T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

WASTE MANAGEMENT FOR RENOVATION CONSTRUCTION PROJECTS IN IRAQ

MASTER THESIS

Mohammed Abdullah Mohammed H. SHUBBAR

Engineering Management Department

Engineering Management Master in English Program

FEBRUARY 2024
ISTANBUL

T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

WASTE MANAGEMENT FOR RENOVATION CONSTRUCTION PROJECTS IN IRAQ

MASTER THESIS

Mohammed Abdullah Mohammed H. SHUBBAR
(211281026)

Engineering Management Department

Engineering Management Master in English Program

Thesis Advisor: Assist. Prof. Dr. Tuğbay Burçin GÜMÜŞ

Second Advisor: Assist. Prof. Dr. Omar Ekrm AL-JUBOORI

Istanbul 2024

T.C.
İSTANBUL GEDİK ÜNİVERSİTESİ
Lisansüstü Eğitim Enstitüsü Müdürlüğü

Jüri Tez Onay Formu

12.02.2024

LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Bu çalışma 12.02.2024 tarihinde aşağıdaki jüri tarafından Mühendislik Yönetimi Dalı, Mühandislik Yönetimi (Tezli Yüksek Lisans) Programı Yüksek Lisans Tezi olarak kabul edilmiştir.

TEZ JÜRİSİ

Dr. Öğr. Üyesi Tuğbay Burçin GÜMÜŞ
Danışman
İstanbul Gedik Üniversitesi

Üye (İmza)	Üye (İmza)
Doç. Dr. Redvan GHASEMLOUNIA	**Dr. Öğr. Üyesi Mert TOLON**
İstanbul Gedik Üniversitesi	İstanbul Gedik Üniversitesi

DECLARATION

I Mohammed Abdullah Mohammed H. SHUBBAR declare that current thesis entitled “Waste Management for Renovation Construction Projects in Iraq” is an original work. I accomplished it myself to obtain the master's degree in Engineering Management. I also declare that present thesis or any part of it has not been presented to obtain any other degree or submitted as a research paper in any other institution or university. (12/02/2024)

Mohammed Abdullah Mohammed H. SHUBBAR

DEDICATION

I am grateful first to my Creator Allah (God) for granting the skills, strength, and aptitude required to conduct my research. My heartfelt thanks and love go to my father's pure spirit that always encouraged and inspired me to pursue higher education; without God and my father, I would not have been who I am now. Every moment of my life is a debt owed to my father, and I give him thanks with each breath.

I am also indebted to my compassionate and kind mother for her constant blessings and prayers for me; may God bless her life. Thanks are also due to my wonderful wife for encouraging me to keep moving forward to pursue my post-graduate studies. She created the best conditions for me to conduct my research.

Finally, my thanks go to my lovely kids whom I sincerely adore and hope the best for them in their academic and future life, to my brother, sister, and all my friends and colleagues.

TABLE OF CONTENT

Page

ABBREVIATIONS

C&D	: Construction and Demolition
C&D.W	: Construction and Demolition Waste
M.S.W.	: Municipal Solid Waste
EPA	: Environmental protection Agency
USEPA	: The US. Environmental Protection Agency
Mt	: Million tons
EU	: European Union
EPD	: Environmental Protection Department
GCC	: Gulf Cooperation Country
CSO	: Central Statistics Organization
RICS	: Royal Institute of Chartered Surveyors
HVAC	: Heating, Ventilation, and Air Conditioning
CII	: Construction Industry Institute
SRB	: Sulfate-reducing bacteria
C&DWM	: Construction and Demolition Waste Management
3Rs	: Reduce- Reuse and Recycle
WHP	: Waste Hierarchy Principles
4Rs	: Reduce- Reuse, Recycle, and Recover
DFA	: Department of Environmental Affairs
WMS	: Waste Management System
BIM	: Building Information Management
CWM	: Construction Waste Management
C&IW	: Commercial and Industrial Waste
RII	: Relative Importance Index
M	: Mean
S.D	: Standard deviation
x_i	: Weight value for factor
f_i	: Number of Frequencies
N	: Total number of respondents
alpha	: Cronbach's coefficient
K	: Number of items in a category
S_i^2	: Variance associated with item (i)
S_t^2	: Variance associated with the sum of all (k) item scores
MOCH	. Ministry of Construction, Housing, Municipalities, and Public Works
BOQ	: Bill of Quantities
SVM	: Support Vector Machine
SMO	: Sequential Minimal Optimization
IQD	: Iraqi Dinar
WC	: Waste Cost
RMSE	: Root Mean Square Error
MAPE	. Mean Absolute Percentage Error
CE%	: Cement Waste Percentage
SA%	: Sand Waste Percentage
GR%	: Gravel Waste Percentage
BR%	: BRC Waste Percentage
MT%	: Mosaic Tile Waste Percentage

CP% : Cement Plastering Waste Percentage
MPE : Mean Percentage Accuracy
AA : Average of Accuracy
R^2 : Coefficient of Correlation

LIST OF TABLES

Page

LIST OF FIGURES

Page

WASTE MANAGEMENT FOR RENOVATION CONSTRUCTION PROJECTS IN IRAQ

ABSTRACT

The construction sector plays a crucial and immediate role in the advancement and wealth of civilizations. Nevertheless, rapid population growth, along with extensive development of infrastructure and building projects to meet diverse living standards, has accumulated substantial quantities of construction debris. Renovation plays a crucial role in the process of urbanization in Iraq; it is now a widespread practice in the country, particularly in the remodeling of government buildings in the education sector, to address the increasing demand caused by population increase. Construction, renovation, remodeling, refurbishing, and demolition activities produce significant quantities of hazardous and non-hazardous waste materials that might impact the natural environment and the general population. The current study aims to establish the factors that lead to the increase of waste in renovation projects in the education sector of Iraq, to calculate its percentage and cost, and to build a mathematical model that estimates the cost using a Support Vector Machine.

The research commences with a thorough review of the literature to determine the possible factors affecting waste for renovation projects in Iraq. A survey was carried out to investigate the views of the supervising engineers, the owners, consultants, and contractors working in the public and private sectors in Iraq; the objective is to determine the main factors that impact waste construction in Iraq.

Historical data on the percentage and cost of waste for basic materials in renovation projects were obtained from companies working in both the Ministry of Higher Education and Scientific Research and the Ministry of Education. The database consists of (30) completed projects. Six input parameters were used to build the SVM model. These inputs are Cement waste percentage (CE%), Sand waste percentage (SA%), Gravel waste percentage (GR%), BRC waste percentage (BR%), Mosaic tile waste percentage (MT%), and Cement Plastering waste percentage (CP%). The developed estimation equation demonstrates a degree of average accuracy of (84.466%), with the coefficient of determination (R^2) (97.2%).

Keywords: *Construction and Demolition Waste, Debris, Waste Management, Solid Waste, Recycling Materials, Renovation Projects, Support Vector Machine*

IRAK'TA YENİLEME İNŞAAT PROJELERİNDE ATIK YÖNETİMİ

ÖZET

İnşaat sektörü medeniyetlerin ilerlemesinde ve zenginleşmesinde çok önemli ve acil bir rol oynamaktadır. Bununla birlikte, hızlı nüfus artışı ve farklı yaşam standartlarını karşılayacak altyapı ve bina projelerinin kapsamlı gelişimi, önemli miktarda inşaat enkazının birikmesine neden oldu. Irak'ta kentleşme sürecinde yenileme önemli bir rol oynamaktadır. Her ne kadar ülkede artık yaygın bir uygulama olsa da, özellikle eğitim sektöründeki hükümet binalarının yeniden şekillendirilmesi, nüfus artışından kaynaklanan artan talebin karşılanması amacıyla yapılıyor. İnşaat, yenileme, yeniden modelleme, yenileme ve yıkım faaliyetleri, doğal çevreyi ve genel nüfusu etkileyebilecek önemli miktarlarda tehlikeli ve tehlikesiz atık madde üretmektedir. Bu çalışma, Irak'ın eğitim sektöründeki yenileme projelerinde israfın artmasına neden olan faktörlerin belirlenmesini, yüzdesini ve maliyetini hesaplamayı ve Destek Vektör Makinesi kullanarak maliyeti tahmin etmek için matematiksel bir model oluşturmayı amaçlamaktadır.

Irak'taki yenileme projelerinde israfı etkileyen tüm olası faktörleri incelemek için literatürün kapsamlı bir incelemesi yapıldı. Irak'ta atık inşaatını etkileyen ana faktörleri bulmak amacıyla Irak'taki kamu ve özel sektör şirketlerinde çalışan mal sahipleri, danışmanlar, denetçi mühendisler ve müteahhitlere yönelik bir anket yapıldı.

Yenileme projelerinde temel malzeme atıklarının yüzdesi ve maliyetine ilişkin tarihsel veriler, hem Yüksek Öğretim ve Bilimsel Araştırma Bakanlığı hem de Milli Eğitim Bakanlığı'nda çalışan şirketlerin kayıtlarından elde edilmiştir. Veritabanı (30) tamamlanmış projeden oluşmaktadır. SVM modelini oluşturmak için altı giriş parametresi kullanıldı. Bu girdiler Çimento atık yüzdesi (%CE), Kum atık yüzdesi (%SA), Çakıl atık yüzdesi (%GR), BRC atık yüzdesi (%BR), Mozaik karo atık yüzdesi (%MT) ve Çimento Sıva atık yüzdesidir (CP%). Geliştirilen tahmin denklemi, belirleme katsayısı (R2) (%97,2) ile ortalama doğruluk derecesini (%84,466) göstermektedir.

Anahtar Kelimeler: *İnşaat ve Yıkıntı Atıkları, Enkaz, Atık Yönetimi, Katı Atık, Geri Dönüşüm Malzemeleri, Yenileme Projeleri, Destek Vektör Makinesi*

1. INTRODUCTION

1.1 Overview

The building sector is critical for every country's economic and social development. Buildings, roadways, airports, bridges, and other structural services are considered as the most important and prominent aspects in determining how society works. Significant population expansion, along with improving the living standards connected with extraordinary technical developments, have prompted the engineering skills in building firms to establish more complex, longer, and durable buildings each year. Currently, there are several challenges with time, cost overruns, and the significant production of construction waste volumes (Abdul-Rahman et al., 2013 and Nagapan et al., 2012). The construction sector claimed that large amounts of building material waste are unacceptably being created on construction sites (Ekanayake and Ofori, 2000).

Furthermore, the construction waste volumes don not only have a negative effect on the financial aspect, but they also contribute to environmental damage (Formoso et al, 2002). Due to these factors, construction waste became the primary focus of a number of research projects carried out worldwide. In general, the building sector has been responsible for the use of natural resources in enormous quantities, which has produced a considerable amount of waste related to construction and demolition (C&D). (C&D) waste accounts for the highest quantity of all types of solid waste. Multiple studies have provided statistical data indicating a major volume of construction and demolition debris being produced. For example, the United States construction industry annually generates more than hundred million tons of construction and demolition debris (Mills et al., 1999).

Additionally, according to Rogoff and Williams, (1994) roughly 29% of the solid waste generated in the United States comes from the construction sector. Construction waste creation has caused significant concerns both locally and worldwide. As a growing country, Iraq faces the building waste problem, resulting in unlawful disposal and contributing to ecological damage and to a rise in project costs. The issue may become even more severe if nothing is done to solve it. Thus, it is necessary to place a greater emphasis on identifying the causes that are responsible for the development of construction waste on building sites. Additionally, it is necessary to ensure the appropriate management on site, related to previous planning and the lawful use of resources.

1.2 Research Hypothesis

A substantial amount of material wastage is associated with the fast expansion of the construction industry in Iraq, particularly in rehabilitation projects. The real percentages of waste from local building materials surpassed the limits established by the Iraqi Ministry of Building, Housing, Municipalities, and Public Works. In the event that construction waste is produced, expenses associated with the rehabilitation will be incurred.

1.3 Purpose of Thesis

The accumulation of building waste materials is considered a serious problem that poses danger to the construction industry. This issue has considerable consequences, both in terms of its ecological impact and the efficiency of the sector (*Formoso et al., 20002).* The exponential growth in the amount of building projects worldwide resulted in a momentous rise in the volume of construction debris, beyond permissible thresholds. On the local level, Iraq is experiencing several challenges in the building industry, mostly with the variations of project costs caused by the significant rise in waste rates from construction creation. The prices are beyond the allowable limitations established via the Ministry of Construction, Housing, Municipalities and Public Works (MOHMPW). This would serve as a motivation for the researcher to carry out the present investigations of thesis and to assess the effect of construction and demolition waste on various aspects, to analyze the variables influencing the formation of construction waste across different phases of a project's life cycle, and to forecast the costs of waste in renovation projects.

1.4 Research Justification

The current research was motivated by these factors:

1- Refurbishment activities in Iraq are facing several challenges, mostly stemming from the substantial increase in building waste, which has led to major deviations in project costs.
2- Much research emphasizes identifying building waste components rather than measuring and predicting volumes of restoration trash.
3- To maximize the advantages of utilizing new technology, it is crucial to maintain the efficiency of the administration process in building projects. This may be achieved by accurately predicting the amounts of construction waste and understanding its importance in both cost and time estimations.
4- The creation of infrastructure and building waste also poses a threat to the successful completion of building projects, contributing to a shortage of valuable raw materials. This is due to the fact that a substantial portion of the overall project cost, ranging from 4% to 10%, is squandered (Ayem, 2014).
5- Consequently, the accumulation of garbage from building and demolition projects alongside highways and in front of construction projects without transportation to dumps poses a hazard to the health of the public resulting in the contamination of the natural environment.

1.5 Research Objectives

The research objectives are to:

1. Examine the main factors affecting waste for renovation projects in Iraq.
2. Study the percentage and cost of waste materials resulting from the renovation projects in Iraq.
3. Build a mathematical model to assess the cost of waste in the renovation construction projects using a support vector machine.

1.6 Research Methodology

This study first reviews diverse forms of waste management in construction highlighting their characteristics. On the basis of their understanding, the researcher determines the waste quantities and costs. In the second stage of this study, a mathematical model is developed to determine waste costs based on a comprehensive review of a group of construction projects that suffer from waste. The following steps are performed in this research:

1. Literature Review: investigating the status of the waste management methods of construction projects.
2. Data Collection and Analysis: gathering factual data on construction projects experiencing waste problems in some local and global countries.
3. Building a Mathematical Model: mathematical models predict the waste cost of the construction projects; they are built according to historical data using support vector machines.
4. Model Verification and Evaluation: some spare data will be analyzed to find out the validity of the model.

Table (1.1) summarizes the majority of the prior research papers on the issue of building waste in a chronological order.

1.7 Previous Studies

Table 1.1 Provides a comprehensive overview of prior research undertaken on the subject of building debris, organized in chronological order.

Table 1.1: The Previous Studies

Number	**Author name & year**	**Country**	**Research Name**	**Results**
1	Kulatunga et al., 2008	Sri Lanka	Sources of Construction Material Wastage In Sri Lankan Sites	Presents the results of a research conducted in Sri Lanka with the aim of identifying the origins of trash generated from building materials. The study found that lack-capacity subcontractors have a significant waste effect due to the limited resources such as trained labour, warehouses, and material handling procedures.
2	Akhir et al., 2013	Malaysia	Factors of Waste Generation throughout Construction Life Cycle	The factors were categorized into seven groups and then grouped together based on their occurrence in relation to the different stages of the building lifecycle. Error purchasing and poor craftsmanship are major factors of construction waste. Waste-generating elements' critical phases are identified.

Table 1.1: (Cont.) The Previous Studies

Number	Author name & year	Country	Research Name	Results
3	Bekr, 2014	Jordan	Study of the Causes and Magnitude of Wastage of Materials on Construction Sites in Jordan	The study identified several factors that contribute to material waste on job sites in Jordan. They include prevalent design and customer changes, modification due to worker errors, poor agreements, inadequate material preservation, insufficient reduction in waste strategies, inexperienced employees, inadequate location, transport damage, theft, vandalism, and quantity surveying errors. Additionally, the survey discovered that the sum of waste materials on Jordanian building sites is between 15% and 21%.
4	Khaled et al., 2014	Iraq	Investigation of Material Waste Incurred in the Construction Projects at Karbala Province In Iraq	Conclusions indicate that the trash proportions of building materials at the regional level are quite large exhibiting considerable variation among the projects examined. Furthermore, there is a noticeable absence of excitement among all participants when it comes to minimizing waste.
5	Alkaabi, 2016	Iraq	Master Thesis: Waste Management System in the Iraqi Construction Sector	This research tackles the growing waste issue in Iraqi building projects by identifying the waste amounts. The masonry material had the greatest waste rate (13.5–16%). The study revealed a lack of waste management systems in Iraqi building projects due to a lack of engagement from project stakeholders.
6	Khaleel and Al-Zubaidy, 2017	Iraq	Quantification Of Construction Waste Generated In Construction Projects Of Iraq	This study compares the public and private sectors of Iraqi project waste in terms of assessment and occurrence of important building material waste. Lime and gypsum, according to the results, produce the most building waste compared to other components. More construction trash is produced by private projects compared to governmental ones.
7	Suaathi aliannan et al., 2018	Malaysia	Determining Root Cause of Construction Waste Generation: A Global Context	Waste from construction is triggered by «Permanent design modifies», «Unsuitable preservation of materials», «Poor administration of materials», «Impact of weather», and «Errors when purchasing from providers».
8	Khaled et al., 2018	Iraq	Waste Management on Construction Sites	Research examines Karbala's building debris. Figures demonstrate a significant waste rate in the regional building industry. the contractors' disinterest in reducing waste

Table 1.1: (Cont.) The Previous Studies

Number	Author name & year	Country	Research Name	Results
9	Khaleel and Al-Zubaidy, 2018	Iraq	Major factors contributing to the construction waste generation in building projects of Iraq	The study identifies 15 elements that contribute to construction waste creation; they are sub-categorized into three classes: on-site materials management, materials utilizing, conveyance and warehousing, and site management techniques. Results indicated that site destruction, double-dealing and inept subcontractor technical personnel were among the most important variables in each of the categories.
10	Ghafourian et al., 2018	Malaysia	Construction and Demolition Waste: Its Origins and Causes	The impacts of waste origins in different areas by the creation of construction waste may vary depending on the different methods of waste from construction and demolition (CDW) handling. The quantity of produced construction and demolition waste (CDW) is contingent upon the chosen CDW management method.
11	Luangcharoenrat et al., 2019	Thailand	Factors Influencing Construction Waste Generation in Building Construction: Thailand's Perspective	This study evaluated and ranked total of (28) elements that brought about the development of construction waste in building projects. The elements that were investigated were categorized into four main groups. The components of the project are as follows: (1) the design and documentation; (2) human resources; (3) construction techniques and scheduling; and (4) goods and purchasing. The results of the research indicate that elements connected to documentation and design play a major role in the creation of waste from construction.
12	Hittini & Shibeika, 2019	United Arabic Emirates	Construction Waste Management In Uae: An Exploratory Study	Studies have indicated that a deficiency in awareness continues to have a detrimental effect on the administration and oversight of construction and demolition waste.
13	Maad & Sadeq, 2019	Iraq	Reducing Waste of Construction Materials in Civil Engineering Projects In Iraq	The study identified several key factors that contribute to materials wastage in construction projects in Iraq. Furthermore, the study discovered that both private and public entities in the building industry in Iraq do not prioritize waste management in their plans or give it sufficient attention. Additionally, the study showed that the material wastage percentage in Iraqi construction sites ranges from 5% to over 11%.

Source: Prepared by the author

2. RENOVATION, CONSTRUCTION AND DEMOLITION WASTE

2.1 Overview

The building and demolition waste, which has been a persistent global problem, has lately increased due to the expansion of the population and the concomitant rise in housing needs. The increasing worldwide urbanization and construction boom resulted in a substantial increase in the quantities of building and demolition debris, which was traditionally dumped in landfills. Debris generated by building and demolition operations represents a significant component of overall solid waste in almost every country. In addition, it does not only exhaust a significant amount of both renewable energy and resources but it also releases a huge amount of greenhouse emissions. The construction sector frequently relies on a significant amount of natural resources, leading to the production of large amounts of building- and demolition-related waste.

This chapter elucidates the core concept of construction and remodelling waste. Different perspectives have been utilised to determine the classification of construction and demolition trash. Previous research has identified the sources of building debris and the factors that affect the pace of trash generation. This chapter encompasses the following key subjects: the notion of waste, the categorization of waste, the description of waste from building and demolition, the worldwide and local quantity of waste from construction, categorizations of construction waste, the production of building waste, types of construction rubbish, reasons for refurbishment, factors that impact the frequency of construction waste era, and prior research and studies on the topic.

2.2 The Concept of Waste from Historical View

Brunner and Rechberger, (2014) pointed out that the majority of human actions produce waste. The generation of waste remains a substantial cause for apprehension, persisting from the ancient era to the present day (Chandler et al, 1997). Recently, there has been an increase in both volume of waste and the frequency generated. The rise is in both waste volume and the variety of waste materials (Vergara and Tchobanoglous, 2012). Due to the little population growth and abundant land resources, effective management was not a significant concern during that period. The trash generated during that time was readily assimilated by the ecosystem without any deterioration (Tchobanoglous et al, 1993). The industrial revolution drove people to migrate from rural regions to urban areas, resulting in a notable surge in trash production, commencing in the sixteenth century (Wilson, 2007). The influx of people to urban areas caused a significant rise in the amount and assortment of waste generated within cities. During that period, the municipal trash streams started to include significant amounts of items such as metals and glass (Williams, 2005). Considering that the landfills functioned as habitats for rodents and other insects, they posed significant risks to the general population's health. Inadequate waste handling practices have led to several outbreaks, with substantial mortality rates (Tchobanoglous et al., 1993). As a result, during the eighteenth century, government authorities started to manage waste systematically in order to guard public health (Tchobanoglous et al, 1993). Environmental progress was a prevalent phenomenon in the majority of developed nations. The surge in urbanization and development in nascent nationhood leads to a resurgence of the identical archaeological difficulty that established previously experienced nations (Wilson, 2007).

2.3 Classifications and Types of Waste

Waste classification commonly relies on many criteria such as physical states, physical qualities, possibility for reuse, biodegradability, production source, and the extent of environmental effect (Demirbas, 2011; Dixon and Jones, 2005; White et al., 1995). White et al. (1995) categorized waste into three primary classes on the bases of their physical shape: solid, liquid, and gaseous waste. Multiple classifications are evident throughout many countries. Below, are the most often employed classes:

- Physical state

- Garbage that is solid
- Throwaway liquids
- Exhaust gas

- Origin

- Garbage from Homes and Communities
- The waste of industry
- The waste from agriculture
- Business refuse
- Debris resulting from the demolition and building processes
- Waste from mining

- Ecological consequences

- Toxic substances
- Innocuous trash

2.4 Types of Solid Waste

Considering the fact that solid waste encompasses several categories of garbage, it is essential to undertake a concise examination of the diverse kinds of solid waste.

