13]also, there are two fundamental reasons for waste management: the economic advantages, and the environmental advantages.

Environmental Advantages include:

- Reduced quantity of waste generated and hence, minimized amount of wastes disposed off at landfills, which therefore extend the life span of landfills;
- Reduced Environmental effects as a result of disposal, e.g. noise, pollution, and decreased global warming;
- Minimization of the risk of immediate and future environmental pollution and harm to human health.
- Conserving natural resources due to reduced demand for virgin materials due to recycled packaging.

Economic Advantages include:

- Reduced Transportation cost
- Less Disposal Cost
- Minimized Purchase quantity and raw materials
- Reduced Purchase price of new materials (when considering reuse and recycling)
- Increased returns achieved by selling waste materials to be reused and recycled.

Other Advantages:

- Enhanced Work Efficiency and Productivity
- Improved Profit Margin
- Improved image of the company, Competitiveness and Client Satisfaction
- Increased site safety

❖ It is also reported that the net benefit of reusing and recycling of waste materials is estimated at **2.5%** of the total project budget [7]. Thus, in view of these advantages and the negative impact of construction wastes on successful project delivery, it is essential identify main causes of waste.

2.10.4. Barriers for Adoption of Waste Management

Barriers for widespread adoption of waste management (Reduce, reuse and recycle) system in India as stated by [6] are the following:

1. Lack of Awareness in the Industry:

The major barrier in the industry is the lack of awareness among local contractors, construction labor and architects about waste management techniques and approach. Usually most of the waste that is produced during the construction process is the result of poor handling and techniques.

2. Lack of interest from clients:

Another main reason for an ignorant industry is lack of importance given by clients in imposing waste reduction and management practices into the projects. Clients do not support those activities which do not offer tangible benefits to them. Potential of significant cost saving is not yet voluntarily implemented in projects and timing is given major preference.

3. Lack of proper training and education

Lack of Contractor federations and professional institutions in the country which could significantly raise awareness among the clients and contractors about the possible economic benefits and its social consequences.

4. Lack of skilled labor:

Major portion of construction labor in the industry is unskilled. Due to which proper waste handling methods are not adopted. Thus it is very important that contractors and sub-contractors should develop awareness and skills in labor which is mostly illiterate.

5. Lack of market competition:

The above mentioned barriers make the industry as a whole to be fragmented and fail to extract benefits from the much evident aspects. This leads to lack of competition among contractors, for e.g. if one contractor makes good cost savings from a project and increases their profit margins. Eventually this should then incentivize other contractors to get involved with waste minimization and management techniques. But mostly from a contractor's viewpoint, taking up waste minimization and management is more of ex *ante* issue where risks are associated with the contractor to bear the cost implications. This will become widespread only after taking project initiative and then benefiting from them.

***6. Lack of Government Interventions*:**

Government regional, national policies and regulations are limited and are not implemented appropriately. Regulations like landfill tax or tax incentives to incorporate this approach in the project might enforce industry to explore cost savings seriously.

7. Lack of waste reduction approach by architects:

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

In general:

- The preparation of a waste management plan at the early stages of a project is essential to facilitate suitable arrangements for proper management of waste and a sequence of operations to sort and segregate materials. Transportation associated with the movement of materials and waste should also be considered [5].
- Clean and healthy living conditions in cities and towns cannot be achieved without reliable and regular waste collection and adequate disposal systems [31].
- Failure to reduce, reuse and recycle societal wastes is unsustainable. It stands to reason that efficient and effective elimination and minimization of waste and reuse of materials are essential aspects of design and construction activity[45].
- Creativity, persistence, knowledge of available markets and business, and understanding of applicable regulations are important skills for design and construction professional[45].

2.11. ROLES OF STAKEHOLDERS IN MANAGING WASTE IN CONSTRUCTION

A number of stakeholders are involved in the construction waste management process. Each of them involved take different roles in construction projects with very different objectives [32]. Waste is a shared responsibility between all parties of the supply chain, from the client down to the waste contractor [13]. Effective management of building-related waste requires coordinated action of government, business, and professional groups and their activities. Table below provides a summary of stakeholders involved in the construction projects and roles in construction waste management at different stages of construction.