1- **Municipal Solid Waste (M.S.W):** Municipality solid waste (MSW) is a significant waste flow that has received considerable research attention. According to White et al., (1995), MSW has many repercussions; it refers to waste that is produced from residential and commercial business establishments. Kaseva and Gupta, (1996) defined municipal solid waste as a garbage that is gathered by city authorities, encompassing rubbish from industrial, commercial, institutional sites, from households, non-hazardous solids and non-pathogenic hospital waste.

2- **Construction and Demolition Waste (C&D.W):**

The term "construction and demolition waste" defines the debris and materials produced from renovation, construction, remodeling, or repair activities, comprising building and site improvement materials (Harvard Green Campus Initiative, 2004). Materials such as concrete, asphalt, brickwork, lumber, metal, plastic, soundproofing, paper goods, and cardboard make up the majority of the building and demolition (C&D) wastes (Meyer and Walsh, 1996).

3- Industrial Waste: according to Ngoc and Schnitzer, (2009), waste from industries refers to what is generated during the handling of primary resources for the manufacturing of new supplies. Additionally, it was stated that certain pollutants possess toxicity, while other materials are non-toxic.
4- Agricultural Solid Waste: Tchobanoglous, (1993) defined agricultural wastes as the by-products generated from operations such as animal farming, planting crops, and milk manufacturing.
5- Commercial Solid Waste: businesses that produce solid or semi-solid garbage include food chains, markets, workplaces, hotels, accommodations, printing shops, gas stations, and auto repair businesses, among many others. This type of waste is known as commercial solid waste (Tchobanoglous, 1993).

2.5 Definitions of Waste that is generated during the construction and demolition process

The building industry is well recognized as a significant generator of solid waste in contrast to other economic sectors, as evidenced by environmental and statistical studies from many nations (Al-Hajj and Hamani, 2011, Durana et al., 2006). The definition of construction waste lacks unanimity. Table 2.1 below presents many definitions of construction and demolition residues:

Table 2.1: Definition of Construction and Demolition Waste

Source	Definition
American Protection of the Environment Agency (EPA)	"Construction and demolition waste refers to the discarded materials resulting from the building, renovation, repair, and demolishing of buildings like residential and commercial buildings, roads, and bridges."
Tchobanoglous, et al., 1977	Waste resulting from the destruction of buildings and other structures is categorized as demolition waste. Construction wastes encompass the discarded materials resulting from the construction, remodeling, and repair activities carried out on residential properties, commercial buildings, and other structures.
Harvard Green Campus Initiative, 2004	"Construction, remodeling, renovation, or repair operations generate solid waste, including building and site improvement materials."
Hong Kong (Polytechnic 1993)	"By-product produced and eliminated from construction, refurbishment, and demolition sites, or locations for construction and civil engineering structures"
European Council Directive 91/156/EEC	"Any substance or object that the possessor throws away, intends to throw away, or is obligated to throw away."

Table 2.1: (Cont.) Definition of Construction and Demolition Waste

Source	Definition
McDonald and Smithers (1998)	Deviation from the amount of materials that were accepted and delivered on site compared to the amount that was used according to specifications and precisely measured again.
Ekanayake and Ofori, 2000	Any material that requires transportation either off-site per the structure site or within the structure site itself
Koskela	All inefficiencies resulting in the utilization of equipment, labour, materials, or money in amounts that are more than what may be regarded as required for the construction of a structure are considered to be inefficient.
Koshy and Apte	"Non-value added activities" refer to any losses incurred by processes that incur either direct or indirect expenses contributing any value to the product as seen by the client.
Alarcón et al., 2002	The expenses incurred due to high quality standards, the need for rework, unnecessary transportation, extensive distances, inappropriate management practices, and inadequate constructability.
Wang et al. (2014)	Excessive depletion of valuable natural resources.
Shen et al. (2004)	Construction wastes are composed of both organic and inert materials that result from various construction activities, like civil and building construction, land excavation, clearing out sites, roadwork, demolition, and building renovation, at all the construction project stages.

Source: Prepared by the author

Multiple definitions available from various research papers on building waste. The researcher relied on his subjective viewpoint to delineate the notion of construction waste revealing some similarities to Koshy and Apte Non-value added activities which "refer to any losses incurred by processes that generate direct or indirect costs without contributing any value to the product as seen by the client."

2.6 Classification of debris from building and tearing down structures

Creating a comprehensive list of construction and demolition (C&D) waste that embrace all projects worldwide has proven to be difficult due to the diverse array of building processes. However, there have been many attempts in the past to categorise and classify construction and demolition trash. The categorization of Construction and Demolition (C.D) Waste may be succinctly summarised by drawing upon previous studies.

1. Waste products are classified based on their origin. As reported by (Papadopoulos et al. 2003); they include:

A. Excavation materials which involve various substances such as earth, granular particles of rock or mineral, gravelly soil, stone, earthen material composed of fine-grained minerals, and any other substance generated during digging activities. They are widespread in all interpretation activities, particularly in underground building and infrastructure activities.

B. Road construction and maintenance materials which contain several substances used in the construction for up keeping roads, including asphalt as well as gravel, metal, sand and materials derived from road operations.

C. Demolition materials, often known as debris, which comprise dirt, concrete, bricks, gravel, gypsum, sand, stone, and other similar substances. The composition of buildings is not uniform and it varies based on factors such as location, kind, age, shape, usage, and size.

D. Worksite waste materials that encompass a variety of substances including plastic, lumber, glass, paper, metallic items, wires, pigments that exist and any other materials generated during on-site operations such as repairs, support, expanding, and extension.

2. Waste materials are categorized by Symonds Group Ltd based on their origin or the nature of the project as follows:

A. New construction waste whose composition is determined by the kind of building work that was performed and the methods that were applied: the majority of the time. This is the result of materials being damaged while ordering an excessive quantity.

B. Renovation waste which shares a similar composition with demolition wastes.

C. Demolition waste whose composition is determined by the construction processes and materials employed in the building being demolished.

3. Waste material is categorized into direct waste and indirect waste. Skoyles, 1976 a, b, c) characterized them as follows:

A. Direct waste which refers to material that must be replaced due to defects within the substance itself.

B. Implicit waste which is attributed to:

- Implied garbage that refers to the improper use of materials deviating from the specified requirements.
- Production waste, referring to the additional materials used on-site beyond what is specified in the list of amounts, due to specific on-the-spot needs.
- Carelessness waste: excessive amounts of a few materials utilized due to the contractor's carelessness and the workers' inaccuracies.

4. The waste generated during construction and demolition is classified on the basis of its nature:

A. Physical waste: the waste originating from renovation, construction, and demolition comprising civil and building construction, land excavation, roadwork, site clearance, renovation and building demolition (Poon et al., 2001, Foo et al., 2013).

B. Non-Physical Construction Waste refers to inefficiencies in cost and time management that commonly occurs during construction activities. Work disruptions, delays, postponements in implementation, work obtaining, rework, and unneeded tasks are significant timeframe wastage (Teo and Loosemore, 2001).

Shanmugapriya and Subramanian, (2013) defined cost overrun as an increase in costs or a deviation from the budget. Cost overrun refers to the occurrence of unanticipated expenses that exceed the predetermined budget.

It is important to note that there is no recognized standard for categorizing C&D waste. However, the most commonly used approach is to classify it based on its source or origin. This method is advantageous since it provides valuable insights into the characteristics of the waste.

2.7 Construction Waste Composition Categories

Construction and demolition waste (CDW) composition might vary across different countries, based on the precise construct techniques employed. The Iraqi structural concrete were predominantly utilized in commerce constructions, wherein partitioning are constructed using bricks or blocks that are interconnected by cement mortar and then coated with cement or gypsum renders. Ceramic tiles, marble, or

Styrofoam are frequently used to cover facades, while boards of gypsum are commonly employed for fake ceilings (Atabi et al., 2023).

Modifying the construction method will result in a corresponding alteration in the nature of the generated trash. Lau et al, (2008) and Nagapan et al, (2012) are among the many researchers engaged in the classification of CDW. They found that housing construction generates several types of trash, including lumber, cardboard, concrete, metal, bricks, roofing, packaged containers sythenic, and other items. Furthermore, Maytham et al., (2019) argued CDW encompasses several categories of waste, including solid waste derived from the deconstruction, construction, extension, rehabilitation efforts, and destruction of buildings, roadways, bridges, and infrastructure improvements. Furthermore, a variety of materials can be introduced including bitumen, concrete, masonry, lumber, aluminum, glass, and reinforcement bars made of steel.

Wrapping debris, pipes, insulation, and wire: while the composition of various waste products may differ, their commonality lies in the fact that minimizing, reusing, and recycling them is advantageous for the environment. This practice reduces the usage of natural resources besides the quantity of waste dispatched to landfills.

Analyzing the components of building wastes is essential for efficient waste management. The European Union (Sepa, 2019) classifies construction debris into eight distinct types:

a. Masonry, mortar, porcelain, and tile.
b. Glazing, timber, and synthetic material made from polymers.
c. Thermal coal and bitumen.
d. Metallic element.
e. Soils, comprising soil drawn from polluted site, soils extracted from dredging as well as rocks
f. Asbestos-containing materials, insulation, and related products.
g. Building supplies that include gypsum.
h. Waste from other construction.

The U.S. Environmental Protection Agency (USEPA, 2017) categorizes construction debris into fifteen distinct types, which include:

1. Materials composed of bitumen.
2. Materials pertaining to the soil.
3. Materials pertinent to electricity construction.
4. Components associated with shielding.
5. Components associated with masonry and concrete construction.
6. Substances associated with steel.
7. Materials associated with painting.
8. Objects pertaining to cardboard.
9. Substances associated with petroleum-based goods.
10. Elements pertinent to roofing construction.
11. Materials associated with vinyl.
12. (Gypsum-related) components.
13. Wood-related substances.
14. Things that are wood-related containing contaminants.
15. Assorted groupings

It is crucial to acquire basic knowledge related to the various sorts of products one`s organization manufactures, as many of them can be salvaged, repurposed, or recycled. Additionally, this knowledge allows one to effectively separate the garbage, ensuring that the waste collectors can appropriately and securely remove it from the premises.

2.8 The Amount of Construction and Demolition Waste

Construction and demolition (C&D) debris is a distinct category of waste, not being considered part of city garbage, The items that are categorized as construction and demolition debris include materials such as timber, metal, plasterboard, plaster, stone, earthen tile, shingles made of asphalt cement mortar, and asphalt concrete. These materials are utilized in the construction of buildings, roads, bridges, and other structures. The generation estimate quantifies the volumes of (C&D) debris resulting from operations such as building construction, renovation, and demolition, as well as road and bridge construction, and other structural projects. The source of this information is the Environmental Protection Agency (EPA) in 2009.

The quantity and nature of garbage created from construction and demolition activities vary across different countries. The ratios of (C&D W) waste in Europe and the USA, resulting from the percentage of recently constructed, renovated, and demolished buildings range among 8%, 44%, and 48%, respectively. Additionally, the construction and demolition waste ratio constitutes between 10% and 30% based on the overall waste stream delivered to landfills in the respective nations (Altuncua & Kasapseçkina, 2011). (CDW) waste makes up the most significant waste flow internationally, accounting for approximately 30-40% of the overall solid waste (Jin et al., 2019 and Tam et al., 2006).

Annually, a substantial amount of (C&D) trash is produced all over the world, as demonstrated by the figures made public regarding C&D waste in a variety of regions or countries. For instance, it was anticipated that China would produce approximately 2,300 millions of tonnes of construction and demolition debris in 2019, making it the largest producer of C&D waste in the world (Forward, 2020). The American States produced nearly 600 Mt of C&D waste in 2018 (USEPA). The community of Europa (EU) produced 834 Mt of construction and demolition waste in 2018, which accounted for 36% of the entirety of the waste in 2018 (Eurostat 2020). In 2016, Brazil's expected production of Construction and Demolition (C&D) trash was 100 million metric tonnes (Rosado et al. 2019); nearly 30% of the whole waste was produced by Australia in 2016-17, which was 20.4 million tonnes of construction and demolition waste (Pickin et al. 2018). This represents a rise of 20% over the previous decade.

In Germany, the quantity of building waste is approximately 30 million tons, whereas the amount of demolition debris is around 14 million tons. The Environmental Protection Department (EPD) in Hong Kong reports that construction waste makes up 25% of the whole municipal solid waste (Ajayi et al., 2015). In 2013, (Won et al. 2016) observed that waste produced in construction and demolition (C&D) activities accounted for almost 50% of the total solid waste in South Korea. In addition, Hwang and Boa, (2011) stated that the quantity of waste that the construction industry produces is approximately four times greater than that of home waste.

Figure 2.1 shows demolition of constructions and recycling of waste internationally.

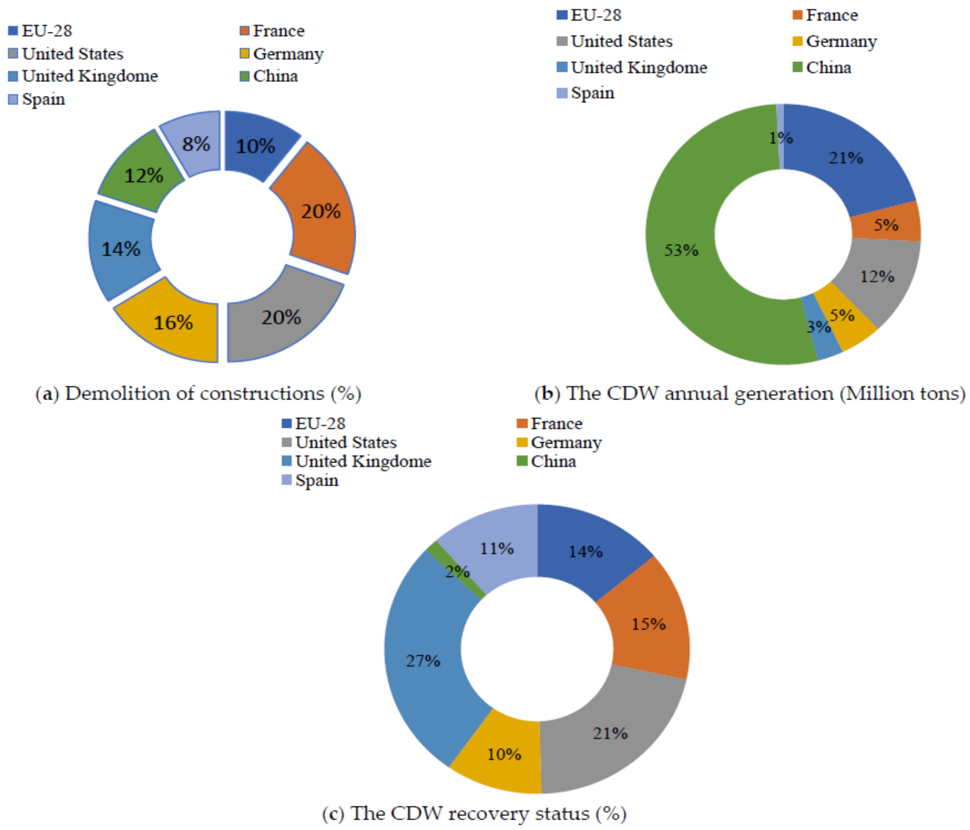

Figure 2.1: Demolition of Constructions and Recycling of Waste Globally

Source: (Eurostat 2016) , (Zheng et al., 2017).

According to Green Middle East in 2007, the Gulf Cooperation Council (GCC) countries generate approximately 80 million tons of waste each year, about half of this waste is made up of construction materials, while roughly 33% is municipal solid waste, and what remains is industrial waste (http://www.greenmiddleeast .com/sw/default.html.). The solid waste levels in the Gulf Cooperation Council (GCC) are estimated to be approximately 120 million tons per year by some sources (Gautam et al., 2009).

In Iraq, the Central Statistics Organization (CSO) provided data on the production of (C&D) trash and total solid waste for the years 2015, 2016, and 2017, as outlined in Table 2.8. Figure 2.2 presents the proportions of (C&D) trash in relation to the total amount of solid waste in the urban areas of Iraq.

Table 2.2 displays the Demolition and Construction debris for the years 2015, 2016 and 2017 (Ministry of Planning - Central Statistics organization (CSO), the Republic of Iraq).

Table 2.2: Waste Generated from C&D During 2015, 2016, 2017

City	2015		2016		2017	
	C&d waste (ton/year)	**Total Waste (ton/year)**	**C&d waste (ton/year)**	**Total Waste (on/year)**	**C&d waste (ton/year)**	**Total Waste (ton/year)**
Baghdad center	583,890.5	4,118,259	3,500, 8	3,838,237.4	59,766.4	2,522.159.9
Outskirts of Baghdad	15,001.5	321,273	95,201	634,245	117,424	680,777
Karbala	214,255	563,633	436,950.4	867,130.8	331,769.6	794,741.4
Babil	73,182.5	347,298	356,308.2	785,437.2	186,848.8	575,874,8
Salah- Aldin	22,520.5	269,480	462,321	825,806	823,911.5	1,556,554
Maysan	126,472.5	645,284	93,568	430,123	46,364	401,919
Muthanna	184,992	348,977	179,220.8	357,869.8	60,435.2	219,077.2
Wasit	61,320	364,015	232,194	606,506	219,078	539,544
Qadisiya	134,247	452,345	167,080	579,244	236,712	554,659
Diyala	26,243.5	354,306	85,128	409,928	74,223.2	440,158.2
Anbar	NOT-RECORDED	Not-recorded	Not-recorded	Not-recorded	2.073,483	2,954,364
Kirkuk	7,482.5	377,155	99,297.6	385,298.67	86,412.8	384,420.8
Dhi Qar	6,0063	262,997	80,924.8	620,201.8	95,707	701,822.5
Najaf	285,101.5	902.098	341,587.7	895,451.2	490,947	1,168,301
Ninewa	Not -recorded	Not-recorded	Not-recorded	Not-recorded	3,210,299.2	3,899,283.8
Basra	433,547	1,647,647	2,120,484	3,310.214	2,249,905.6	3,276,539.6

Source: Ministry of Planning - Central Statistics organization (CSO) The Republic of Iraq. www.cosit.gov.iq/.

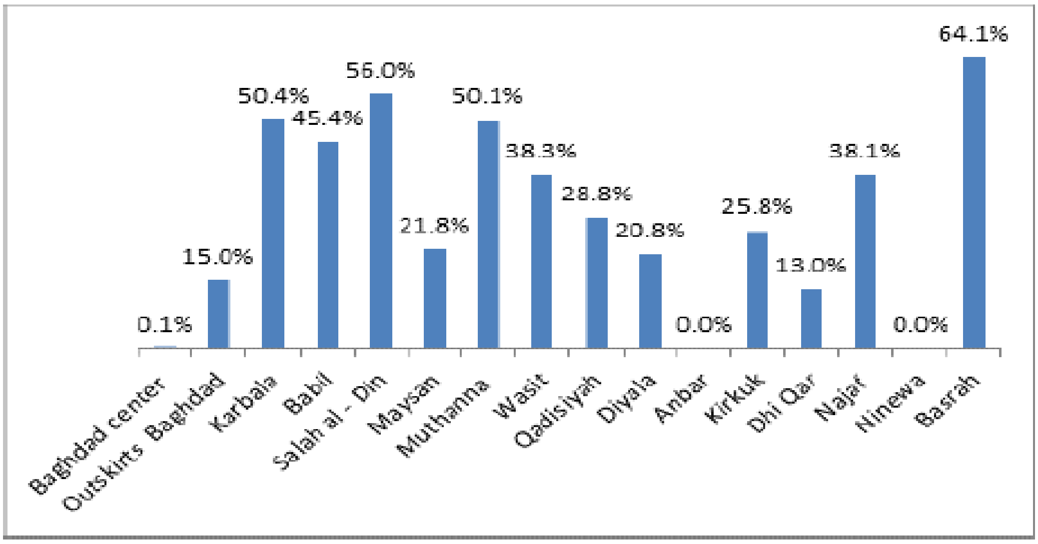

Figure 2.2: Percentage of (C&D) Trash in Relation to the Total Garbage Generated by Each City in Iraq in 2015.

Source: Ministry of Planning - Central Statistics organization (CSO) The Republic of Iraq. www.cosit.gov.iq/.

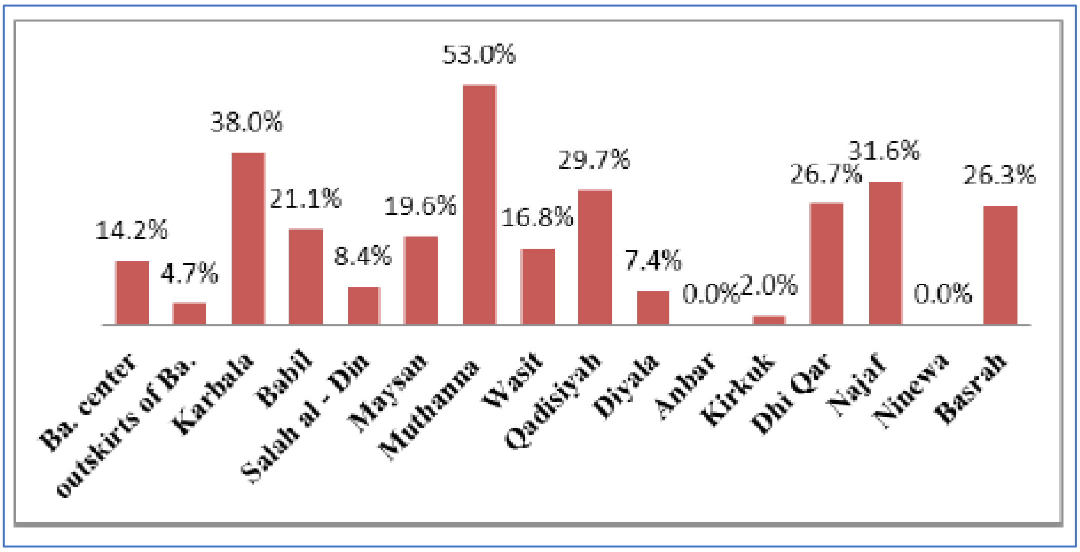

Figure 2.3: Percentage of (C&D) Trash in Relation to the Total Garbage Generated by Each City in Iraq for the Year 2016.

Source: Ministry of Planning - Central Statistics organization (CSO) The Republic of Iraq. www.cosit.gov.iq/.

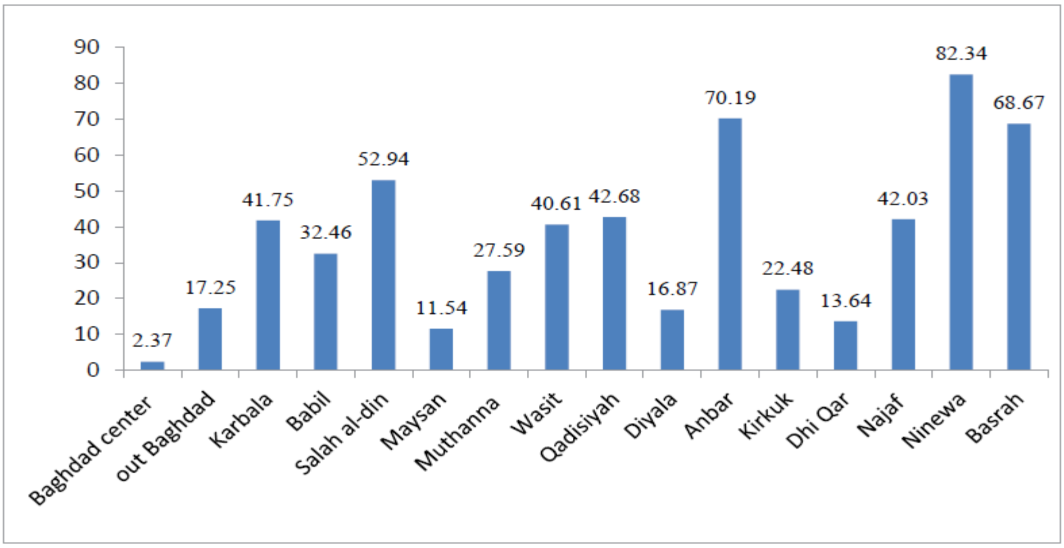

Figure 2.4: Percentage of (C&D) Trash in Relation to the Total Garbage Generated by Each City in Iraq for the Year 2017.

Source: Ministry of Planning - Central Statistics organization (CSO) The Republic of Iraq. www.cosit.gov.iq/.

While reviewing the literature on construction waste, the researcher did not find studies on (C&D) waste in Iraq, despite the substantial amounts of waste generated and the likelihood of increased quantities in the future owing to the rise in construction projects. Furthermore, Iraq lacks a comprehensive waste management system for construction projects. The methods for managing the various forms of trash produced in buildings in Iraq vary depending on that characteristics regarding the materials being generated (Al-Ansari et al., 2013).

2.9 Renovation Reasons

Renovations and refurbishments often lead to the replacement of construction materials and components due to factors such as degradation, corruption, changes in needs, or fashion. As a result, the old materials are rendered as waste. These processes may occur with high frequency. The use phase is the most protracted part of the construction life cycle. Consequently, substantial amounts of garbage are produced at this phase. Renovation operations are expected to generate 30-50% of total construction trash (Arslan et al., 2012).

It can be inferred that 10% of the materials utilized throughout the construction phase are discarded as waste. These wastes were characterized as uncontaminated materials that were reasonably simple to categorize for recycling and reusing. Higgins, (1995) observed that demolition and remodeling activities generate ten times more debris than that of the development phase. The text is enclosed in the tags. The categorization of these wastes produced throughout these stages was challenging due to their contamination and complexity.

Table 2.3: Reason for Renovation Reason for Renovation

<table>
<tr><td colspan="2">As per the Ruler Organization of Certified Surveyors (RICS), renovations tend to be handled. There are two primary reasons: degradation and out-datedness. These guidelines are universally applicable and valid in any country. Recently in Iraq, it is likely that there has been a combination of these factors. The chart is revised to accurately represent the Iraqi experience based on the Ruler Organization of Certified Surveyors (RICS) handbook from 1986. Each of these factors has contributed to the ongoing rebuilding project in Iraq. The rationale behind the renovation is shown in Table 2.3.</td></tr>
<tr><th>Renovation Category</th><th>Reason to renovate</th></tr>
<tr><td>Deterioration</td><td>• The degradation of materials and the disintegration of components, such as the degeneration of electrical and heating, finishes, the corrosion of water pipelines, and ventilation, and air conditioning (HVAC) systems.
• Deterioration resulting from acts of violence, such as armed combat or looting</td></tr>
</table>

Table 2.3: (Cont.) Reason for Renovation Reason for Renovation

Obsolescence	• Alteration of the purpose or specifications of a structure, like transforming confectionery storage into a footwear shop. • Inadequacy to support contemporary technique. • Inability to integrate the growth in the number of users. • The style is becoming outdated.. • Updated specifications for installed materials and components. • The fact that the user's status has been changed, which forces him to make an upgrade or vice versa. • The site's or location's status changing, making the present building inadequate. • New regulations necessitate building modifications..

Source: Royal institute of Chartered Surveyors (RICS) 1986.

2.10 Source of Construction Waste Generation

Out of the numerous papers published globally on construction generated waste and its management, there are only a limited number of studies that have specifically aimed to uncover the elements that contribute to the generation of construction trash. Researchers investigating construction waste creation identified various sources of construction trash that may increase throughout the course of a project's life cycle (Khaleel and Zubaidy, 2018).

Formoso et al., (1999) and Formoso et al., (2002) specified a number of factors that must be taken into account when dealing with waste creation; these include transport, motion, inventory, manufacturing, delays in transportation, transport errors, and overproduction as illustrated in Table 2.4.

Table 2.4: Sources of Construction Waste

Source	Description
Overproduction	Excessive production refers to the production of more materials than necessary, leading to wasting of labour, resources, and machinery.
Transportation	Conveyance of various building supplies on a construction site. This sort of issue arises from insufficient materials management during transportation, sometimes owing to the use of insufficient apparatus or poor path way issues chosen on the construction site. These problems can be attributed to the absence of proper preparation.
Motion	The needless shifts replaced by labourers on building sites. This type was caused by a poor work layout, insufficient work procedures, or shifts being substituted by others.

Table 2.4: (Cont.) Sources of Construction Waste

Source	Description
Replacement	Applying expensive substance skilled personnel, or advanced technology for small tasks.
The inventory	Dealing with needless/inflated stocks of materials from renovation that will be changed into waste owing to unsuitable conditions, degradation, missing, and vandalism.
Duration of wait	The term "idle time" refers to the period when the labor gang or equipment is not being utilized owing to insufficient coordination and synchronisation of material flow.
Compiling	The term is used to describe the kind of action that required resources and that could be decreased to its minimum levels by modifying the technological advancement used.
Manufacturing of faulty goods	This refers to waste generated as a consequence of failure to complete a job or to engage in certain behaviour to meet the planned specifications or quality standards. This might arise due to inadequate planning and control, insufficient coordination including the design and production processes, and the team's insufficient qualifications together with different related factors.
Others	Waste of any distinct type, including but not limited to burglary, vandalism, extreme weather incidents, etc.

Source: (Formoso et al., 1999), (Formoso et al., 2002).

2.11 Demolition Waste

According to Kourmpanis et al., (2008), the method of demolition frequently used is among the most vital ones that clarifies how CDW is managed. According to Poon, et al., (2001) and Fatta et al., (2003), the technique employed for the demolition of a structure has an impact on the properties and composition of the resulting materials. Kourmpanis et al. (2008) categorized demolition procedures into three distinct groups:

• **Conventional demolition:** buildings are razed through the use of dynamite, shattering balls, mechanical upward approaches, sometimes known as breakers.

• **Total demolishing:** also known as the deconstructionist approach. This procedure is executed by inverting the sequential processes of building. Manual deconstruction refers to the process in which workers utilize light mechanical instruments to demolish structural elements, resulting in a greater recovery of supplies in contrast to traditional demolition procedures.

- **Partial destruction:** this process combines the two previously described demolition technologies. Workers use light mechanical tools to remove high-value elements before proceeding with conventional demolition.

While choosing the proper demolition process, project managers must develop their own strategy to manage the generated materials.

3. CONSTRUCTION WASTE MANAGEMENT AND SUSTAINABLE DEVELOPMENT

3.1 Overview

The building industry is the focal point of the nation's economy. The need to establish projects that can build new public infrastructure or refurbish old ones arises from the fluctuation in living standards and the significant population expansion. However, it is important to note that every project generates construction waste, resulting in increased project cost variation and adverse effects on environmental circumstances represented by the exhaustion of natural resources and the scarcity of landfill capacity for waste disposal (Dajadian and Koch, 2014). Thus, it is imperative to effectively handle waste materials on building sites.

A significant environmental issue in the building sector is the effective handling of (C&D) waste. C&D waste can be effectively handled to mitigate its environmental and economic impacts. The aim of construction C&D waste management is to mitigate adverse environmental effects by limiting waste generation and ensuring proper disposal. C&D wastes are a significant environmental concern in numerous nations, leading to the implementation of various policies to address this issue. The management of (C&D) waste has been integrated into the state's policy framework, and comprehensive specifications and advice have been introduced to address these concerns (Arslan et al., 2012).

3.2 Management of Construction Materials

The inadequate handling of materials during site operations is a vital element that negatively impacts the building projects (Kasim, 2008). Materials are the most important component of any building construction process. Thus, if material management in building operations is not properly handled, significant project cost variances will occur. The overall project cost might be effectively controlled by adopting remedial steps to address cost variances that arise during the project (Phani et al. 2013; Alin Veronika et al. 2006)). The research conducted by the Construction Industry Institute (CII), indicated that the installed materials and equipment account for fifty to sixty percent of the overall cost of the project and that they have an effect on eighty percent of its schedule (Caldas et al. 2014). The fundamental Principles of Site Material Management shed light on the various aspects that are taken into account during the designing and planning stages of a site in order to ensure effective material management. On a great number of projects, inefficient practices regarding the management of materials are not only visible but they also result in significant time and financial waste (Randolph et al., 2005, Pauline et al., 2014). A productive and cost-effective site requires appropriate material management. A successful materials management approach guarantees that the precise quality and amount of materials are chosen, bought, transported, and securely dealt with on site appropriately and carefully (Kanimozhi et al. 2014, Donyavi et al., 2009). Construction materials management falls into five phases, which are primarily used on construction sites: planning, the procurement process, logistics, handling, and waste management procedures. Planning encompasses the activities of material procurement, scheduling, and quantification, (Kasim 2011, Caldas et al. 2014, Kanimozhi and Latha 2014, and Patel and Vyas, 2011). Material procurement identifies to the possession of materials and services from other organizations. In contrast, logistics focuses on the on-site transportation of items. Conversely, materials handling refers to the comprehensive process of moving raw materials, work in progress, or finished commodities inside a building site.

3.3 Construction Waste Management

The management of (C&D) waste has emerged as a significant environmental concern in the building sector due to its enduring impacts. The unregulated disposal of C&D wastes does not only pose a substantial environmental burden but it also incurs financial expenses. A reasonable management approach can mitigate the environmental and economic impacts of C&D wastes. The objective of construction C&D waste management is centered on waste reduction and proper disposal, both of which contribute to the mitigation of adverse environmental effects.

Hwang and Yeo (2011) defined waste management as an inclusive and incorporating system that involves the gathering, treatment, recovery, transportation, storage, and disposal of waste. The researchers emphasized that this system aims to attain and maintain the proper quality of the environment and promote sustainable development. The building waste management is regarded as a complex and intricate strategy due to its potential application in many project activities (Letcher & Vallero, 2011).

Meghani et al., (2011) and Kareem and Pandey (2013), concluded that efficient waste management system is the most effective approach that regulates the waste produced during various stages of a project. The rising recognition of the importance of waste management and its environmental consequences has elevated it to a higher level in construction project management (Formoso et al., 2002).

3.4 Impact of Construction and Demolition Waste (CDW)

The majority of C&D waste is currently being disposed of in landfills, a process which leads to numerous environmental, socio-economic, and sustainability issues (Elgizawy et al., 2016) as follows:

1- Ecological Consequences

Construction sites are frequently diagnosed as the primary source of several environmental issues, including the dispersion of dust, generation of noise and vibration, and contamination of groundwater and soil. The primary issue in waste management is the buildup of waste in landfills, which have restricted capacity, creating less strict laws for landfill operations and environmental protection. Furthermore, the process of biodegradation of wastes in landfills gives rise to numerous health and environmental issues. When Gypsum drywall is exposed to moisture due to a decrease in drainage, sulfate-reducing bacteria (SRB) utilize sulfate as a receptor for electrons to generate H2S4, which is known for its unpleasant odor (Elgizawy et al., 2016).

According to Kanimozhi and Latha, (2014) and Phani et al. (2013), construction activities typically have detrimental impacts on the environment. These include the depletion of resources and natural land for development, the production of waste and diverse types of contamination, the disruption of ecological balance, the alteration of living environments, sewage issues, decreasing natural resources, and increased energy consumption.

2- Socio-economic Impacts

An essential issue with C&D wastes is the pervasive cross-contamination and indiscriminate blending of various materials. The incorporation of various materials complicates the recycling or reuse procedure, necessitating time-consuming and labor-intensive human sorting. The mixing process includes the usage of dangerous substances including asbestos and specific heavy metals like chemical solvents, lead, and adhesives. It is crucial to keep these substances distinct from the waste material that will be recycled or reused. The recycling of C&D waste remains an expensive procedure when compared to the low cost of numerous raw materials employed in the construction industry (Elgizawy et al., 2016).

3- Sustainability Impacts

As Horvath, (1999) puts it, the building sector is widely recognized as the primary contributor to environmental pollution utilizing natural resource. Sjostrom, (1998) observed that within the European community, building-related activities account for more than 40% of energy consumption and nearly 40% of man-made waste. The current construction procedures of garbage disposal in landfills contribute to the exhaustion of natural resources and the negligence of energy conservation. Sustainable construction strategies can help limit the energy consumption involved in extracting raw materials and manufacturing processes. Given the significant impact of construction and demolition waste across all domains, it is crucial to prioritize the management of such trash in multiple sectors

3.5 Benefits of Construction and Demolition Waste Management

According to Dixit et al., (2010), Garbarino and Blengini, (2013), Agyerum, (2012), Al-Moghany, (2006) and Tam, (2013), enhancing proper handling of garbage plans in building, remodeling, and demolition projects can yield the following benefits:

1. Minimizing expenses associated with landfills, labor wages, transportation, and other related costs.

2. Mitigating the rate of resource depletion and the adverse effects on nature.

3. Reducing computational resources resulting in cost savings.

4. Recycling which is a frequently used in major construction projects to save expenses associated with transporting and disposing of leftover materials.

5. Securing monetary gains derived from the sale of specific recycled materials.

6. Preserving the value of spaces and locations by utilizing landfill sites while also safeguarding the environment from surface and groundwater pollution.

7. Decreasing the effort dedicated to estimating the amounts of waste in construction projects.

9. Providing support to achieve timely completion, cost effectiveness, and the desired quality of construction projects.

10- Minimizing the environmental impacts of disposal, such as noise and pollutants.

11- Decreasing the garbage transportation for disposal, resulting in reduced noise, pollution from vehicle generation, and energy consumption.

12- Decreasing waste generation.

13- Optimal utilization of generated waste.

14- Enhancing site safety.

15- Promoting work productivity.

3.6 Construction waste Management and Sustainable Strategies

The strategies employed in the Construction and Demolition Management of Waste (C&D WM) are founded on three fundamental principles, commonly referred to as the "3Rs" principle. This principle is also known as the hierarchy of C&D WM. The three concepts mentioned are reduction, reuse, and recycling (Lu & Yuan, 2011).

The Waste Hierarchy Principles (WHP) was developed to address various waste concerns and to decrease the quantity of garbage dispatched to landfills. Researchers such as Kareem and Pandey, (2013), and Bagdi et al., (2013) introduced a new strategy called "Recover," also known as "waste to energy," which is now included as part of the existing strategies. This new strategy is placed at the bottom of the hierarchy, just before land-filling, making it the fourth component of the 4Rs. The concepts of 3Rs and 4Rs can also be applied to reduce construction waste throughout the various project stages.

Figure 3.1 shows the waste hierarchy principle. It affirms that the most environmentally favored approach is positioned at the highest level of the hierarchy, while the least desirable strategy is positioned at the lowest level.

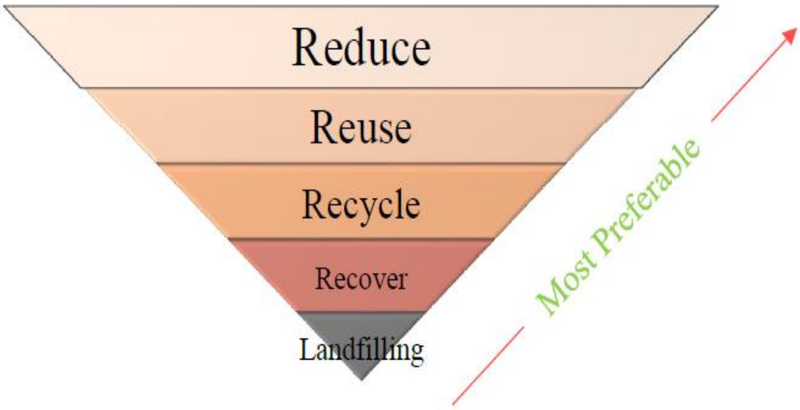

Figure 3.1: Waste Hierarchy Principles

Source: Department of Environmental Affairs, Pretoria, 2012. (DFA)

3.6.1 Reduce

Reduce rework caused by errors and poor workmanship, and planning to minimize off-cuts. This conclusion is supported by Osmani et al., (2008), Jaillon et al., (2009), and Lu and Yuan, (2013). Reducing construction waste is often regarded as the most effective and efficient means of waste management. It is able not only reduce the construction waste production, but also to decrease the expenses associated with waste transportation, disposal, and recycling. Given its paramount importance in construction waste management, it is unsurprising that reduction has been thoroughly investigated by numerous researchers, resulting in the development of diverse solutions for waste reduction. The U.S. Environmental Protection Agency (EPA) defined source reduction as the deliberate actions taken in the design, manufacture, procurement, or materials use to decrease their amount or toxicity prior to their entry into the waste stream.

Lu & Yuan, (2011), Seydel et al., (2002), and Begum et al., (2007) classified waste reduction into five distinct groups as follows:

1. Waste reduction by government law.

2. Waste reduction through design.

3. Establishing an efficient system for waste management (WMS).

4. Implementing low-waste technology.

5. Raising consciousness about waste reduction among contractors.

Pickin et al. (2018) highlighted various advantages for minimizing waste:

- Generating revenue by collecting certain materials
- Minimizing expenses by acquiring fewer materials,
- Decreasing CO2 emissions and the cost of trash transportation to landfills, among other benefits. To achieve the most favorable environmental and cost outcomes, it is crucial to minimize waste generated in construction activities by adopting standardized sizes and quantities (Ding et al., 2016 and Llatas and Osmani, 2016).

Furthermore, the implementation of building information modeling (BIM) might provide valuable assistance and improvements to CWM, especially in the design phases. Researchers such as Sacks et al., (2010) have emphasized the need to study the effects of using informational communication-related approaches and technologies, such as BIM, in order to reduce construction waste during the construction and design phases of a building. Liu et al., (2015) endeavored to examine the application of BIM in tackling the issue of building waste production. These attempts include the utilization of Building Information Modeling (BIM) to enhance coordination, the proficient use of resources and materials, the reinforcement of structural elements to reduce waste from rebar, the management of waste during demolition, and the enhancement of waste management practices on construction sites.

3.6.2 Reuse

Reuse is the second approach to managing construction waste, following reduction. It involves preventing rejected materials from being disposed of; instead they are reused to their fullest potential for the same or different purpose. Reuse refers to the practice of utilizing construction materials multiple times on a site. This can involve using the same material more than once for its original purpose, like the use of formwork in construction. It can also involve repurposing materials for an alternate use, as in the use of cut-corner steel bars for shelves or the utilization of stony fractions for road base material (Duran et al., 2006). This technique requires little action or effort, making it the most preferred alternative following reduction (Peng et al., 1997).

As a result, there are several methods for reusing materials in building. According to Wang and Li (2011), several contractors utilized damaged bricks and stones as a base layer for accessing road leading to the site of the building. In addition, they utilized construction materials such as lumber or plywood to create their provisional shed on the premises.

Common materials that are appropriate for the reuse encompass doors, brick, cabinets, roof and flooring tiles, wood, and ornamental objects such as fireplaces and stonework (EPA, 2009).

3.6.3 Recycling

When the cost of implementing both reduction and reuse techniques has grown too high, it becomes imperative to turn to the third alternative method of waste management. Recycling is a beneficial procedure that substitutes the production of raw resources. Implementing this alternative for waste management offers significant economic benefits due to its minimal resource and effort requirements (Tams, 2013).

The Environmental Protection Agency (EPA, 2009) stated that the recycling process offers several benefits. Regarding the construction projects, the following information is provided:

1. By conserving landfill space, we can decrease the demand for new dumps and the expenses that are incurred.

2. Mitigating the generation of emissions of greenhouse gases along with other contaminants by minimizing the necessity to harvest primary resources and transport new materials over great distances.

3. Conserving energy and minimizing the environmental consequences of material production by avoiding extraction and manufacturing procedures.

4. By recycling existing materials on-site, one may save money, decreasing trash disposal costs, transportation costs, and the expenses associated with purchasing new building materials.

5- The recycling industry generates job opportunities and stimulates the economy.

The economic feasibility and social acceptance of recycled materials are two primary challenges concerning recycling. From a pure economic perspective, recycled materials are only appealing when they are cost-effective and of comparable quality to raw resources. Surprisingly, according to popular belief, the price of raw resources is actually lower than that of recycled materials. In addition, there is typically public concern over the quality of materials that are reused or recycled (Lu & Yuan, 2011).

Regarding the EPA 2009 study, some of the prevalent applications for conventional construction waste include:

1- Concrete:

Concrete is frequently subjected to recycling. The object is compressed; the supporting rod is extracted, and the substance is sifted to determine its dimensions. Recycled concrete may be used in many market outlets such as road foundation, generic fill, and/or asphalt aggregate, which is drained media.

The market for the recycled aggregate from concrete relies on the level of demand and the proximity to the market. At densely populated urban areas with strong demand, the expenses associated with disposing of waste at landfills are expensive, and the distances required for transportation are very short. Consequently, it is relatively effortless to sell concrete debris in these locations. In rural regions characterized by lower landfill expenses and greater distances between the factory and the market, the financial feasibility of recycling may not yet rival that of disposal (Winkler, 2010).