Table 2.22: Roles of Stakeholders Involved in Construction Waste Management

Stakeholder	Objective	Role in Construction Projects	Roles in Construction Waste Management
Government	Doing the benefits of the society and the general public	- Setting up legislative, institutional and administrative frameworks; - Enforcement and monitoring; - Targets and directions setting; - Providing waste treatment and disposal facilities; - Government is also a client who initiates construction projects and specify what, how and where the construction should be built	- Managing waste by legislative and administrative measures - Mandating waste reduction practices for construction projects by legislations - Waste reduction targets and directions setting by formulating waste reduction plans, strategies and policies ; - Creating both financial and non-financial incentives to the private market to reduce construction waste - Providing waste treatment and disposal facilities; - Educating stakeholders knowledge on waste management and awareness building, e.g. workshops, leaflets, guidelines and etc. - Fostering communication, co-operation and information sharing among stakeholders; - Technological innovations and imports of waste technologies; - Supporting the creation of markets for recycled materials; - As a client of construction projects, government could specify waste reduction requirements in the project specifications and project tenders; - Adding credits to low-waste designs and contractors with good waste management practices in the bidding procedure of projects
Developer	Profit making; Primary concern is to build, sell and earn profits; prefer short project schedule and cost saving	A client of construction contractors who initiates construction projects and specify what, how and where the construction should be built	- As a client of construction projects, government could specify waste reduction requirements in the project specifications and project tenders - Involving both project designers and construction contractors in the planning of construction projects so that they could exchange experiences and knowledge on low-waste construction methods and designs - Prioritizing waste reduction in policy agenda and adding credits to low-waste designs and contractors with good waste management practices in the

			bidding procedure of projects; - Complying to laws
Project Designer	Profit making; Meeting specifications required by clients (i.e. developers or government)	Designing how construction project to be built and construction methods for developers	- Incorporating low-waste design options in the project design plan; Incorporating opinions from construction contractors who have a better knowledge on construction works and operations on-site
Materials Supplier	Profit Making; Primary concern is to sell materials as many as possible for profits	Selling construction materials to construction contractors	- Advising contractors with the right amount of materials and arranging for taking back surplus materials at an agreed price; - Minimizing packaging materials used in protecting materials for transporting
Machine Supplier	Profit Making; Primary concern is to sell construction machines and equipment as many as possible for profits	Selling construction machines and equipments to construction contractors	- Promoting low-waste machines and machines for low-waste construction methods to contractors; - Arranging maintenance and take-back services to their machines; - Using recycled materials in producing new construction materials
Waste Handling Equipment Supplier	Profit Making; Primary concern is to sell waste handling equipments as many as possible for profits	Selling waste handling equipments or providing lending services of waste handling equipments, e.g. waste containers, to construction contractors	- Promoting to construction contractors the use of waste handling equipments, for example, in sorting and storing construction waste on-site more efficiently; - Selling waste handling equipments or providing lending services of waste handling equipments, e.g. waste containers, to construction contractors
Waste Management and Solutions Company	Profit Making; Primary concern is to sell waste management concepts and solutions to contractors for profits	- Selling waste management and reduction plans, suggestions and solutions to construction contractors during the construction; - Providing waste management services to construction contractors	- Providing waste management and reduction plans, suggestions and solutions and other waste management services to construction contractors during the construction; - Providing waste reduction and minimization advises to developers, government and contractors on the design and planning of construction projects
Labour Training Institution	Could be driven by profit-making or voluntary to provide benefits to the industry and society; Primary concern is to train qualified labours for construction works	- Training labours for construction industry, including scaffolding, formwork, cement forming and etc. - Granting certifications and qualifications to qualified labours	- Training labours with low-waste construction methods and skills required - Granting certifications and qualifications to qualified labours who could carrying out low-waste construction methods and educated with waste management knowledge and awareness for construction operations
Environmental	Could be driven by profit-making or	- Providing education to stakeholders on	- Providing education to stakeholders on