Recycling concrete offers several advantages compared to disposing it off in a landfill or burying it. Preventing the deposition of concrete debris in landfills conserves valuable space in these areas. Additional advantages of concrete recycling include those documented according to the code (ASTM C 172-90, 2009 and Ganiron, 2013): (a) Product sourced locally from local suppliers. (b) Decrease in the amount of truck traffic, a replacement to a non-renewable source. (d) Reduction in expenses. (e) No costs for disposal. (f) Enhanced transportation efficiency resulting in cost reduction. Utilizing recycled material such as gravel diminishes the necessity for gravel extraction. Furthermore, there are economic advantages. Recycled concrete is a building material that is obtained without any cost to the community.

The individuals responsible for generating the concrete trash are required to pay a price for its recycling (Ganiron, 2013, Ganiron, 2015). In order to readily fulfill design standards and produce a high-quality final result, it is essential to begin with clean and high-quality debris, as seen in Figure 3.2 (Ganiron, 2013).

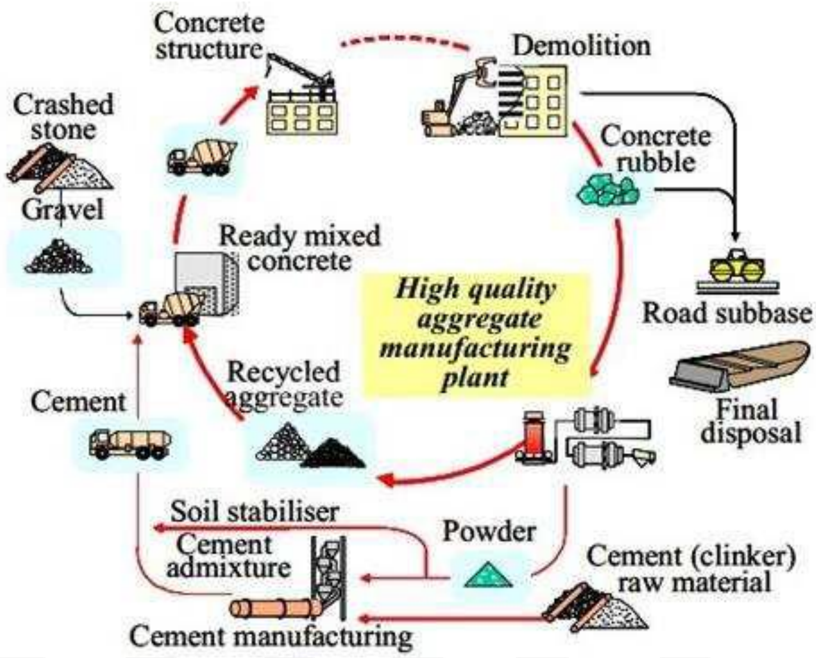

Figure 3.2: Process of Waste Concrete Recycling

Source: (Ganiron, 2013)

2- Asphalt Shingles:

Old asphalt shingles may be restored and used again. Asphalt shingles may be recycled into new asphalt mixtures once the nails have been removed.

3- Metals:

Metals encountered on building, deconstruction, or rehabilitation locations should be recycled. Typical metallic substances consist of the metal aluminium, zinc, and steel. Metal components which are acceptable for recycling or scrapping at local distance are generally easily accessible. By melting and reforming metals into metal products. metal markets are firmly established.

4- Wood:

Make use of timbers, wood with considerable dimensions, plywood and other comparable items, flooring, moulding, and lumber that is longer than six feet. Reusing unprocessed wood can be accomplished by recycling, processing it into carpeting, crushing it to form an engineered board, using it as fuel for furnaces, or mulching it if it is not treated.

5- Land Clearing Residuals

In contrast to soil, which can be used as a covering or fill, shrubs and trees can be converted into mulch or compost.

6- Brick:

Use clean masonry for historical renovation. Crush clean bricks to recycle. Recycled brick markets as aggregate, waste media, and fill. Masonry bricks can also replace significant volumes of natural materials like sand and gravel. Broken bricks made from clay and other masonry may be used to fill pipes trenches (Peng et al., 1997).

Some of the materials generated during building and demolition operations are considered harmful or are categorized as hazardous waste. Construction waste materials that may need specific treatment comprise latex paint, solvents for chemicals, and sealants. The materials must be regulated in accordance with local guidelines. Lead-based paint might be subjected to planning, extraction, and recycling at a leading smelter or it can be disposed of in a suitable manner. The leftover wood may also be repurposed or recycled (the Environmental Protection Agency EPA 2009).

3.6.3.1 Factors affecting recycling construction materials

Research has identified the primary elements that impact recycling adoption of building debris. Kartam, (2004), Ben Nakhi and Alhumoud, (2019) and Chinda, (2016) pinpointed five elements that influence the recycling of building waste:

1- The pureness of recycled material is crucial for determining whether recycling or alternative disposal options are more suitable. This is because the concentrations of dangerous elements in recycled building materials play a significant role in this decision-making process.

2- The expense associated with gathering and transporting. The expenses associated with sifting, converting into useable material, and disposing of any remaining material in landfills or incinerators.

(3) The imperative need for materials that are recycled to adhere to the relevant and necessary standards and regulations.

4- The abundance of recycling markets and the strong competition within the business.

5- The government must incentivize and regulate the markets for lucrative recycling of C&D wastes in order to promote and support their development.

6- Although higher tipping costs in many regions would incentivize recycling, it is crucial for recycling to be economically feasible in comparison to the cost of using new materials.

7- The closeness of the recycling plants to the sites is also crucial in order to minimize the expenses associated with transporting materials from the site to the recycling plant.

3.6.4 Recover

Recovery was placed fourth within the hierarchy for construction management of waste, indicating its level of importance. Recovery is the process of extracting components or materials from trash in a way that maintains their original form, allowing them to be reused in the same way they were first generated (Nagapan, 2012). Recovery methods can effectively decrease the amount of garbage that is ultimately deposited in landfills. In Germany, the utilization of burning technology has facilitated the retrieval of metals trash. This recovery technology is capable of removing around 2 to 3 kilograms of hazardous heavy metals from 1 ton of waste through the process of evaporation and burning. Therefore, this strategy efficiently addressed the issue of reducing the amount of space occupied in the landfill. Additionally, the gas that is created during the process of handling is utilized for the purpose of generating energy (Economics Reference Paper, 2011). The recovery measures have been implemented in several nations. Nevertheless, the government must provide assistance for this endeavor as the establishment of the recovery plant may incur a significant financial cost.

3.6.5 Landfill Disposal

Disposal is the final alternative; it might be regarded as the least favorable factor in attaining sustainability for managing waste. Nevertheless, several countries deposit their building debris in landfills. In Malaysia, the Department of National Management of Solid Waste disclosed that there are around 289 landfills in the nation (Nagapan et al., 2012). However, the disposal technique is not an optimal solution as the primary objective of sustainable waste management is to minimize the quantity of garbage discharged into the environment.

To decrease transportation expenses, it is advisable to locate the dumps in close proximity to the building site. The processing operations should adhere to ecologically sustainable practices, while the garbage collection phase ought to be cost-effective and efficient to limit financial outflows. When it comes to disposal, it is necessary for all the trash produced to go through a series of pre-treatment procedures to minimize the quantity of solid waste ultimately transported to the landfill (http://www.iaeme.com/IJM/index.asp).

3.7 Construction and Demolition Waste Management Streams

A waste stream refers to the whole flow of trash from its origin, whether it is generated by home or industrial sources, until it is ultimately disposed of. Final disposal encompasses several waste management methods, including the recovery or recycling process, landfill burial and/or waste-to-energy conversion. The building and demolition waste stream may exhibit certain similarities to the industrial and commercial streams. The C&I (Commercial and Industrial) and C&D (Construction and Demolition) waste streams possess distinct characteristics. For instance, although certain elements of construction may be categorized as C&I trash, such as discarded drawings, the majority of construction activities generate garbage that needs a distinct waste stream. The presence of both natural and possibly dangerous materials in C&D waste is the reason for its mixed composition. Generally, many forms of natural building and demolition debris, such as wood, may be recycled. Even artificial construction and demolition debris, such as asphalt, may be recycled and used to create fresh asphalt (Clean Management Environmental Group, Inc.).

Abdelhamid, (2014) identified two main categories of waste streams for tackling C&D waste:

1. Source Distinction: this is the prevailing approach where contractors categorize the materials on the construction site into different containers

based on the specific requirements of the market. Demolition companies or professionals often do this task. The subcontractors employed at the site often yield the most value (or lowest cost) when it comes to recycling garbage. This approach also minimizes landfill trash by collaborating with other marketplaces to supply particular items that may be processed for end customers.

2. Single-Stream: this recycling method, also known as commingled trash recycling, is not frequently used on construction sites. This approach involves the accumulation of different forms of waste at the construction site, which are then placed in shared containers and transported to a recycling facility. At the facility, the waste is sorted by a recycler who divides it into components that may be sold on the market. The adoption of this method is increasing in municipal household collection due to its ability to achieve better rates of recyclable collection compared to a source-separated system, where householders need to separate metal, plastic, glass, and paper.

Waste management might involve off-site or on-site recycling sorting (Gaurav, et al. 2019). On the same note, on-site recycling isolates materials to make a new product that can be used as a raw material for other construction activities, whereas off-site recycling separates and transports used materials for construction to other construction companies (Almaliki, 2020).

3.8 The objective of Construction Waste Management Plants

The primary objectives of waste management plants in processing C&D W are the following (Hiete, 2013):

1- The process of segregating different types of waste, such as separating plastics, wood, and steel from aggregates, in order to facilitate their recycling, reuse, and safe disposal.

2- The process of grinding, crushing, and sorting, employed to get certain sizes of grain, resulting in items that may be sold in the market.

3- The deconstruction process that involves sorting and sieving to remove pollutants including heavy metals, asbestos, gypsum, and tar from the primary waste streams. It is important to minimize the entry of these contaminants into the resulting aggregate waste streams during deconstruction, since their removal becomes more challenging later on.

3.9 Construction and Demolition Waste during the Life Cycle of Project

Katz and Baum, (2011) classified the construction work into three different phases on the basis of the kind of waste produced: the building frame, the early finishing works, and the final finishing works (Figure 3.3). The study examined the correlation between the quantity of construction debris and the duration of the construction process. The waste created during structural frame building was comparatively lower than that in prior times.

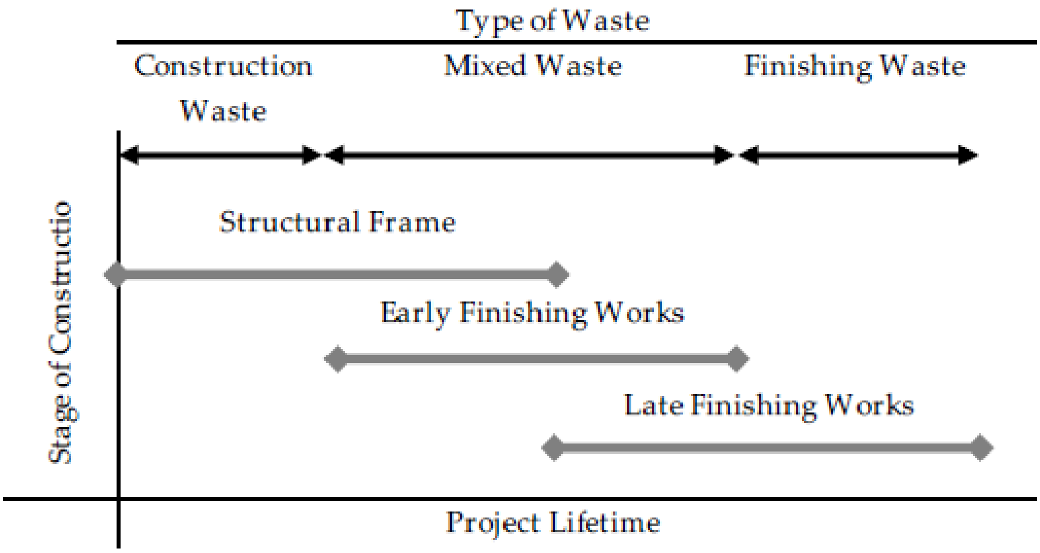

Figure 3.3: Construction Process and Waste Type Modified From

Source: (Katz and Baum, 2011).

3.10 Environmental Impact Assessment from c&d Waste

Throughout each stage of construction, the presence of solid waste results in an adverse environmental effect. Over the past thirty years, the globe has been struggling with environmental contamination, part of which is attributed to undesirable substances. The absence of sustainable strategies to address this problem will have a detrimental effect on future generations (Hossain et al., 2011). Multiple academics have also emphasized the diverse impacts of building solid waste. Njoroge's (2012) research revealed that inadequate management of construction solid waste, namely in terms of processing and disposal, has detrimental effects on the ecosystem and leads to several public health issues, including lead poisoning and asbestosis. Similarly, Nor et al., (2013) observed that building solid waste exhausts natural resources, obstructs sewage systems, alters the living environment, escalates energy consumption, and disrupts ecological equilibrium.

the findings of Saadi et al., (2016), the construction sector's rising waste production from building projects is expected to lead to the future restriction of direct garbage disposal techniques. This is due to the significant environmental impact caused by the vast quantity of waste created. The majority of current landfills are already at capacity, with some having exceeded the permissible contamination threshold. Hence, it is imperative to implement alternative strategies to minimize the buildup of trash and to promote projects that focus on reusing, reducing, and recycling the existing solid waste.

To put it another way, waste management encompasses the activities of collecting, monitoring, processing, transporting, and discarding waste products.

The primary contributors to the health issues in society and environmental pollution are the waste materials generated by building sites. Furthermore, it leads to the decrease and exhaustion of natural resources, so impacting the long-term viability of a building project. As per the findings of Eze et al. (2016), the generation of material wastes at construction project sites leads to detrimental effects on the construction project itself, the environment, and the economy. The environmental consequences of material wastage encompass soil pollution, water contamination, and landscape degradation (Fadiya et al., 2014).

4. FIELD WORK

4.1 Introduction

This chapter introduces the framework in which the field study was conducted. It displays the data gathering procedure of the study sample characteristics and statistical data testing, and then it discusses the work performed to acquire the experts' viewpoints utilizing a questionnaire to pinpoint the most dominant factors of waste for renovation construction projects in Iraq by the range of factors attained from the literature review.

The field study investigates the critical factors of the waste problems in construction projects from the perspective of contractors, owners and consultants in the Iraqi construction industry. The pilot questionnaire accompanied by personal interviews with experts and project managers from the private construction sector is used to obtain a comprehensive set of influential factors of construction waste. The questionnaire results are analyzed, and a list of (76) major factors is set.

4.2 Appraisal of Construction Waste Factors

These steps focus on the procedure used to restrict the scope of the study and to focus on the most important variables:

1. Reviewing relevant literature to learn more about the various waste factors in construction projects in different countries, with a focus on Iraq and the region, where (76) factors were specified and categorized into six major classes: design, planning and documentation, construction method, material and procurement, workers, site situation and external factors. The number of factors in each group is displayed in Table (4.1).
2. Expert opinions from a questionnaire survey were analyzed to determine the most dominant factors affecting waste for renovation construction projects in Iraq. The questionnaire was handed to experts responsible for executing

projects in the public and private sector companies in various governorates of Iraq.

3. Historical data related to the most important factors from the companies perspectives related to the private sector in Iraq was extracted to offer data to model development.

Table 4.1: Number of Factors in Each Category

No.	Categories	No. of factors
1	Design, Planning & Documentation	14
2	Material and Procurement	18
3	Construction Method	19
4	Workers	8
5	Site Situation	7
6	External Factors	10
	Total	**76**

4.3 Data Collection Methods

The research covered the data required to realize the theoretical aspect of numerous sources, representing the research studies, the reference books, the published articles and research papers, available inside or outside the country. This study is directed to specialists executing in the public and private sectors. Table (4.2) presents the names of private companies and governmental institutions performing the questionnaire with specialists working in these institutions.

Table 4.2: Governmental Institutions and Private Companies

No.	Organization Title	Sent	Received
1	**Ministry of Higher Education and Scientific Research**		
1.1	University of Baghdad	12	8
1.2	University of Technology	10	7
2	**Ministry of Construction, Housing, Municipalities and Public Works**		
2.1	Ashour General Constructive Constructing Company	9	5
2.2	Al-Mansour Contracting Company	5	3
3	**Private Companies**		
3.1	Baghdad Governorate	15	10
3.2	Diyala Governorate	6	4
3.4	Karbala Governorate	10	6
3.6	Najaf Governorate	7	5
3.13	Wasit Governorate	6	4
	Total	**80**	**52**

4.4 Field Surveys

4.4.1 Pilot questionnaire

Interviews were conducted with a group of consultants, owners, and contractors with expertise in executing public and private projects. Table (4.3) summarizes the results based on comparing general information about the interviewees who participated in this study.

All of the interviewees possess academic qualifications such as PhD, M.Sc., and/or B.Sc., and have more than twenty experience years in the construction sector in Iraq. The prime objective of the pilot questionnaire was to certify that the questionnaire was precise in attaining the relevant influential factors in Iraq; it also aimed to utilize such experiences for modifications of the list of factors that were highlighted in the research subject. After reducing the factors from (84) to (76), an inclusive list of information was obtained. This list was used as a basis for building a questionnaire.

Table 4.3: Interviewees Background

Academic Qualification	Field of Practice	Affiliation	Work sector	Years experience
PhD	Building Construction	University of Baghdad	Public	25
PhD	Building Construction	University of Baghdad	Public	30
PhD	Building Construction	University of Technology	Public	20
PhD	Building Construction	University of Technology	Public	23
MSc	Building Construction	Ashour General Constructive Constructing Company	Public	22
BSc	Building Construction	Al-Fao General Engineering Company	Public	30
BSc	Building Construction	Project manager	Privet	32
BSc	Building Construction	Project manager	Privet	28
BSc	Building Construction	Project manager	Privet	22
BSc	Building Construction	Project manager	Privet	21
BSc	Building Construction	Project manager	Privet	35

4.4.2 Questionnaire Form

A closed questionnaire structure was made to determine factors affecting waste for renovation construction projects in Iraq; the questionnaire relies on prior inside and global studies supported by novel issues raised through discussion with the participants, as demonstrated in Appendix (A). The questionnaire was directed to participants in the Iraqi construction industry, comprising owners, site engineers, contractors, project managers, and consultants. The questionnaire consists of two parts as follows:

Part 1: General information specifies the governorate, affiliation, education degree, experience and work sector.

Part 2: The (72) factors affecting waste for renovation construction projects in Iraq were listed, seeking the opinion of the Iraqi experts about the one/ones to be applied or to be confronted in the local practice. As aforementioned earlier in the chapter, the factors are categorized into six classes.

4.5 Characteristics Respondents

The whole number of the distributed questionnaire forms was (80), of which (15) were directed to contractors and (65) to the other parties, i.e. owners, consultants and supervising engineers. The fully answered forms received were (5) from contractors and (47) from the other parties above. They formed a response rate of (65%). The participants are (9.62%) owners, (23.08%) consultants, (57.69%) supervising engineers and (9.62%) contractors, as revealed in Figure (4.1).

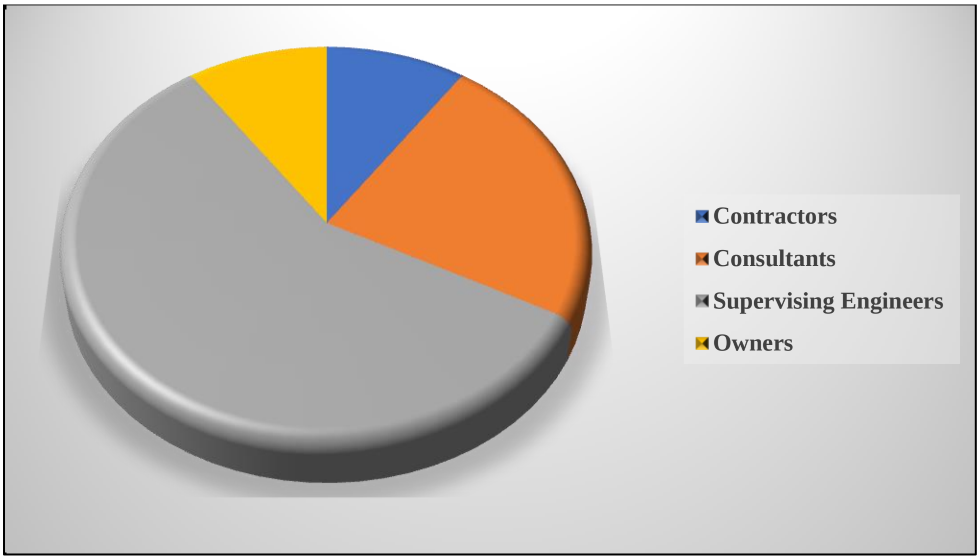

Figure 4.1: Percentages of Respondent's Affiliations

Table (4.4) highlights the educational background of the participants: (25%) of them hold a (PhD) degree, (36.54%) have an (MSc) degree, (34.62%) hold a (BSc) degree, and (3.85%) hold a (Diploma) degree.

Table 4.4: Respondent's Educational Degree

Education degree	No.	Percentage
PhD	13	25%
MSc	19	36.54%
BSc	18	34.62%
Diploma	2	3.85%
Total	**52**	**100%**

On the other hand, Figure (4.2) shows the percentages of the participants` experiences: (11.54%) have (< 6) years of experience, (9.62%) have (6-10) years of experience, (13.46%) have (11-15) years of experience, and (65.38%) have (>15) years of experience.

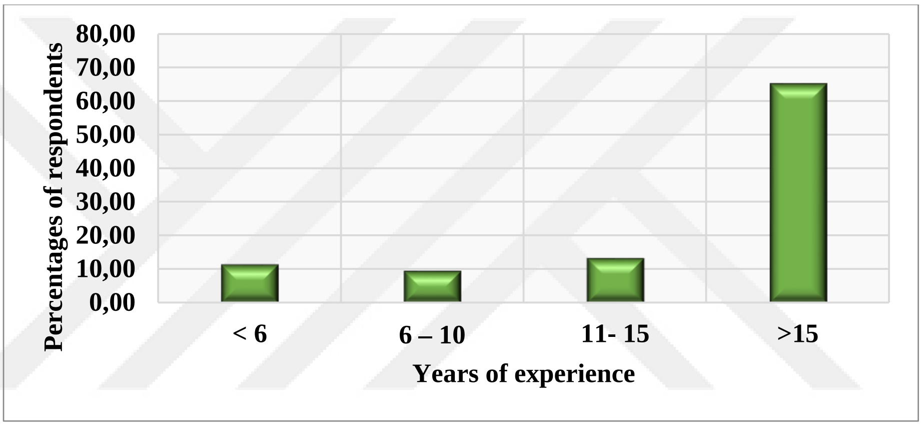

Figure 4.2: Respondent's Experience Percentages

Figure (4.3) shows the percentages of respondents in the work sector: (82.69%) work in the private and (17.31%) work in the public sector.

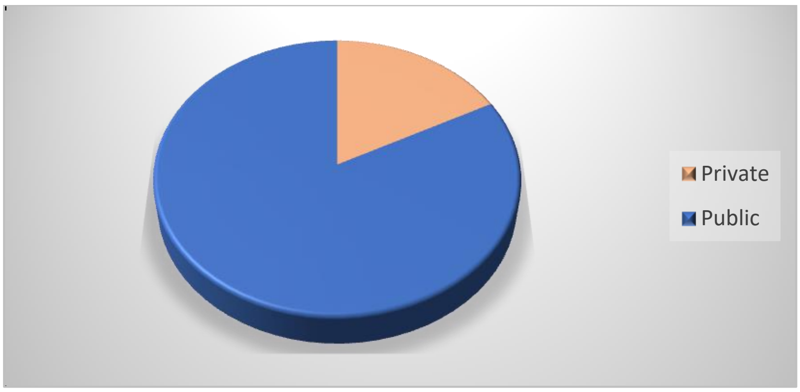

Figure 4.3: Work Sector Percentage Of Respondents

4.6 Questionnaire Analysis

The questionnaire was planned using the 5-point Likert scale to answer each question. The relative importance is also calculated based on Hasan and Mohammed, (2018) calculation criteria. The researchers used the relative importance index (RII) method to specify the relative importance of factors affecting waste for the renovation construction project. The five-point Likert scale ranging from (1 = very low important) to (5 = very high important) is applied and converted into relative importance index (RII) for each factor in the questionnaire utilizing equation (4.1) (Hasan and Mohammed, 2018). The arithmetic mean and standard deviation were calculated based on the statistical analysis of the questionnaire data according to equations (4.2) and (4.3), respectively (Hasan and Mohammed, 2022).

$$RII = \left(\frac{\sum W}{A * N} \right) \quad (4.1)$$

Where:

W: the respondents' weight, which ranges from 1 to 5,

A: the respondents' highest weight (for each factor), and

N: the total number of respondents is equal to (52).

$$M = \frac{\sum_{i=1}^{k} xi * fi}{N} \quad (4.2)$$

$$S = \sqrt{\sum_{i=1}^{k} (xi - M)^2 * \frac{fi}{n-1}} \quad (4.3)$$

Where:

M: mean.

S: standard deviation

x_i: weight value for factor.

f_i: number of frequencies.

N: the total number of respondents which is equal to (52).

For each answer, the researcher adopted the class weighted mean or interval, as presented in Table (4.4) (Al-Dhaheri, 2018).

Table 4.5: Weight Value and Class Interval of Descriptive Frequencies

Descriptive Frequency (Level)	Class Interval (Weighted Mean)	Weight Value (WV)
Very low	1.00 - less than 1.80	1
Low	1.80 - less than 2.60	2
Medium	2.60 - less than 3.40	3
High	3.40 - less than 4.20	4
Very high	4.20 - 5.00	5

Appendix (B) highlights the comparative significance index, mean (M) and standard deviation (S.D) values for (76) factors, together with the final ranking and screening on the basis of the questionnaire findings. It was found that weights of RII were in the range of (0.592 - 0.858). Table (4.6) displays the categories' comparative significance index, standard deviation and mean.

Table 4.6: RII for Each Category

Categories	RII	Mean	St. Dev
Design, Planning & Documentation	0.751	3.757	0.937
Material and Procurement	0.703	3.516	0.958
Construction Method	0.752	3.759	0.822
Workers	0.764	3.820	0.892
Site Situation	0.712	3.558	0.915
External Factors	0.745	3.723	1.002

4.7 Reliability and Validity Test

It is necessary to verify the reliability and validity of the questionnaire findings in order to pinpoint their consistency and the degree to which they authentically represent the case under study. The reliability coefficient is regarded satisfactory when it is more than (0.7). Higher internal consistency of data is realized when the reliability coefficient approaches (1). Accurate representative data also indicate that the questionnaire was properly designed and that the study sample was suitably chosen. The Cronbach's coefficient (alpha) measure was applied to ensure the reliability and validity of the findings utilizing equation (4.4) for the reliability test and equation (4.5) for the validity test (George and Mallery, 2003). The values between (0.0) to (1.0) are viewed the standard range for Cronbach's coefficient (alpha).

$$\alpha = \frac{K}{K-1}\left[1 - \frac{\sum_{i=1}^{K} S_i^2}{S_t^2}\right] \quad (4.4)$$

$$V = \sqrt[2]{\alpha} \quad (4.5)$$

Where:

K: is the number of items in a category.

S_i^2: is the variance related to item (i).

S_t^2: is the variance linked to the sum of all (k) item scores.

Table (4.7) reveals the findings of the reliability and validity tests for each category in the questionnaire. It was concluded that Chronbach's Alpha values were within the range of (0.853- 0.926), which is high enough to secure the test reliability and validity.

Table 4.7: Reliability and Validity for Categories

Categories	No. of items	Reliability*	Validity
Design, Planning & Documentation	14	0.855	0.925
Material and Procurement	18	0.926	0.962
Construction Method	19	0.912	0.955
Workers	8	0.896	0.947
Site Situation	7	0.868	0.932
External Factors	10	0.853	0.924

***** (Cronbach's Alpha)

4.8 Normality Test

The Kolmogorov-Smirnov test was carried out to identify whether the questionnaire results were normally distributed. Normal data distribution is attained when the P-value of the Kolmogorov-Smirnov test is more than (0.05), and the skewness and kurtosis measures are close to zero (Berger & Zhou, 2014). Table (4.8) shows the P-values (Sig.) for each category according to the questionnaire, which appears to be more than (0.05). This indicates that the group results follow a normal distribution pattern, as indicated in Figures (4.4) to (4.9).

Table 4.8: Normality Test for Categories

Categories	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Design, Planning & Documentation	0.091	52.0	0.200	0.985	52	0.753
Material and Procurement	0.097	52.0	0.200	0.969	52	0.188
Construction Method	0.079	52.0	0.200	0.985	52	0.767
Workers	0.089	52.0	0.200	0.962	52	0.100
Site Situation	0.073	52.0	0.200	0.985	52	0.758
External Factors	0.086	52.0	0.200	0.987	52	0.820

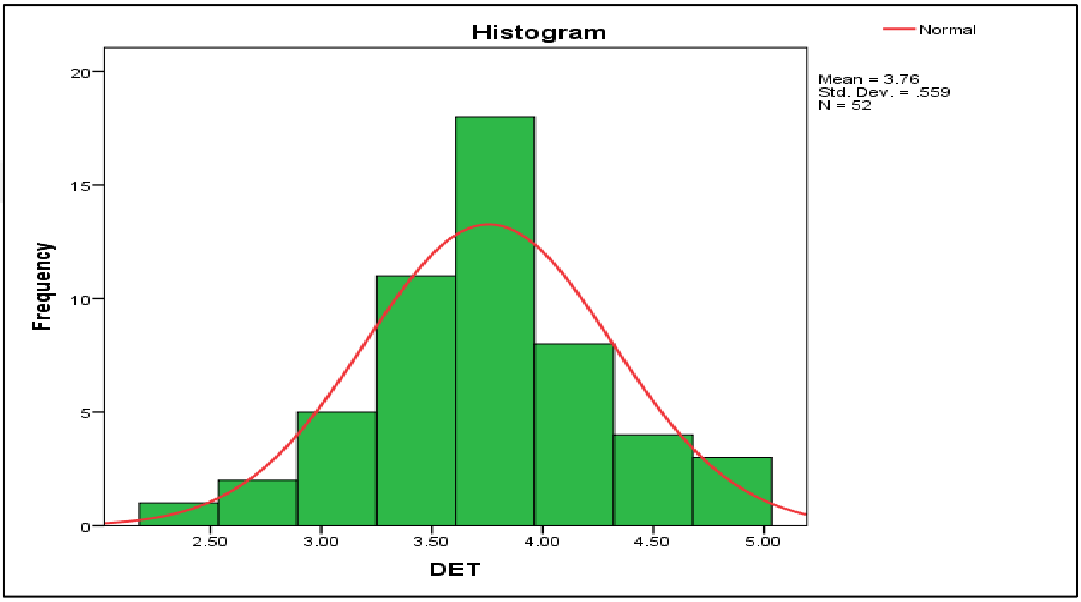

Figure 4.4: Normal Distribution Chart for Design Category

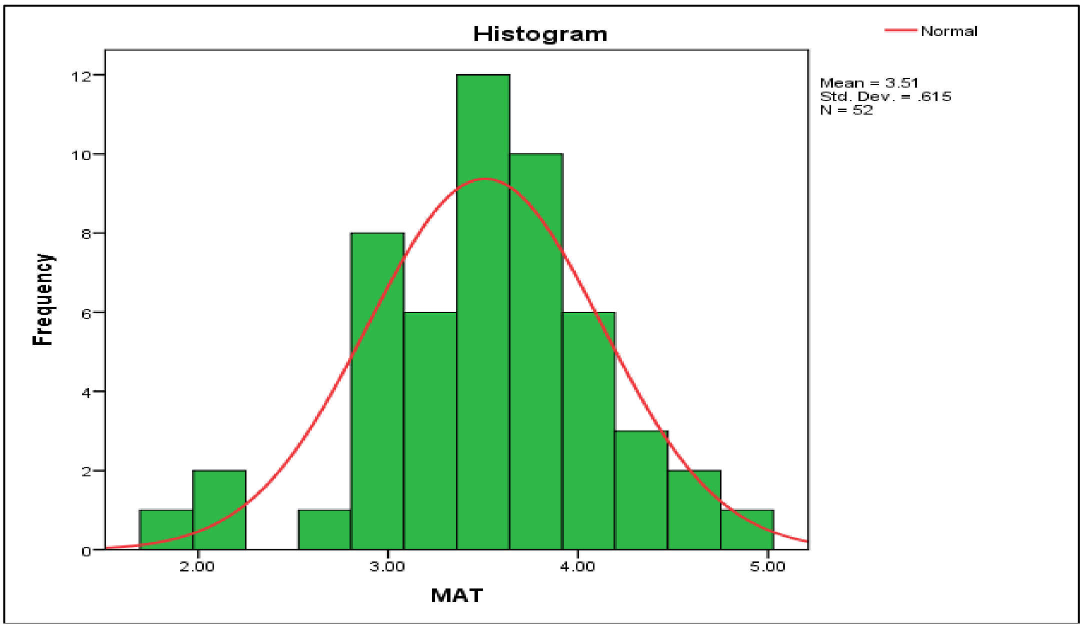

Figure 4.5: Normal Distribution Chart for Material Category

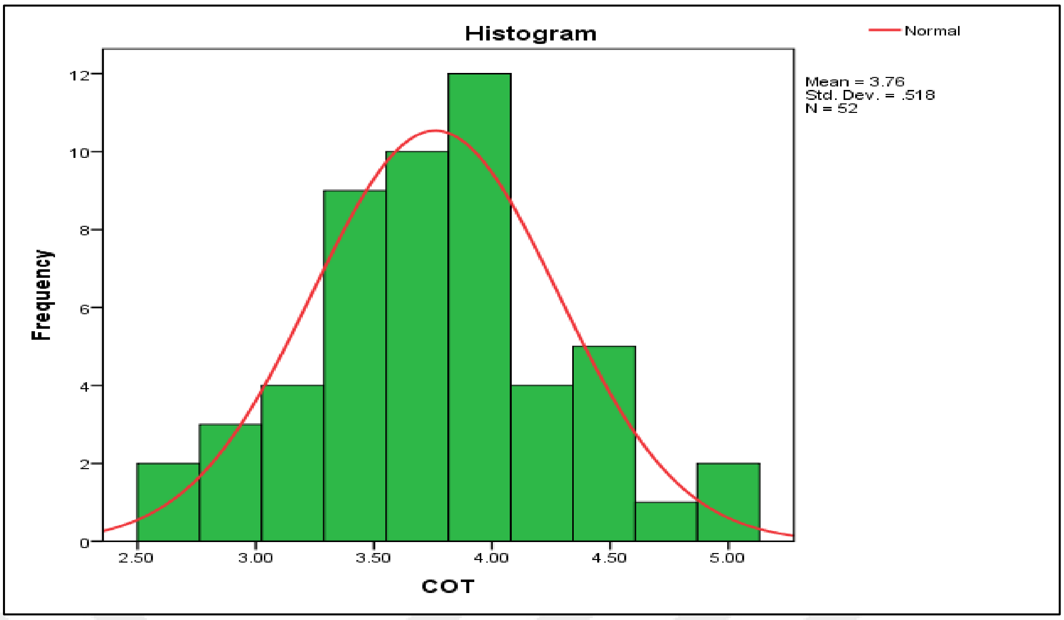

Figure 4.6: Normal Distribution Chart for Construction Category

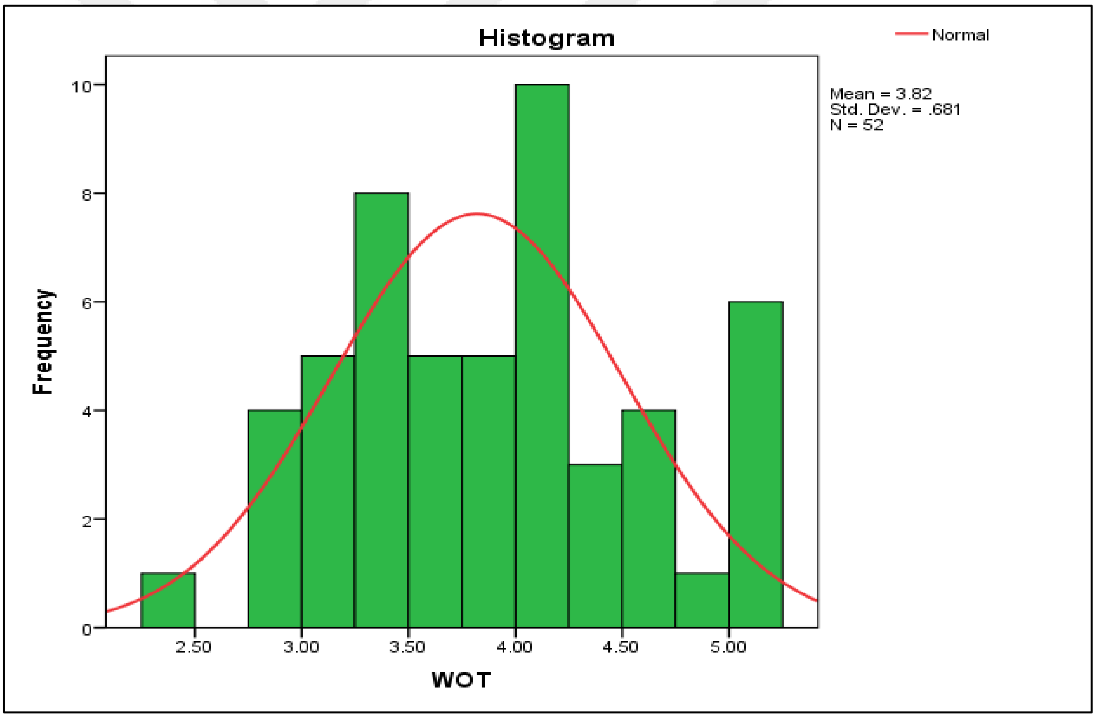

Figure 4.7: Normal Distribution Chart for Workers Category

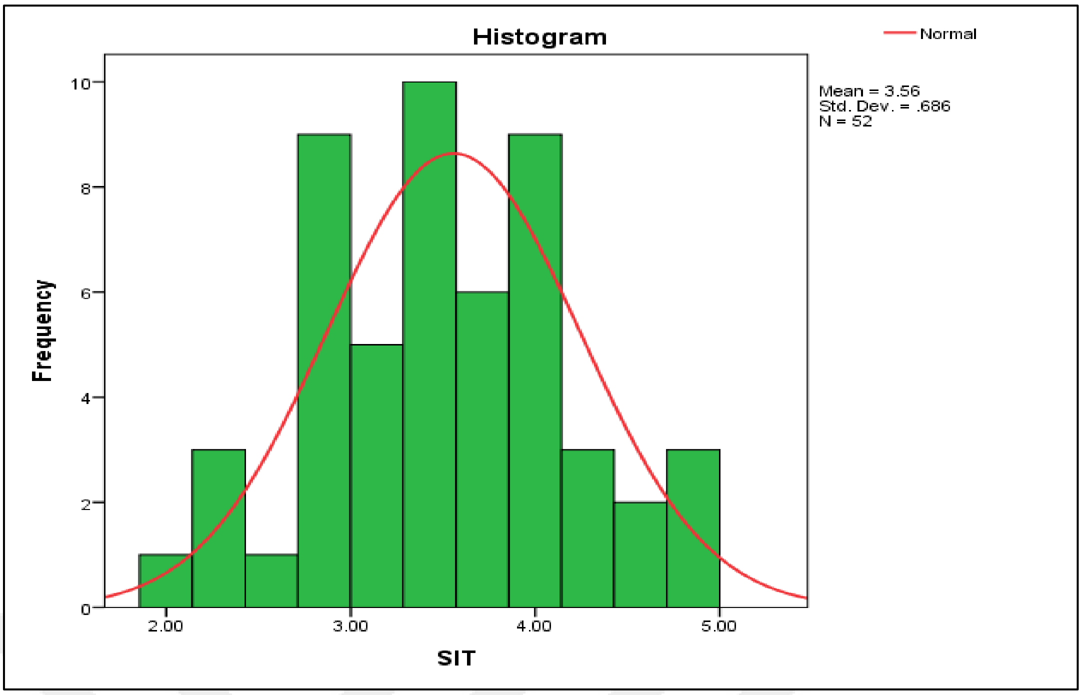

Figure 4.8: Normal Distribution Chart for Site Category

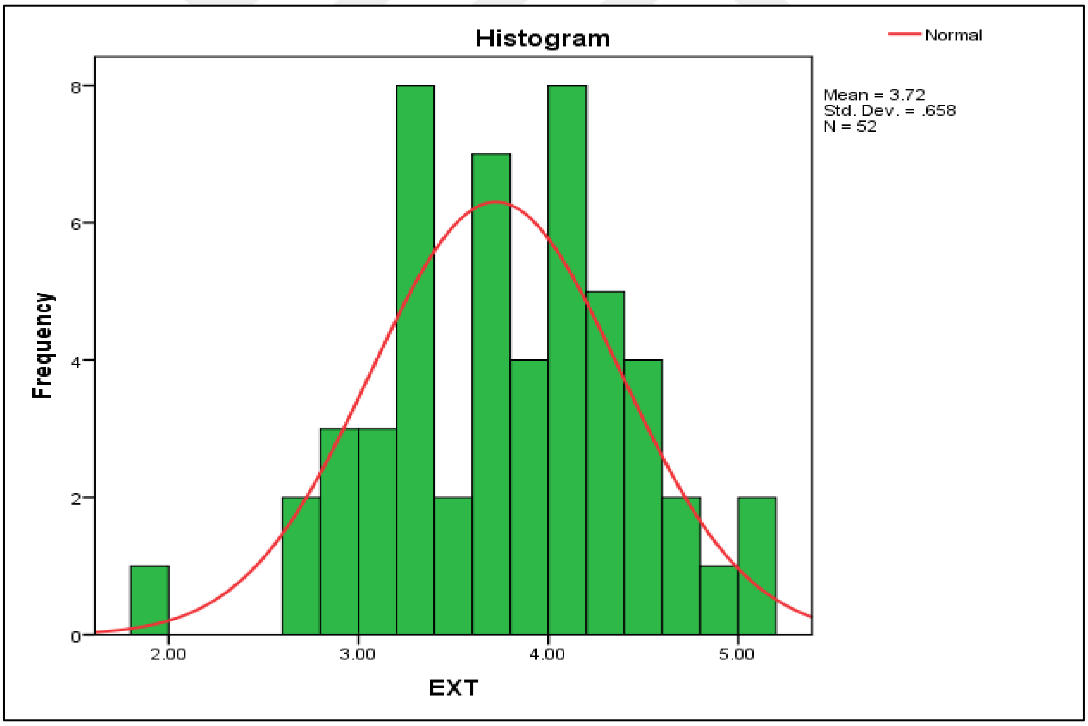

Figure 4.9: Normal Distribution Chart for External Category

4.9 Pearson's Correlation

The parametric test, Pearson's correlation test, measures relations between two continuous variables. These tests are used in cases that assume normality or variance homogeneity in data. It compares medians rather than means, so the impact is minimized when the data incorporates one or two outliers. The Pearson correlation method is commonly used for numerical variables; it allocates a value between − 1 and 1, where 0 is no correlation, 1 is a total positive correlation, and − 1 is a total negative correlation. This means: a correlation value of 0.7 between two variables would indicate the presence of a positive and significant relationship between the two. A positive correlation indicates that if variable A rises, then B will also rise, whereas a negative correlation affirms that if A rises, B falls down (Nettleton, 2014).

Table (4.8) reveals the Pearson's correlation coefficient findings of the categories in the questionnaire. It was concluded that there is a comparatively good consensus between categories. Pearson's correlation coefficient values range within (0.308-0.806).

Table 4.9: Correlation Coefficient between Categories

Categories		Design	Material	Construction	Workers	Site	External
Design	Correlation Coefficient	1	0.515**	0.463**	0.308*	0.314*	0.528**
	Sig. (2-tailed)		0.000	0.001	0.026	0.023	0.000
	N	52	52	52	52	52	52
Material	Correlation Coefficient	0.515**	1	0.648**	0.594**	0.534**	0.600**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000
	N	52	52	52	52	52	52
Construction	Correlation Coefficient	0.463**	0.648**	1	0.806**	0.664**	0.738**
	Sig. (2-tailed)	0.001	0.000		0.000	0.000	0.000
	N	52	52	52	52	52	52
Workers	Correlation Coefficient	0.308*	0.594**	0.806**	1	0.658**	0.711**
	Sig. (2-tailed)	0.026	0.000	0.000		0.000	0.000
	N	52	52	52	52	52	52
Site	Correlation Coefficient	0.314*	0.534**	0.664**	0.658**	1	0.690**
	Sig. (2-tailed)	0.023	0.000	0.000	0.000		0.000
	N	52	52	52	52	52	52
External	Correlation Coefficient	0.528**	0.600**	0.738**	0.711**	0.690**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	
	N	52	52	52	52	52	52
**Correlation is significant at the 0.05 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).							