and Waste Management Training Agency	voluntary to provide benefits to the industry and society; Primary concern is to educate stakeholders with environmental and waste management knowledge	environmental and waste management knowledge, training stakeholders with waste management skills and providing latest information on management concepts and technologies; - Providing certifications and qualifications to qualified labours, e.g. green certifications, practitioner branding and labeling, award scheme and etc.	environmental and waste management knowledge, training stakeholders with waste management skills and providing latest information on management concepts and technologies; - Providing certifications and qualifications to qualified labours and companies with good waste management practices, e.g. green certifications, practitioner branding and labeling, award scheme and etc. to encourage waste reduction initiatives across the industry
Construction Labour	Working for salary and job satisfaction	- Carrying out construction works onsite, including scaffolding, formwork, cement forming and etc.	- Conducting waste management practices on-site which facilitate waste reduction, such as minimizing contamination of recycled materials, selective demolition, carefully manage and use the materials to avoid wasting, and etc.
Construction Contractor	Profit Making; Prefer short and well scheduled project time and cost saving	- Managing and carrying out construction operations, including site layout planning, logistic planning and etc.	- Conducting and Managing waste reduction practices on-site during construction operations; - Incorporating waste management plan and waste reduction measures in the site layout plan and logistic plan during the planning stage; - Suggesting to developers or government waste reduction construction methods and practices; - Building linkages to other stakeholders in the supply chain to maximize the chances for reusing surplus materials and recycling recyclables by transporting materials to places who can utilize them - Promoting awareness on waste reduction to construction staffs
Hauler	Profit Making; Prefer to save costs by traveling shorter distance than initially required by projects	- Transporting recyclables and construction waste to designated destinations	- Avoiding flytpping and transporting waste to designated sites; - Coordinating with construction constructors to transport waste to places which could utilize the construction waste for other purposes
Scavenger	Profit Making; Prefer to pick up uncontaminated recyclables as many as possible for profits	- Picking up recyclables with good market and high value for reselling them to recyclers	- Picking up recyclables with good market and high value for reselling them to recyclers; - Coordinating with construction contractors for sorting waste sand picking up recyclables
Recycler	Profit Making; Prefer to recycle materials at low cost and sell them at a price that could make a profit; Prefer	- Recycling collected construction waste into new products, e.g. rock pieces and concrete are recycled into aggregates for	- Coordinating with construction contractors, scavengers and haulers to pick up waste from construction sites;

	to have a bigger market receiving recycled products	cement production	- Developing and importing technologies to recycle wider range of waste; - Coordinating and promoting to materials manufacturers to use the recycled products for producing new products; - Assuring the recycled products are in qualified standard which could be reused in high-value purposes
Private Waste Facility Provider or Operator	Profit Making; Prefer to have constant supply of waste to utilize the facilities	- Providing or operating waste facilities such as sorting, recycling and disposal facilities	- Providing or operating waste facilities such as sorting, recycling and disposal facilities; - Investing and importing wider range of waste facilities, for examples, sorting facilities which could sort out wider range of waste with different sizes, recycling facilities which could accept more types of waste and etc., - Marking sure all waste are accepted and treated according to their designated ways by the legislations
Research and Development Company	Profit Making; Prefer to develop new technologies which would be demanded by the market	- Developing new technologies such as sorting, recycling and disposal facilities which might be demanded by the market and providing innovations on the use of materials in construction, low-waste construction methods and waste management concepts	- Developing new technologies such as sorting, recycling and disposal facilities to treat waste efficiently and providing innovations on the use of materials in construction, low-waste construction methods and waste management concepts
Exchange Platform Provider	Could be driven by profit-making or voluntary to provide benefits to the industry; Prefer to link up as many stakeholders as possible in the industry	- Providing communication platform for exchanging information across the industry and sharing contacts among stakeholders in the industry so that better linkages and communications could be established and potential businesses suppliers, clients and partners could be networked	- Providing communication platform for exchanging information across the industry and sharing contacts among stakeholders in the industry so that better linkages and communications could be established and potential businesses suppliers, clients and partners could be networked - Encouraging networking of materials suppliers, project contractors and waste facility provider to trade waste for new purposes and to avoid wasting
Property Company	Profit making; Primary concern is to sell property at high price	- Marketing the new construction to the market and selling them for profits	- Marketing to the end buyers the benefits of low-waste construction and waste management practices implemented during the construction to the end buyers; - Promoting to the end buyers the benefits of waste management and reduction and the concept of socially and environmentally responsible purchasing