4.10 Internal Consistency

Internal consistency is the consistency of each questionnaire item with the domain to which that item belongs. The internal consistency of the questionnaire is calculated by simple correlation coefficients (Pearson's correlation). Table (4.9) shows the internal consistency of the design category. The results indicate that all the correlation values for the design are significant because the probabilistic values have less than the significance level (0.01), and the correlation values range between (0.305-0.786). On the other hand, Table (4.10) illustrates the internal consistency of the material category. The results indicate that all the correlation values for the material are significant because the probabilistic values have less than the significance level (0.01), and the correlation values range between (0.578-0.822). In addition, Table (4.11) displays the internal consistency of the construction category. The results indicate that all the correlation values for the construction are significant because the probabilistic values have less than the significance level (0.01), and the correlation values ranged between (0.405-0.723). Furthermore, Table (4.12) presents the internal consistency of the workers category. The results indicate that all the correlation values for the workers are significant because the probabilistic values have less than the significance level (0.01), and the correlation values range between (0.528-0.851). Also, Table (4.13) displays the internal consistency of the site category. The results indicate that all the correlation values for the site are significant because the probabilistic values have less than the significance level (0.01), and the correlation values range between (0.712-0.779). Finally, Table (4.14) reveals the internal consistency of the external category. The results indicate that all the correlation values for the external are significant because the probabilistic values have less than the significance level (0.01), and the correlation values range between (0.566-0.717). All these results affirm the internal relationship between each category and its factors.

Table 4.10: Correlation between Designs with Their Factors

Code	Factor	Pearson's correlation	Sig*
DE1	Frequent design changes	0.575**	0.00
DE2	Design errors	0.675**	0.00
DE3	Lack of design information	0.606**	0.00
DE4	Complicated design	0.423**	0.00
DE5	The conflict between design and other contract documents	0.582**	0.00
DE6	Document problems	0.731**	0.00
DE7	Not implementing green building practicing	0.469**	0.00
DE8	Mistake assessment of material quantities	0.361**	0.00
DE9	Errors in contract documents	0.740**	0.00
DE10	Poor design	0.727**	0.00
DE11	Carelessness during quantity analysis and measurement	0.547**	0.00
DE12	Inexperienced designer	0.727**	0.00
DE13	Ineffective planning and scheduling	0.786**	0.00
DE14	Lack of waste management plan	0.305*	0.00
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)			

Table 4.11: Correlation between Materials with Their Factors

Code	Factor	Pearson's correlation	Sig*
MA1	Wrong material storage	0.591**	0.00
MA2	Damage during transportation of materials	0.718**	0.00
MA3	Poor quality of materials	0.584**	0.00
MA4	Delay during delivery of materials	0.694**	0.00
MA5	Ordering or supplier errors of materials	0.769**	0.00
MA6	Material quality problems	0.626**	0.00
MA7	defective materials	0.752**	0.00
MA8	damaged materials	0.675**	0.00
MA9	Packaging problem	0.653**	0.00
MA10	Lack of possibilities of ordering small quantities	0.657**	0.00
MA11	shortage in materials	0.612**	0.00
MA12	Inadequate material handling	0.578**	0.00
MA13	Stored material far away from the construction site	0.620**	0.00
MA14	Carelessness of worker during handling materials	0.694**	0.00
MA15	Material transportation problems	0.822**	0.00
MA16	Material inventory not well documented.	0.607**	0.00
MA17	materials supplied unbound	0.647**	0.00
MA18	materials not fit to the specification	0.647**	0.00
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)			

Table 4.12: Correlation between Constructions with Their Factors

Code	Factor	Pearson's correlation	Sig*
CO1	Frequent demolitions due to rework and change orders	0.590**	0.00
CO2	Wasteful use of material on construction	0.723**	0.00
CO3	Poor site management	0.583**	0.00
CO4	crews interfering	0.652**	0.00
CO5	Poor supervision	0.622**	0.00
CO6	Lack of coordination among parties	0.580**	0.00
CO7	Inappropriate construction method	0.536**	0.00
CO8	Tools and equipment misuse/ malfunction	0.666**	0.00
CO9	Wrong team / subcontractor selection	0.573**	0.00
CO10	construction errors	0.405**	0.00
CO11	On-site construction waste -sorting	0.598**	0.00
CO12	The magnitude and complexity of the construction	0.673**	0.00
CO13	Utilizing a product that does not fit	0.683**	0.00
CO14	Problem during fabrication	0.671**	0.00
CO15	scarcity of equipment	0.681**	0.00
CO16	equipment failure during construction	0.636**	0.00
CO17	Used old equipment	0.654**	0.00
CO18	Non-availability of equipment	0.715**	0.00
CO19	Extended project duration	0.642**	0.00
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)			

Table 4.13: Correlation between Workers with Their Factors

Code	Factor	Pearson's correlation	Sig*
WO1	Frequent demolitions due to rework and change orders	0.822**	0.00
WO2	Wasteful use of material on construction	0.792**	0.00
WO3	Poor site management	0.851**	0.00
WO4	crews interfering	0.850**	0.00
WO5	Poor supervision	0.783**	0.00
WO6	Lack of coordination among parties	0.765**	0.00
WO7	Inappropriate construction method	0.758**	0.00
WO8	Tools and equipment misuse/ malfunction	0.528**	0.00
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)			

Table 4.14: Correlation between Sites with Their Factors

Code	Factor	Pearson's correlation	Sig*
SI1	Poor site conditions	0.768**	0.00
SI2	Unforeseen ground conditions	0.779**	0.00
SI3	Congestion at the site	0.723**	0.00
SI4	Difficulties accessing construction	0.767**	0.00
SI5	Vandalism	0.751**	0.00
SI6	Damage caused by third parties	0.712**	0.00
SI7	Accident at site	0.749**	0.00
** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)			

Table 4.15: Correlation between External with Their Factors

Code	Factor	Pearson's correlation	Sig*
EX1	Effect of weather	0.717**	0.00
EX2	Stealing of materials	0.593**	0.00
EX3	Waste due to the nature of building demolition or renovation works	0.640**	0.00
EX4	Absence of waste recycling programs	0.705**	0.00
EX5	Lightning problem at site	0.566**	0.00
EX6	Improper governmental role toward construction waste reduction	0.645**	0.00
EX7	Weak waste collection/transportation	0.701**	0.00
EX8	Delay due to official holidays	0.673**	0.00
EX9	Administrative corruption	0.657**	0.00
EX10	Lack of management legislation	0.682**	0.00

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

4.11 Summary

In this chapter (76), factors affecting waste for renovation construction projects in Iraq were specified and categorized into six major categories: design, material and procurement, planning and documentation, construction method, workers, site situation and external factors. The experts gave their opinion through a questionnaire survey. The questionnaire results were gathered and then analyzed to find the most dominant factors by using relative important index analysis. Pearson's correlation was used to determine the correlation between categories and to define the internal consistency between categories with their factors.

5. MODELLING COST OF WASTE FOR RENOVATION PROJECTS

5.1 Overview

This chapter applied the observed data on the construction materials wastage in renovation projects. Construction materials were determined based on a number of concepts. The observed data was gathered through interviews, field observations, and constructed projects records. Additionally, the method applied for assessing diverse construction materials' waste was illustrated. Finally, a mathematical model is designed to measure the cost of waste in renovation construction projects using support vector machine.

5.2 Selection of Waste Materials

Based on the methodology applied in this study, construction waste was measured for the different construction materials. The material was collected from varied sources and data was gathered from different sites. The methodological and quantitative approaches were combined together to elicit the required data. The data resources were interviews, documentary records, field observations and questionnaire forms.

Several reasons informed the selection of the construction materials. Since the construction materials play a crucial role in most construction activities, they are vulnerable to damage in the construction sites. Some studies indicated that these materials surpassed the permitted limits drawn by the Ministry of Construction, Housing, Municipalities and Public Works (MCHMPW) (Khaled et al., 2015). Appendix [C] highlights the limits specified for most construction materials as cited in the Standard Guide of Price Analysis for the Building and Construction Sector.

The current study incorporates lime and gypsum, cement, sand, gravel, ceramic wall tiles and floor tiles while measuring the waste generated during the construction phase. The wastage produced from subjected materials was assessed from different aspects based on the varied activities involved in each project in order to collect more precise results that are closer to reality.

5.3 Data Acquisition

Four samples of construction projects obtained from private companies were used to measure construction waste. Percentage analysis is based on waste materials for various activities. The data required to construct models are drawn from projects completed between 2018 and 2023. The project is awarded to one execution agency, the engineering affairs of Baghdad University and the General Directorate of School Buildings in the Ministry of Education. It includes eliminating damaged items, replacing them with new items, and maintaining some of the already damaged items.

The related data was collected along with the waste percentage for each construction project by considering design drawings, studying the storage issues (sheets), holding meetings with the project managers and staff, and examining the work methodology and monthly reports; besides, taking into consideration the differences that may appear between the acquired and implemented quantities, going over the materials purchasing records with the real sums of the work items. Waste percentage (W %) was measured by applying equation (5.1).

$$W\% = \frac{Estimated\ Material - \text{Consumed Material}}{Estimated\ Material}\ X\ 100\% \qquad 5.1$$

Where:

Estimated Material: the purchased quantity of each material required to implement a specific item in accordance with the design.

Consumed Material: the actual amount of the executed work items

5.4 Case Studies Description

5.4.1 Case study 1

Table (5.1) shows the primary information for the project on the renovation of the Dar-Al Salam building. Information about project costs is extracted from the civil work bill of quantities (BOQ), as shown in Table (5.2).

Table 5.1: Main Information for Case 1

Project Name:	Renovation of building Dar-Al Salam
Establishment Date of the building	1939
The Building Surface Area:	200m^2
Number of floors:	1
Number of times of rehabilitation since the establishment:	0
Type of Rehabilitation:	High-class rehabilitation to produce a multi-use hall
The execution agency:	The engineering affairs of Baghdad University
The beneficiary agency:	College of Dentistry in the University of Baghdad
Total Cost:	175,040,000 ID
The building location:	Bab-Al Muaazam in Baghdad
The project time started on	15-5-2022
The project time ended on	1-2-2023

Source: Engineering Affair of Baghdad University

Table 5.2: Bill of Quantities (BOQ) for Case 1

No.	Activity Details	Quantities	Unit	Price (IQD)	Cost (IQD)
1	Whole Slab Removal	Whole quantity about 200m^2	Whole quantity	5,000,000	5,000,000
2	Mosaic Removal	200	m^2	5,500	1,100,000
3	Putting and compact Subbase	100	m^3	30,000	3,000,000
4	Reinforced Concrete for Beams and Slab	49	m^3	450,000	22,050,000
5	Concrete Casting on the Ground with BRC	46	m^3	250,000	11,500,000
6	Concrete Tiles on the Floor	205	m^2	35,000	7,175,000
7	Masonry Brick Work	45	m^3	250,000	11,250,000
8	Windows Removal	Count	Count	750,000	750,000
9	Gypsum Wall Plastering Removal	290	m^2	5,000	1,450,000
10	Gypsum Wall Plastering	290	m^2	15,000	4,350,000
11	Cement Plastering	200	m^2	13,000	2,600,000
12	Steel Frame Instillation	31	m^2	75,000	2,325,000
13	Gypsum Board for walls and slab	440	m^2	45,000	19,800,000
14	Mosaic Tiles	195	m^2	40,000	11,700,000
15	Marble Strip	160	m.l	15,000	2,400,000
16	Exterior cement Plastering Removal	100	m2	6,000	600,000
17	Marble Stair tiles Installation	49	m.l	70,000	3,430,000
18	Anti Termites Fighting	Count	Count	500,000	500,000

Table 5.2: (Cont.) Bill of Quantities (BOQ) for Case 1

No.	Activity Details	Quantities	Unit	Price (IQD)	Cost (IQD)
19	Reinforced concrete Stair	4	m^3	450,000	1,800,000
20	Stone Cladding	70	m^2	85,000	5,950,000
21	Brick Cladding	70	m^2	115,000	8,050,000
22	Stone Cover Tiles	20	m.l	25,000	500,000
23	Composed Wood Interior Cladding	200	m^2	60,000	12,000,000
24	Aluminum Windows Installation	18	m^2	180,000	3,240,000
25	Interior Painting	175	m^2	7,000	1,225,000
26	Exterior Painting	125	m^2	7,000	875,000
27	Decorative Logo Foam	4 units	units	2,250,000	2,250,000
28	Exterior Aluminum Handrail	7	m.l	150,000	1,050,000
29	Armored Doors	2	Number	1,350,000	2,700,000
	Total				**146,720,000**

Source: Engineering Affair of Baghdad University

5.4.2 Case study 2

Table (5.3) shows the primary information for the project on the renovation of the Dental Industry Laboratory. Information about project costs is extracted from the civil work bill of quantities (BOQ), as shown in Table (5.4).

Table 5.3: Main Information for Case 2

Project Name:	**Renovation of building Dental Industry Laboratory**
Establishment Date of the building	1941
The Building Surface Area:	$240m^2$
Number of floors:	1
Number of times of rehabilitation since the establishment:	2
Type of Rehabilitation:	High-class renovation
The execution agency:	The engineering affairs of Baghdad University
The beneficiary agency:	College of Dentists at the University of Baghdad
Total Cost:	233,215,000 IQD
The building location:	Bab-Al Muaazam in Baghdad
The project time started on	15-6-2023
The project time ended on	1-2-2024

Source: Engineering Affair of Baghdad University

Table 5.4: Bill of Quantities (BOQ) for Case 2

No.	Activity Details	Quantities	Unit	Price (IQD)	Cost (IQD)
1	Mosaic Tiles Removal Work	350	m^2	5,000	1,750,000
2	Concrete Base Floor Removal	350	m^2	10,000	3,500,000
3	"Reinforced Concrete Ground Floor With BRC	350	m^2	35,000	12,250,000
4	Gypsum Plastering Removal Work	550	m^2	4,000	2,200,000
5	Marble Casting in The Floor	350	m^2	70,000	24,500,000
6	Ceramic Casting in The Wall and The Ground	400	m^2	40,000	16,000,000
7	Gypsum False Ceiling Tiles	350	m^2	23,000	8,050,000
8	Interior Painting	450	m^2	7,000	3,150,000
9	Aluminum Doors	14	m^2	200,000	2,800,000
10	Aluminum Windows	40	m^2	180,000	7,200,000
11	Armored Doors	13	m^2	420,000	5,460,000
12	Concrete Floor Tiles with All Water Insulation	300	m^2	40,000	12,000,000
13	Anti Termites Fighting	120	m.l	12,000	1,440,000
14	Hyrp Ceiling Removal	350	m^2	4,000	1,400,000
15	Scrap Waste Removal	whole quantity	whole quantity	350,000	350,000
16	Gypsum Plastering Wall	150	m^2	15,000	2,250,000
17	Exterior Cement Plastering	400	m^2	13,000	5,200,000
18	Laboratory Counter Renovation	90	m.l	100,000	9,000,000
	Total				**118,500,000**

Source: Engineering Affair of Baghdad University

5.4.3 Case study 3

Table (5.5) shows the primary information for the project on the renovation of Bathrooms in Science College. Information about project costs is obtained from the civil work bill of quantities (BOQ), as shown in Table (5.6).

Table 5.5: Main information for Case 3

Project Name:	**Renovation of Bathrooms in Science College**
Establishment Date of the building	1970
The Building Surface Area:	Consist of eight bathrooms have 18m^2 for each one
Number of floors:	1
Number of times of rehabilitation since the establishment:	3
Type of Rehabilitation:	High-class renovation
The execution agency:	The engineering affairs of Baghdad University
The beneficiary agency:	College of Science in the University of Baghdad
Total Cost:	72,042,000 IQD
The building location:	Jadriya in Baghdad
The project time started on	1-8-2023
The project time ended on	25-12-2023

Source: Engineering Affair of Baghdad University

Table 5.6: Bill of quantities (BOQ) for Case 3

No.	**Activity Details**	**Quantities**	**Unit**	**Price (IQD)**	**Cost (IQD)**
1	Ceramic wall removal and Partition	728	m^2	4,000	2,912,000
2	False Ceiling Removal	158	m^2	4,000	632,000
3	Ceramic Floor Removal	158	m^2	6,000	948,000
4	Concrete Ground Floor Removal	75	m^2	20,000	1,500,000
5	Putting a compact Subbase in the Ground	75	m^2	4,000	300,000
6	Reinforced concrete Ground Floor Casting with BRC	75	m^2	30,000	2,250,000
7	Cement Plastering on the Wall	728	m^2	15,000	10,920,000
8	Porcelain tiles on the Wall	728	m^2	45,000	32,760,000
9	Plastic false ceiling tiles	158	m^2	15,000	2,370,000
10	Mosaic Tiles	158	m^2	38,000	6,004,000
11	Metal Door Maintenance	8	number	100,000	800,000
12	PVC Doors Installation	25	m^2	200,000	5,000,000
13	Masonry Brickwork	100	m^2	25,000	2,500,000
14	Glass installation	14	ft^2	4,000	56,000
	Total				**68,952,000**

Source: Engineering Affair of Baghdad University

5.5 Percentage and Cost of Waste Materials

In order to calculate waste materials in renovation projects, one needs to apply equation (5.1) to the primary materials used in the construction works of the projects under the study. Tables (5.7), (5.8), and (5.9) summarize the waste percentage for case1, 2 and 3 respectively.

Table 5.7: Waste Percentage in Case 1

No.	Construction Material	Purchase Quantity	Consumed Quantity	Waste Quantity	Unit	Waste Percentage (%)	Price (IQD)	Cost (IQD)
1	Concrete Pouring For Slab and Beam	50.5	49	1.5	m^3	3.0%	75,000	112,500
2	Brick	47	45	2	m^3	4.3%	79,000	158,000
3	Subbase	110	100	10	m^3	9.1%	20,000	200,000
4	Sand	100	80	20	m^3	20.0%	20,000	400,000
5	Gravel	45.5	40	5.5	m^3	12.1%	25,000	137,500
6	Cement	29960	28000	1960	kg	6.5%	140	274,400
7	Gypsum Board	497	440	57	m^2	11.5%	5,000	285,000
8	Lime Plastering	339	290	49	m^2	14.5%	3,000	147,000
9	Concrete Tile for Roof	225.5	205	20.5	m^2	9.1%	9,000	184,500
10	Concrete Casting for Ground	47	46	1	m^3	2.1%	70,000	70,000
11	Rebar (Steel Reinforcement)	6375	6000	375	kg	5.9%	1,200	450,000
12	Timber	210	200	10	m^2	4.8%	1,000	10,000
13	Mosaic Tile (30×30) cm	230	195	35	m^2	15.2%	40,000	1,400,000
14	Marble Stripe (60×10) cm	183	160	23	m.l	12.6%	8,000	184,000
15	BRC	36	32	4	Pieces	11.1%	30,000	120,000
17	Cement Plastering	210	200	10	m^2	4.8%	13,000	70,000
18	Stone Cladding	75.6	70	5.6	m^2	7.4%	18,000	100,800
19	Brick Cladding	78.5	70	8.5	m^2	10.8%	35,000	297,500
20	Paints	327	300	27	m^2	8.3%	3,000	81,000
21	Plastic Pipes	39	36	3	m.l	7.7%	4,000	12,000
22	Steel Frame	34.4	31	3.4	m^2	9.9%	25,000	85,000
23	Bitumen	2.1	2	0.1	Barrel	4.8%	150,000	15,000
25	Composite Wood Interior Wall Cladding	213	200	13	m^2	6.1%	18,000	234,000
	Total							**5,088,200**

Table 5.8: Waste Percentage in Case 2

No.	Construction Material	Purchase Quantity	Consumed Quantity	Waste Quantity	Unit	Waste Percentage (%)	Price (IQD)	Cost (IQD)
1	Cement Plastering for Walls	472	400	72	m^2	15.3%	13,000	936,000
2	Lime Plastering Walls	180	150	30	m^2	20%	15,000	450,000
3	Ceramic Casting in the Wall and Ground	432	400	32	m^2	8%	40,000	1,280,000
4	Concrete Tiles	320	292	28	m^2	9%	9,000	252,000
5	Mosaic Tiles	385	350	35	m^2	9.1%	40,000	1,400,000
6	Gypsum False Ceiling Tiles	364	350	14	m^2	4%	22,000	308,000
7	Interior Painting	473	450	23	m^2	5%	7,000	161,000
8	Concrete Ground Casting with BRC	360	350	10	m^2	3%	35,000	350,000
9	Cement	15600	15000	600	kg	3.8%	140	84,000
10	Sand	10	8	2	m^3	20%	25,000	50,000
11	Gravel	30	29	1	m^3	3.30%	20,000	20,000
12	BRC	32	30	2	Piece	6.3%	30,000	60,000
	Total							**5,351,000**

Table 5.9: Waste Percentage in Case 3

No.	Construction Material	Purchase Quantity	Consumed Quantity	Waste Quantity	Unit	Waste Percentage (%)	Price (IQD)	Cost (IQD)
1	Percaline Tile for Wall	730	715	15	m^2	2%	45,000	675,000
2	Bricks	14.5	13.5	1	m^3	7.00%	79,000	79,000
3	Mosaic Tile	170	158	12	m^2	7.00%	38,000	456,000
4	False Ceiling	166	158	8	m^2	5%	15,000	120,000
5	Subbases	10	8	2	m^3	20%	30,000	60,000
6	Cement	14600	13800	800	kg	5.50%	140	112000
7	Sand	28	26	2	m^3	7.15%	25,000	50,000
8	Gravel	8	7.5	0.5	m^3	6.25%	20,000	10,000
9	Concrete	75.5	75	0.5	m^2	0.66%	200,000	100,000
10	BRC	7	6	1	Piece	14.30%	30,000	30,000
11	Cement Plastering	750	728	22	m^2	2.93%	15,000	330,000
	Total							**2022000**

5.6 Support Vector Machine

The support vector machine (SVM) is a graceful tool that could be applied to find answers to pattern recognition and regression problems. SVM has attracted the attention of a lot of researchers from the mathematical programming society and the neural network over the past few years since it is able to offer excellent generalization performance. SVMs have also proved to be of value to numerous real-world applications (Shevade et al., 2000). This chapter applies sequential minimal optimization (SMO) to find answers to the regression problems using SVM. The presented algorithm is an expansion of the SMO algorithm suggested by Platt, (1998) for the SVM classifier design. Ease of implementation and computational speed are remarkable features of the SMO algorithm. Consequently, one needs to review the most significant results of the study by using the SVM technique to realize the research objective: to find a more precise mathematical equation.

5.7 Input and Output SVM Model

The foundation of an adequate database is the prime precondition for the SVM application. Data on the completed projects was collected from the University of Baghdad and the General Directorate of School Buildings in the Ministry of Education within the research framework presented in this thesis. The data was related to the percentage and cost of waste for essential materials used in renovation projects. It is relevant to point out that all the completed projects were performed under the same climatic conditions in the same region since they seriously influence the time considered to accomplish a project taking into account the total cost of its operation. The established database comprises thirty completed projects concerned with the project renovations. Six input parameters are used to construct the SVM model. These inputs are:

- Cement waste percentage (CE%)
- Sand waste percentage (SA%)
- Gravel waste percentage (GR%)
- BRC waste percentage (BR%)
- Mosaic tile waste percentage (MT%)

- Cement Plastering waste percentage (CP%)
- Output parameter:
- Waste Cost (WC)

Appendix (D) presents actual data on the percentage and cost of waste for basic materials in renovation projects.

5.8 Data Preparation

The collected data were categorized into sets including: training, testing, and validation assigning (70%) data to the training set, (25%) to the validation set, and (5%) to the testing set for the model. Consequently, the records of a total number of (20) projects are utilized for training, (8) for validation, and (2) for testing the model. The input and output variables are pre-processed by being scaled to terminate their dimension confirming that all variables obtain identical interest all through training. Scaled values are measured for the output parameter by dividing (1000000) to reduce scaling between input and output parameters.

5.9 Developing the SVM model

Table (5.10) displays the best kernel function model, with the poly kernel selected in this model with the lowest root mean square error (0.1103) and the higher correlation (0.971). The kernel is considered the best alternative to be used in this model. SVM Model’s root means square error (0.7115) and means absolute error (0.5724) as shown in Table (5.11), where the best value parameter (C) (10) and the highest correlation coefficient (0.971) were used. Concerning the range of parameter C, the SVM model’s performance is comparatively unaltered (1 to 10). To clarify the impact of epsilon on the SVM model, Table (5.12) shows that 0.001 epsilon had the best correlation coefficient (0.971) and the lowest root mean square error (0.7115) with mean absolute error (0.5724); consequently, it was used in this model. The results demonstrated that the SVM Model’s diverse parameter epsilon has little impact on the performance of the model, mainly in the range of epsilon (0.001 to 0.01).

Table 5.10: Effects of the Kernel Function on SVM

Kernel Function	MAE	RMSE	Coefficient Correlation
Normalized poly kernel	0.6543	1.8349	0.894
Poly kernel	0.9571	1.1644	0.971
RBF kernel	0.999	1.215	0.960

Table 5.11: Effect of the Parameter C in SVM Model Performance

Parameter C	MAE	RMSE	Coefficient Correlation
1	0.9571	1.1644	0.96
2	0.9144	1.113	0.961
3	0.8716	1.0618	0.964
4	0.8289	1.0108	0.964
5	0.7861	0.96	0.953
6	0.7434	0.9095	0.942
7	0.7007	0.8593	0.97
8	0.6579	0.8095	0.964
9	0.6152	0.7603	0.971
10	0.5724	0.7115	0.96

Table 5.12: Effect of the Parameter Epsilon in SVM Model Performance

Epsilon	MAE	RMSE	Coefficient Correlation
0.001	0.5724	0.7115	0.971
0.002	0.6752	0.774	0.962
0.003	0.775	0.8501	0.945
0.004	0.785	0.7411	0.922
0.005	0.6852	0.7693	0.962
0.006	0.6742	0.7895	0.947
0.007	0.7413	0.8423	0.957
0.008	0.6821	0.7584	0.968
0.009	0.7521	0.7222	0.963
0.01	0.8647	0.748	0.97

5.10 Model Equation

The Weka program shows the optimal SVM model’s connection weights (Table 5.13).

Table 5.13: Weight Estimates for Model WC

Input	Weights	Bias
CE	3.276	5.7302
SA	-5.414	
GR	- 0.725	
BR	-1.115	
MT	-2.357	
CP	-6.831	

Based on Table 5.13, the cost of waste in renovation projects equation was developed using (SVM):

$$WC = 5.7302 + \{(3.276\ CE) - (0.5.414\ SA) - (0.725\ GR) - (1.115\ BR) - (02.357\ MT) - (6.831\ CP)\} \quad (5.2)$$

5.11 Validity and Verification of Model

For the model development, it is important to test the model accuracy and validity. The model is tested and evaluated on the basis of some test or validation data. The model's validation data should incorporate some representative samples drawn from the intended audience; they might be deleted when the model was created. Equation (5.2) calculates the cost of waste in renovation projects. Table (5.14) furnishes the experiment results. The residual values in this table demonstrate that the model is functioning properly.

Table 5.14: Comparison of Observed and Predicted Aspects for Model WC

No. Project	WC Observed	WC Predicted	Residual value
P23	5.280032	4.7166172	-0.563
P24	2.581481	3.3100174	0.729
P25	5.669454	4.8403766	-0.829
P26	2.948084	3.651759	0.704
P27	5.074816	4.557909	-0.517
P28	3.677187	4.0437339	0.367
P29	5.222090	4.6693446	-0.553
P30	3.476493	4.0378817	0.561

WC projections are mapped against real validation data, as indicated in Figure (5.1) which reveals that the SVM model can be generalized to cover this data type. The coefficient of determination (R^2) for this model was (0.972). Consequently, it is safe to state that this model's anticipations are compatible with the collected data.

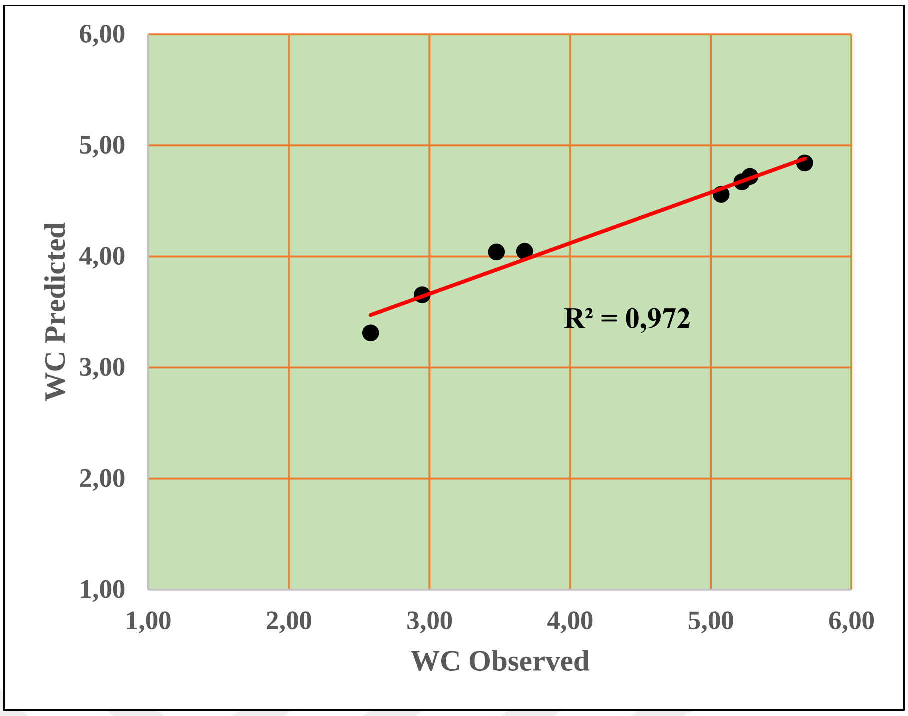

Figure 5.1: Observed vs. Predicted Cost of Waste in Renovation Projects Using SVM

5.12 Parameter Testing of the SVM Model

The correlation coefficient is applied to highlight the comparative correlation and the compatibility between the anticipated and observed data. The coefficient of determination displays how well the model outputs are consistent with the target value (Hasan et al., 2022). As measures of the average error, the Mean Absolute Percentage Error (MAPE) and the Root Mean Square Error (RMSE) are applied only to the independent test data. The results of these statistical parameters are introduced in Table (5.15) for model WC, where the MAPE and Average Accuracy Percentage (AA%) produced by the SVM model (WC) are found to be (15.534%) and (84.466%) correspondingly.

Table 5.15: Statistical Test Results for the SVM Model

Description	Statistical Parameters
MPE%	-4.0178
RMSE	0.6178
MAPE%	15.534
AA%	84.466
R	0.986
R^2	0.972

5.13 Summary

This chapter uses the support vector machine technique to build the cost of waste renovation projects. Data is obtained from (30) completed projects related to the renovation of projects. Six input parameters are used to build the SVM model. These inputs are Cement waste percentage (CE%), Sand waste percentage (SA%), Gravel waste percentage (GR%), BRC waste percentage (BR%), Mosaic tile waste percentage (MT%), Cement Plastering waste percentage (CP%) and Output parameter were Waste Cost (WC). The data was dividing into training, testing and validation sets. Equations are developed using Weka program. The validation statistical parameters (MPE, RMSE, MAPE, AA, and R^2) are applied to ensure the model's validity.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Overview

This chapter summarizes the key findings of the entire study; it provides an appropriate assessment of those findings, and highlights the conclusions drawn by the researcher. The chapter also lists specific benefits of the waste management plans and makes an effort to end further debate or discussion on the construction waste by making fresh suggestions for potential plans for future research. The conclusions, recommendations, and future study sections constitute the three main components of this chapter.

6.2 Conclusions

The following are the principal conclusions of this study:

1. It was discovered that the actual local construction material waste percentages exceeded the ceilings set by the Iraqi Ministry of Construction, Housing, Municipalities, and Public Works. The amount of waste discovered in local sites is significantly larger; a direct comparison with studies conducted in other countries cannot be made.
2. Local contracting firms do not appear to be concerned with material waste, and as a result, they do not implement a methodical control over the use of materials or a clearly defined policy for material management. Additionally, a wide range of waste is observed in the project itself for various building materials. For example, (Case 1) performed well in managing the waste of concrete but it performed poorly in terms of sand consumption. This suggests that businesses can limit the waste of certain materials but they cannot affect all the materials used in the project.
3. The waste percentages differ significantly from one site to the next. Additionally, different levels of waste for the same material may happen at similar sites. The results indicated that the waste percentage of materials at

those (30) sites was a variation in waste indices for the same material. For example, the instance of cement plastering wastage in (Case 16) was nearly (19 %) times higher than that in (Case 2). Similar proportions were also found for other materials at different sites.

4. A few preventive steps, primarily pertaining to managerial actions, can be considered to avoid the majority of the waste that is produced. Given that all of the projects and businesses under investigation were comparatively similar, the low waste percentages at some locations suggest that a sizable amount of material waste is preventable.
5. The questionnaire results found that (10) out of (14) factors related to the design, planning and documentation have the most significance. These factors were: design errors, lack of design information, non-implementation of green building practicing, mistake assessment of material quantities, errors in contract documents, poor design, carelessness during quantity analysis and measurement, inexperienced designer, ineffective planning and scheduling, and lack of waste management plan.
6. The questionnaire results found that (11) out of (18) factors related to material and procurement have the most significance. These factors were: wrong material storage, damage during transportation of materials, poor quality of materials, material quality problems, defective materials, damaged materials, packaging problems, inadequate material handling, carelessness of workers during handling materials, and materials not fitting to the specification.
7. The questionnaire results found that (12) out of (19) factors related to the construction method have the most significance. These factors were: frequent demolitions due to rework and change orders, wasteful use of material in construction, poor site management, poor supervision, lack of coordination among parties, inappropriate construction method, tools and equipment misuse/ malfunction, wrong team/subcontractor selection construction errors, on-site construction waste-sorting, utilizing a product that does not fit, and non-availability of equipment.

8. Also, from the questionnaire results, it can be inferred that the most dominant factors linked to the site situation were: poor site condition, unforeseen ground conditions, vandalism, and damages caused by third parties. However, the most influential factors related to the external factors were: waste due to the nature of building demolition or renovation works, absence of waste recycling programs, improper governmental role toward construction waste reduction, weak waste collection/transportation, administrative corruption, and lack of management legislation.
9. The developed SVM model has proved good accuracy in predicting the cost of waste in renovation construction projects in Iraq based on the results of (MAPE), the (AA) tests and in terms of (R2), the training data, where the (R2) for the SVM model was (0.972).
10. Through an analysis of waste management practices in building projects in developed nations, we are conducting this study to find out and understand the key factors that have contributed to their successful implementation. The goal is to extract valuable lessons from these success stories and explore their potential applicability in the context of waste management in Iraq. For example, the United States can decrease its liability for waste management by employing a separate subcontractor to handle garbage on its sites. This subcontractor would be responsible for predicting and quantifying the quantity of waste generated throughout the project (Dajadian and Koch, 2013). Hong Kong has made a significant contribution to the Construction Waste Management (CWM) policy by implementing the 3R techniques, which involve reducing, reusing, and recycling waste (Lu and Tam, 2013).

6.3 Recommendations

The research has come up with the following recommendations:

1. The local government should contribute to the reduction of waste by creating and enforcing stringent guidelines and laws that limit the amount of debris disposed of in an unrestrained manner, thereby reducing waste.
2. Improving the workers' attitude towards dealing with construction operations and materials by applying a control or reward system.

3. Enhancing the manner of transportation and unloading of materials to avoid wastage of materials that occurs during these processes.
4. Depending on accurate estimates for ordering the materials (sand, gravel, and gypsum) and providing suitable storage places for the materials (sand, gravel, cement and gypsum).
5. Relying on skilled labour workmanship in the implementation of finishing works.
6. Creating a clause in the contract demanding contractors to use construction waste management techniques while work is being performed.
7. Supplying a set of guidelines so that construction companies can employ workable solutions to purposefully and scientifically manage construction waste.
8. Hosting symposiums to promote the contractors' awareness of the use of contemporary, appropriate techniques to reduce waste of materials on construction sites.
9. Holding symposiums to educate those involved in the pre-construction phase on the problems of construction material waste, such as material suppliers, site planning engineers, and designers' procurement committees.

REFERENCES

Abdelhamid, M. S., 2014, Assessment of Different Construction and

Agyerum, K. (2012). Minimizing Materials Wastage at The Construction Stage of a Project through the implementation of lean construction. A Thesis submitted to the Department of Building Technology, Kwame Nkrumah University of Science and Technology, pp,11-12.

Ajayi, S. O., Oyedele, L. O., Bilal, M., Akinade, O. O., Alaka, H. A., Owolabi, H. A., & Kadiri, K. O. (2015). Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements. Resources, Conservation and Recycling, 102, 101-112.

Akhir, N. S. M., Rahman, I. A., Memon, A. H., & Nagapan, S. (2013). Factors of waste generation throughout construction life cycle. In *Malaysian Technical Universities Conference on Engineering and Technology (MUCET). Kuantan, Pahang*.

Al Ayem, A. H. A, 2014, Construction Waste Management System, A thesis Submitted to the Department of Building and Construction Engineering at the University of Technology in Partial Fulfillment of the Requirements for the degree of Master of Science in Building and Construction Engineering (Project Management).

Alajeeli, H. K., & Al Kaabi, S. A. (2016). A study of waste management reality in construction projects in Iraq. *Wasit Journal of Engineering Science*, *4*(1), 75-92.

Al-Ansari, N., Pusch, R., & Knutsson, S. (2013). Suggested landfill sites for hazardous waste in Iraq. Natural Science, 5(4), 463-477.

Alarcón, L. F., Diethelm, S. & Rojo, O. Collaborative implementation of lean planning systems in Chilean construction companies. Tenth Annual Conference of the International Group for Lean Construction (IGLC-10), August, Brazil, 2002. 1-11.

Al-Dhaheri, S. A. M. (2018). Evaluation of Overhead Cost in Iraqi Construction Industry. MSc Thesis, University of Baghdad, Department of Civil Engineering.

Al-Hajj, A., & Hamani, K. (2011). Material waste in the UAE construction industry: Main causes and minimization practices. *Architectural engineering and design management*, *7*(4), 221-235.

Almaliki, A. H. (2020). Construction solid waste management on the building site: A literature review. International Journal of Management (IJM), 11(7), 1099-1106.

Al-Moghany, S. S. (2006). Managing and minimizing construction waste in Gaza Strip. Managing and Minimizing Construction Waste in Gaza Strip.

Altuncu, D., & Kasapseçkin, M. A. (2011). Management and recycling of constructional solid waste in Turkey. Procedia Engineering, 21, 1072-1077.

Arslan, H., Coşgun, N., & Salgin, B. (2012). Construction and demolition waste management in Turkey. Waste Management-An Integrated Vision, Edited by Luis Fernando Marmolejo Rebellon, 313-332.

Arslan, H., Coşgun, N., & Salgin, B. (2012). Construction and demolition waste management in Turkey. *Waste Management-An Integrated Vision, Edited by Luis Fernando Marmolejo Rebellon*, 313-332.

ASTM C 172 -90, Standard Practice for Sampling Freshly Mixed Concrete, Annual Book of ASTM, International Standard Worldwide, (2009).

Atabi, K. L., Reig-Cerdá, L., & Colomer-Mendoza, F. J. (2023). Categorization and Quantification of Construction Waste of Commercial Buildings in Iraq. In E3S Web of Conferences (Vol. 427, p. 02006). EDP Sciences.

Bagdi, N., Aggarwal, V., & Sherwal, N. (2013). Management of construction waste in India: a case of green technology. Glob. J. Manag. Bus. Stud, 3(4), 361-364.

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2007). Implementation of waste management and minimisation in the construction industry of Malaysia. Resources, Conservation and Recycling, 51(1), 190-202.

Bekr, G. A. (2014). Study of the causes and magnitude of wastage of materials on construction sites in Jordan. *Journal of Construction Engineering*, *2014*, 1-6.

Ben Nakhi, A., & Alhumoud, J. M. (2019). Effects of recycled aggregate on concrete mix and exposure to chloride. Advances in Materials Science and Engineering, 2019.

Berger, V. W., & Zhou, Y. (2014). Kolmogorov–smirnov test: Overview. Wiley statsref: Statistics reference online.

Bølviken, T., & Koskela, L. (2016). Why hasn't waste reduction conquered construction?.

Brunner, P. H., & Rechberger, H. (2014). Waste to energy--key element for sustainable waste management. Waste Management (New York, NY), 37, 3-12.

Buah, W. K., Cunliffe, A. M., & Williams, P. T. (2007). Characterization of Products from the Pyrolysis of Municipal Solid Waste. Process Safety & Environmental Protection, 85(5), 450-457. https://doi.org/10.1205/psep07024

Caldas, C. H., Menches, C. L., Reyes, P. M., Navarro, L., & Vargas, D. M. (2015). Materials management practices in the construction industry. Practice Periodical on Structural Design and Construction, 20(3), 04014039. challenges, University of Kassel, Germany.

Chandler, A. J., Eighmy, T. T., Hjelmar, O., Kosson, D. S., Sawell, S. E., Vehlow, J., ... & Hartlén, J. (1997). Municipal solid waste incinerator **residues. Elsevier.**

Chen, C. W., Randolph, P. H., & Liou, T. S. *(2005). Using CUSUM control schemes for monitoring quality levels in compound Poisson production environment: The geometric Poisson process. Quality Engineering, 17(2), 207-217.*

Chinda, T. (2016). Investigation of factors affecting a construction waste recycling decision. Civil Engineering and Environmental Systems, 33(3), 214-226.construction and demolition (C&D) waste, state - of-the- art and future

Construction and Demolition Waste Practices and Their Economic Impact (1999) Report.

Dajadian, S. A., & Koch, D. C. (2014). Waste management models and their applications on construction sites. International journal of construction engineering and management, 3(3), 91-98.

Demirbas, A. (2011). Waste management, waste resource facilities and waste conversion processes. Energy Conversion & Management, 52(2), 1280-1287. https://doi.org/10.1016/j.enconman.2010.09.025

Demolitionwaste Management Approaches, Project Management Institute, Department of Defense**,** "Selection of methods for reduction, reuse, and recycling demolition waste," United State of America, December 2002.

Department of Environmental Affairs (DFA), "Natonal Waste Management Strategy," Department of Environmental Affairs, Pretoria, 2012.

Ding, Z., Yi, G., Tam, V. W. & Huang, T. 2016. A system dynamics-based environmental performance simulation of construction waste reduction management in China. Waste 830 Management, 51, 130-141.

Dixit, M. K., Fernández-Solís, J. L., Lavy, S., & Culp, C. H. (2010). Identification of parameters for embodied energy measurement: A literature review. Energy and buildings, 42(8), 1238-1247.

Dixon, N., & Jones, D. R. V. (2005). Engineering properties of municipal solid waste. Geotextiles &Geomembranes, 23(3), 205-233. https://doi.org/10.1016/j.geotexmem.2004.11.002.

Donyavi, S., & Flanagan, R. (2009, September). The impact of effective material management on construction site performance for small and medium sized construction enterprises. In Proceedings of the 25th Annual ARCOM Conference, Nottingham, UK (pp. 11-20).

Duran, X., Lenihan, H., & O'regan, B. (2006). A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland. Resources, conservation and recycling, 46(3), 302-320.

Duran, X., Lenihan, H., & O'regan, B. (2006). A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland. *Resources, conservation and recycling*, *46*(3), 302-320.

Ekanayake, L., & Ofori, G. (2000). Construction material waste source evaluation, proceedings: Strategies for a sustainable built environment. Strategies for a Sustainable Built Environment, Pretoria, South Afrika.

Ekanayake, L., and Ofori, G. (2000). "Construction material waste source evaluation". Proceedings of the 2nd South African Conference on Sustainable Development in the Built Environment: Strategies for a Sustainable Built Environment. 23-25 August, Pretoria, South Africa.

Elgizawy, S. M., El-Haggar, S. M., & Nassar, K. (2016). Zero Construction and Demolition Waste Approach. International Journal of Research in IT, Management and Engineering, 6(9), 8.

Environmental Protection agency EPA. (2009). "Estimating 2003 Building-Related Construction and Demolition Materials Amounts." EPA 530-R-09-002, <http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/cd-meas.pdf>(Dec. 7, 2010)

EPA, 2009 U.S Environmental Protection Agency-(EPA), 2009, Recover Your

Esin, T., & Cosgun, N. (2005, July). Ecological analysis of reusability and recyclability of modified building materials and components at use phase of residential buildings in Istanbul. In Istanbul: UIA Istanbul XXII World Congress of Architecture-Cities: Grand Bazaar of Architectures.