End Users/ Consumers	Purchasing property with desired properties at low price	- Purchasing desired properties	- Prioritizing waste reduction in purchasing decisions
Industry Association	Providing benefits to the industry	- Providing latest information and news about the industry to stakeholders in the industry; - Providing assistance and supporting services to the industry; - Providing training and education to stakeholders in the industry; - Providing a platform for information exchanging and communication among stakeholders; - Providing branding, labeling, awards and certifications to qualified stakeholders in the industry on various concerned areas; - Promoting and encouraging industry; research and development on inventing more effective waste reduction technologies	- Developing a waste reduction culture or norm in the industry; - Providing latest information and news about the industry on waste management to stakeholders in the industry; - Providing assistance and supporting services to the industry to manage waste; - Providing training and education to stakeholders on waste management in the industry; - Fostering communication, co-operation and information sharing among stakeholders by encouraging information sharing, co-operations and communication among stakeholders; - Providing certifications and qualifications to qualified labours and companies with good waste management practices, e.g. green certifications, practitioner branding and labeling, award scheme and etc. to encourage waste reduction initiatives across the industry; - Promoting and encouraging research and development on inventing more effective waste reduction technologies
✓ Stakeholders with their primary objective for profit making would implement waste reduction and management practices only if the measures offer some co-benefits which may be of interest to the stakeholders.			

CHAPTER THREE

3. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

3.1. Findings from the literature review

In line with the objective, the findings of this study from the literature have proven that:

- Construction industry remains an important economic sector that has a vital role to play in ensuring economic development in a country's economy. This economic development has resulted in an increase in volume of construction and demolition activities. In that, a very high level of waste exists in construction. This results in serious problems both locally and globally.
- Construction industry has an adverse impact on environment due to its generation of construction waste. Besides the environment, the waste generated also affect the cost, productivity, time, profitability, social and economy of the industry, calling for the need to identify the causes of waste and to control them within reasonable limits.
- Waste in construction can culminate as a result of different causes and situations, and construction waste falls into different categories, quantities may vary in type, size, method, material, and location of projects. The origin of waste was depicted as coming from all stages of the construction process and is identified throughout the production phase.
- Construction waste reduction has become an important issue to improve the performance of the construction industry in terms of economy, quality and sustainability.

3.2. Conclusions and Recommendations

A number of causes were identified as the major causes of construction material waste on building construction projects and there also exist a very high variability of waste indices from project site to project site.

- Identify the potential waste early in the design, prior to the commencement of work by setting clear mechanisms to detect waste; and the project activities need to be planned at every stage by every construction personnel who are involved on the project implementation process.

Construction material wastes has an adverse impact on environment and also affect the cost, productivity, time, profitability, social and economy of the industry.

- There is a need to develop a scientific methodology to quantify waste; set an acceptable and approved rate of waste; and develop waste minimization plan and strategies, an effective construction materials management system and implement in construction projects.

In addition, effective management of building-related waste requires coordinated action of government, business, and professional groups and their activities:

- ✓ There need to be a strong intervention from government by mandating waste reduction practices for construction projects by formulating legislative and administrative measures;
- ✓ Developers need to add credits to low-waste designs and contractors with good waste management practices in the bidding procedure of projects;
- ✓ Designers shall incorporate low-waste design options in the project design plan;
- ✓ Suppliers may contribute to waste reduction by arranging for taking back surplus materials at an agreed price and minimizing packaging materials used in protecting materials for transporting;
- ✓ Construction contractors need to incorporate waste management plan and waste reduction measures in the site layout plan and logistic plan during the planning stage and also conduct waste reduction practices on-site during construction operations;
- ✓ Training labours with low-waste construction methods and skills is required. Labours also need to conduct waste management practices on-site which facilitate waste reduction, such as minimizing contamination of recycled materials, selective demolition, carefully manage and use the materials to avoid wasting.

Furthermore, further studies are necessary to increase the existing knowledge in order to help the construction industry to better conceptualize waste and to analyse deeply its main causes and also future studies are necessary on waste management in general and the implementation of waste management plan into construction projects in particular.

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