Eurostat (2020). Waste Statistics. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Waste_generation_excluding_major_mineral_waste (accessed 24 November 2020).

Eurostat. Statistics Explained; Europe Direct Contact Centre: Brussels, Belgium, 2016.

*Fa***diya, O. O., Georgakis, P., & Chinyio, E. (2014).** *Quantitative analysis of the sources of construction waste. Journal of Construction Engineering, 2014, 9.*

Fatta, D., Papadopoulos, A., Avramikos, E., Sgourou, E., Moustakas, K., Kourmoussis, F., ... & Loizidou, M. (2003). Generation and management of construction and demolition waste in Greece—an existing challenge. Resources, Conservation and Recycling, 40(1), 81-91.

Firmansyah, B. A., Veronika, A., & Trigunarsyah, B. *(2006). Risk Analysis in feasibility study of building construction project: case study-PT. Perusahaan gas negara Indonesia. In The Tenth East Asia-Pacific Conference on Structural Engineering and Construction (pp. 145-150).*

Foo, L. C., Rahman, I. A., Asmi, A., Nagapan, S., & Khalid, K. I. (2013). Classification and quantification of construction waste at housing project site. International Journal of Zero Waste Generation, 1(1), 1-4.

Formoso, C. T., Isatto, E. L., & Hirota, E. H. (1999, July). Method for waste control in the building industry. In Proceedings IGLC (Vol. 7, p. 325). Berkeley^ eCA CA: University of California.

Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material waste in building industry: main causes and prevention. Journal of construction engineering and management, 128(4), 316-325.

Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material waste in building industry: main causes and prevention. Journal of construction engineering and management, 128(4), 316-325.

Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material waste in building industry: main causes and prevention. Journal of construction engineering and management, 128(4), 316-325.

Ganiron Jr, T. U. (2013). An investigation of moisture performance of sawdust and banana peels ply board as non-veneer panel. International Journal of u-and e-Service, Science and Technology, 6(3), 43-54.

Ganiron Jr, T. U. (2013). Sustainable Management of Waste Coconut Shells as Aggregates in Concrete Mixture. Journal of Engineering Science & Technology Review, 6(5).

Ganiron Jr, T. U. (2013). Use of recycled glass bottles as fine aggregates in concrete mixture. International Journal of Advanced Science and Technology, 61, 17-28.

Ganiron Jr, T. U. (2015). Exploring the emerging impact of metro rail transit (MRT-3) in Metro Manila. International Journal of Advanced Science and Technology, 74, 11-24.

Garbarino, E., & Blengini, G. A. (2013). The economics of construction and demolition waste (C&DW) management facilities. In Handbook of Recycled Concrete and Demolition Waste (pp. 108-138). Woodhead Publishing.

Gaurav, A., Varma, A. A., & Khan, A. U. (2019). Overview of Construction and Demolition waste and challenges identified to tackle the issue. International Research Journal of Engineering and Technology (IRJET), 6(9), 1548-1552.

Gautam, V. (2009). Solid Waste Management in GCC: Challenges & Opportunities. *South Asia & Middle East, Environmental and Building Technologies Practice*, *54*, 22-28.

George, D., & Mallery, P. (2003). SPSS for Windows step by step: answers to selected exercises. A simple guide and reference, Vol.63, No.1, pp.1461-1470.

Ghafourian, K., Ismail, S., & Mohamed, Z. (2018). Construction and demolition waste: Its origins and causes. *Advanced Science Letters*, *24*(6), 4132-4137.

Green Middle-east, Solid Waste – Solid Growth Prospects", 2017. [Online]. Available: http://www.greenmiddleeast.com/sw/default.ht ml. [Accessed: 07- Apr- 2017].

Harvard Green Campus,2005, Construction waste management, (Accessed 12 January 2005), Available from: http://216.239.59.104/search?q=cache:KDlWMburqfUJ:www.greencampus.harvard.edu/hpbs/documents/CDWaste.pdf+%22construction+waste%22+and+definitions&hl=en

Hasan, M. F., & Mohammed, M. S. (2018). Time overrun model for construction projects in Iraq by using fuzzy logic. Int J Civil Eng Technol, 9(11), 2593-607.

Hasan, M. F., & Mohammed, S. R. (2022). Factors affecting time and cost trade-off in multiple construction projects. Archives of Civil Engineering, 68(2).

Hasan, M. F., Hammody, O., & Albayati, K. S. (2022). Estimate final cost of roads using support vector machine. Archives of Civil Engineering, 68(4).

Hiete, M., 2013, Waste management plants and technology for recycling

Higgins, T. E. (1995). Pollution prevention handbook. CRC Press.

Hittini, B. Y., & Shibeika, A. I. (2019). Construction waste management in UAE: An exploratory study. *WIT transactions on ecology and the environment*, *238*, 679-686.

Hong Kong Polytechnic, 1993, Reduction of construction waste: final report, The Hong Kong Construction Association Ltd., Hong Kong

Horvath, A. (1999). Construction for sustainable development–A research and educational agenda. Berkeley, California, USA. Retrieved December, 21, 2014.

Hossain, M. S., Santhanam, A., Nik Norulaini, N. A., & Omar, A. K. M. 2011. Clinical Solid Waste Management Practices and its Impact on Human Health and Environment - A Review. *International Journal of Integrated Waste Management, Science and Technology, 754-766.*

Housing and Building National Research Center, Egypt. https://doi.org/10.1051/matecconf/201816202034

Hwang, B. G., & Bao Yeo, Z. (2011). Perception on benefits of construction waste management in the Singapore construction industry. Engineering, Construction and Architectural Management, 18(4), 394-406.

Hwang, B. G., & Bao Yeo, Z. (2011). Perception on benefits of construction waste management in the Singapore construction industry. Engineering, Construction and Architectural Management, 18(4), 394-406.

ICF Incorporated. Construction and Demolition Waste Landfills. Available online: https: Incorporated Contract No. 68-W3-0008, May 18, 1995

Jaillon, L., Poon, C.-S. & Chiang, Y. 2009. Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste management, 29, 309-914 320.

Jeruto, K. P., & Mutwol, L. *(2014). An Investigation of the Effect of Interdepartmental Coordination between Material Related Departments on Organizational Performance: A Survey of Eldoret Water and Sanitation Company Limited (Eldowas) Kenya. International Journal of Science and Research (IJSR), 3(5), 1308-1313.*

Jin, R., Yuan, H., & Chen, Q. (2019). Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018. *Resources, Conservation and Recycling*, *140*, 175-188.

Kaliannan, S., Nagapan, S., Sohu, S., & Jhatial, A. A. (2018). Determining root cause of construction waste generation: A global context. *Civil Engineering Journal*, *4*(11), 2539-2547.

Kanimozhi, G., & Latha, P. (2014). Material management in construction industry. Indian Journal of Applied Research, 4(4), 1-3.

Kanimozhi, G., & Latha, P. (2014). Material management in construction industry. Indian Journal of Applied Research, 4(4), 1-3.

Kareem, K. R., & Pandey, R. K. (2013). Study of management and control of waste construction materials in civil construction project. International Journal of Engineering and Advanced Technology (IJEAT), 2(3), 345-50.

Kartam, N., Al-Mutairi, N., Al-Ghusain, I., & Al-Humoud, J. (2004). Environmental management of construction and demolition waste in Kuwait. Waste management, 24(10), 1049-1059.

Kartam, N., Al-Mutairi, N., Al-Ghusain, I., & Al-Humoud, J. (2004). Environmental management of construction and demolition waste in Kuwait. Waste management, 24(10), 1049-1059.

Kasim, N. (2008). Improving materials management on construction projects (Doctoral dissertation, Loughborough University).

Kasim, N. (2011). ICT implementation for materials management in construction projects: case studies. Journal of Construction Engineering and Project Management, 1(1), 31-36.

Katz, A., & Baum, H. (2011). A novel methodology to estimate the evolution of construction waste in construction sites. Waste management, 31(2), 353-358.

Katz, A.; Baum, H. A novel methodology to estimate the evolution of construction waste in construction sites. Waste Manag. 2011, 31, 353–358. [CrossRef] [PubMed] http://www.iaeme.com/IJM/index.asp

Khaled, Z. S., Alshathr, B. S., & Hadi, A. H. (2014). Investigation of material waste incurred in the construction projects at Karbala province IN IRAQ. *International Journal of Civil Engineering and Technology (IJCIET)*, *5*(10), 58-73.

Khaled, Z. S., Alshathr, B. S., & Hadi, A. H. (2015). Development of Construction Material Waste Management System. Journal of Engineering and Technology, 33(7).

Khaleel, T. A. M., & Al-Zubaidy, A. M. (2017). Quantification of construction waste generated in construction projects of Iraq. *Global Journal of Engineering Science and Researches*, *4*(12), 1-3.

Khaleel, T., & Al-Zubaidy, A. (2018). Major factors contributing to the construction waste generation in building projects of Iraq. In *MATEC web of conferences* (Vol. 162, p. 02034). EDP Sciences.

Khaleel, T., & Al-Zubaidy, A. (2018). Major factors contributing to the construction waste generation in building projects of Iraq. In *MATEC web of conferences* (Vol. 162, p. 02034). EDP Sciences.

Koshy, R., & Apte, E. M. (2012). Waste minimization of construction materials on a bridge site (Cement and reinforcement steel)-A regression and correlation analysis. International Journal of Engineering and Innovative Technology, 2(1), 6-14.

Koskela, L. (1992). Application of the new production philosophy to construction (Vol. 72, p. 39). Stanford: Stanford university.

Kourmpanis, B., Papadopoulos, A., Moustakas, K., Stylianou, M., Haralambous, K. J., & Loizidou, M. (2008). Preliminary study for the management of construction and demolition waste. Waste Management & Research, 26(3), 267-275.

Kulatunga, U., Amaratunga, R. D. G., Haigh, R., Rameezdeen, R. D., & Rameezdeen, D. (1987). Sources of construction material wastage in Sri Lankan sites..

Lau, H. H., Whyte, A., & Law, P. (2008). Composition and characteristics of construction waste generated by residential housing project.

Letcher, T., & Vallero, D. A. (Eds.). (2011). Waste: A Handbook for Management. Academic Press.

Ling, Y. Y., & Leo, K. C. (2000). Reusing timber formwork: importance of workmen's efficiency and attitude. Building and Environment, 35(2), 135-143.

Liu, J., Shahi, A., Haas, C. T., Goodrum, P., & Caldas, C. H. (2014). Validation methodologies and their impact in construction productivity research. Journal of Construction Engineering and Management, 140(10), 04014046.

Liu, Z., Osmani, M., Demian, P., Baldwin, A., 2015, A BIM-Aided Construction Waste Minimization Framework, Automation in Construction, Vol. 59, No. 1, PP. 1–23.

Llatas, C., & Osmani, M. (2016). Development and validation of a building design waste reduction model. Waste management, 56, 318-336.

Lu, W. & Yuan, H. 2013. Investigating waste reduction potential in the upstream processes of offshore prefabrication construction. Renewable and Sustainable Energy Reviews, 28, 804-811.

Lu, W., & Yuan, H. (2011). A framework for understanding waste management studies in construction. Waste management, 31(6), 1252-1260.

Lu, W., Yuan, H., 2011, A Framework for Understanding Waste Management Studies in Construction, Waste Management, Vol. 31, No. 1, PP. 1252–1260

Luangcharoenrat, C., Intrachooto, S., Peansupap, V., & Sutthinarakorn, W. (2019). Factors influencing construction waste generation in building construction: Thailand's perspective. *Sustainability*, *11*(13), 3638.

M T. Phani, S V. Mathew and S. Roy, Material Management in Construction – A Case Study, International Journal of Research in Engineering and Technology, 2013, pp. 400-403. Materials at Land Revitalization Projects, October.

Maad, M., & Sadeq, N. (2019). Reducing Waste of Construction Materials in Civil Engineering Projects In Iraq. *ZANCO Journal of Pure and Applied Sciences*, *31*(s3), 257-263.

Maytham KO, Ismail AR, Intidhar JI and Sasitharan N. Construction Waste and its Distribution in Iraq. Indian Journal of Science and Technology. 2019 May; 12(17).

Meghani, M. D., Vyas, C. M., Bhavsar, J. J., & Hingu, R. J. (2011, May). A Study on basic material waste in building industry: Main causes and prevention. In National conference on recent trends in engineering and technology (pp. 13-14).

Meyer, K. S. and Walsh, J. J. (1996) Regs among the Ruins. Wastes 360 recycling summit, September 1996, 20-23.retrieved from http://waste360.com/mag/waste_regs_among_ruins accessed December 2014.

Mills, T. H., Showalter, E., & Jarman, D. (1999). A cost-effective waste management plan. Cost Engineering, 41(3), 35.

Ministry of Planning - Central Statistics organization (CSO) The Republic of Iraq, Ministry of Planning, Central Bureau of Statistics, Department of Environment Statistics, Iraq Environmental Statistics [Internet]. Available from: www.cosit.gov.iq/.

Nagapan, S., Ismail, A. R., & Ade, A. (2012). Construction waste and related issues in Malaysia. Diges FKAAS, 1, 15-20. (Clean Management Environmental Group, Inc.).

Nagapan, S., Rahman, I. A., & Asmi, A. (2012, April). Construction waste management: Malaysian perspective. In International Conference on Civil and Environmental Engineering Sustainability (IConCEES), Malaysia (Vol. 2, pp. 299-309).

Nagapan, S., Rahman, I. A., Asmi, A., Memon, A. H., & Latif, I. (2012, December). Issues on construction waste: The need for sustainable waste management. In 2012 IEEE colloquium on Humanities, Science and Engineering (CHUSER) (pp. 325-330). IEEE.

Nagapan, S., Rahman, I. A., Asmi, A., Memon, A. H., & Zin, R. M. (2012). Identifying Causes of Construction Waste a Case of Central Region of Peninsula Malaysia. International Journal of Integrated Engineering, 4(2).

Nettleton, D. (2014). Commercial data mining: processing, analysis and modeling for predictive analytics projects. Elsevier.

Ngoc, U. N., & Schnitzer, H. (2009). Sustainable solutions for solid waste management in Southeast Asian countries. Waste Management, 29(6), 1982-1995. https://doi.org/10.1016/j.wasman.2008.08.031

Njoroge. G. Kimani. (2012). Environmental Pollution and Impacts on Public Health: environmental pollution and impacts on public health. Retrieved from http://www.unep.org/urban_environment/PDFs/DandoraWasteDump-ReportSummary.pdf.

Nor, R., Raja, H., Noor, M., Ruslan, A., Ridzuan, M., Endut, I. R., Noordin, B., et al. (2013). The Quantification of Local Construction Waste for the Current Construction Waste Management Practices: A Case Study in Klang Valley. *Business Engineering and Industrial Applications Colloquium (BEIAC), 2013 IEEE, 183-188.*

Osmani, M., Glass, J., & Price, A. D. (2008). Architects' perspectives on construction waste reduction by design. Waste management, 28(7), 1147-1158.

Papadopoulos, A.; Fatta, D.; Avramikos, E.; Sgourou, E.; Moustakas, K.; Kourmoussis,F.; Mentzis, A.; Loizidou, M.; (2003) Generation and Management of Construction andemolition Waste in Greece - An existing challenge, Resources Conservation and Recycling journal, Vol 40, Issue 1, Pages 81–91

Patel, K. V., & Vyas, C. M. (2011, May). Construction materials management on project sites. In National Conference on Recent Trends in Engineering & Technology (pp. 1-5).

Peng, C. L., Scorpio, D. E., & Kibert, C. J. (1997). Strategies for successful construction and demolition waste recycling operations. Construction Management & Economics, 15(1), 49-58.

Peng, C. L., Scorpio, D. E., & Kibert, C. J. (1997). Strategies for successful construction and demolition waste recycling operations. Construction Management & Economics, 15(1), 49-58.

Phani, M., & Methew, S. V. (2019). Material management in construction-a case study.

Pickin, J., Randell, P., Trinh, J., & Grant, B. (2018). National waste report 2018. Department of the Environment and Energy, Melbourne, Victoria, Australia.

Pickin, J., Randell, P., Trinh, J., Grant, B. J. D. O. T. E. & Energy, M., Victoria, Australia 2018. National waste report 2018.

Platt, J. (1998). Sequential minimal optimization: A fast algorithm for training support vector machines. Microsoft Research.

Poon, C. S., Ann, T. W., & Ng, L. H. (2001). On-site sorting of construction and demolition waste in Hong Kong. Resources, conservation and recycling, 32(2), 157-172.

Poon, C. S., Yu, A. T., Wong, A., & Yip, R. (2013). Quantifying the impact of construction waste charging scheme on construction waste management in Hong Kong. Journal of construction engineering and management, 139(5), 466-479.

Practice, (2009), Source: www.frost.com

Rahman, I. A., Memon, A. H., Karim, A. A., & Tarmizi, A. (2013). Significant factors causing cost overruns in large construction projects in Malaysia. Journal of Applied Sciences, 13(2), 286-293. Resources, Reduce, Reuse, and Recycle Construction and Demolition

Rogoff M.J, Williams J.F (1994) Approaches to Implementing Solid Waste Recycling Facilities. Noyes, Park Ridge, NJ.

Rosado LP, Vitale P, Penteado CS and Arena U (2019) Life cycle assessment of construction and demolition waste management in a large area of São Paulo State, Brazil. Waste Management 85: 477-489.

Royal institute of Chartered Surveyors (RICS). A guide to life cycle costing for construction. London: Surveyors Publications; 1986.

Saadi N, Ismail Z, and Alias Z 2016. A review of construction waste management and initiatives in Malaysia. *Journal of Sustainability Science and Management 11 101-114* [24] Tam V W Y, Tam C M, Zeng S X, and Ng W C Y 2007. Towards adoption of prefabrication in construction *International Journal of Build. Science and Its Applications 42 3642-3654.*

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). Interaction of lean and building information modeling in construction. Journal of construction engineering and management, 136(9), 968-980.

Sepa. Guidance on Using the European Waste Catalogue (EWC) to Code Waste. Available online:www.sepa.org.uk/media/162682/sepa-waste-**thesaurus.pdf (accessed on 19 July 2017).**

Seydel, A., Wilson, O. D., & Skitmore, R. M. (2002). Financial evaluation of waste management methods: a case study. Journal of Construction Research, 3(01), 167-179.

Shanmugapriya, S., & Subramanian, K. (2013). Investigation of significant factors influencing time and cost overruns in Indian construction projects. International Journal of Emerging Technology and Advanced Engineering, 3(10), 734-740.

Shen, L. Y., Tam, V. W., Tam, C. M., & Drew, D. (2004). Mapping approach for examining waste management on construction sites. Journal of construction engineering and management, 130(4), 472-481.

Shevade, S. K., Keerthi, S. S., Bhattacharyya, C., & Murthy, K. R. K. (2000). Improvements to the SMO algorithm for SVM regression. IEEE transactions on neural networks, 11(5), 1188-1193.

Sjostrom, C. (1998). Sustainable construction and performance based standards and codes. Centre of Built Environment. KTH Royal Institute of Technology, Stockholm.

Skoyles, E.R. (1976a) Waste of Materials and the Contractors Quantity Surveyor. The Quantity Surveyor. 209-211.

Skoyles, E.R. (1976b) A Misuse of Resources. Building Research and Practice. 232-243

Skoyles, E.R. (1976c) Materials Waste - A misuse of resources. Building Research and Practice. BRE Current Paper CP 67/76, pp. 232- 243.

Symonds Group Ltd. (1999 ARGUS), COWI Consulting Engineers and Planners and PRC Bouwcentrum. "Construction and Demolition Management

Practices and their Economic Impacts”. Report to DGXI European Commission.

Symonds, A. R. G. U. S. Cowi and PRC Bouwcentrum (1999). Construction and demolition waste management practices, and the economic impact.

Tam, V. W. (2013). Improving waste management plans in construction projects. In Handbook of Recycled Concrete and Demolition Waste (pp. 9-24). Woodhead Publishing.

Tam, V. W., Soomro, M., & Evangelista, A. C. J. (2018). A review of recycled aggregate in concrete applications (2000–2017). *Construction and Building materials*, *172*, 272-292.

Tchobanoglous, G., Theisen, H., & Vigil, S. A. (1993). Integrated solid waste management: engineering principles and management issues. (No Title).

Tchobanoglous, G., Theisen, H., and Eliassen, R.(1977) Solid wastes: Engineering principles and management issues McGraw-Hill Book Co., New York, N.Y.

Teo, M. M. M., & Loosemore, M. (2001). A theory of waste behaviour in the construction industry. Construction management and economics, 19(7), 741-751.

US Environmental Protection Agency (2019). Facts and Figures about Materials, Waste and Recycling. Available at: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/construction-and-demolition-debris-material (accessed 9 December 2020).

USEPA,U.S Environmental Protection Agency (1995). Construction and demolition waste landfills Draft Report. Office of solid waste. ICF

Usha, D. K., Kanimozhi, G., & Panneerselvam, A. *(2014). Isolation and screening of pectin lyase producing fungi from soil sample of dead organic matters. World Journal of Pharmaceutical Research, 3(10), 563-569.*

V. Gautam, South Asia & Middle East, Environmental & Building Technologies

Vergara, S. E., & Tchobanoglous, G. (2012). Municipal solid waste and the environment: a global perspective. Annual Review of Environment and Resources, 37, 277-309.

Wang, J., Li, Z., & Tam, V. W. (2014). Critical factors in effective construction waste minimization at the design stage: a Shenzhen case study, China. Resources, Conservation and Recycling, 82, 1-7.

Wang, R., & Li, S. (2011, March). Talking about the production and disposing of construction waste from the view of sustainable development. In 2011 Asia-Pacific Power and Energy Engineering Conference (pp. 1-4). IEEE.

Wang, R., & Li, S. (2011, March). Talking about the production and disposing of construction waste from the view of sustainable development. In 2011 Asia-Pacific Power and Energy Engineering Conference (pp. 1-4). IEEE.

Warren, J. D., Chong, W. K., & Kim, C. (2007). Recycling construction and demolition waste for construction in Kansas City metropolitan area, Kansas and Missouri. Transportation research record, 2011(1), 193-200.

White, P. R., Franke, M., Hindle, P., & Doig, A. (1995). Integrated Solid Waste Management: A Life Cycle Inventory. Global Environmental Change-Human and Policy Dimensions, 5(2), 157.

Williams, P. T. (2005). Waste Treatment and Disposal. London, New York: John Wiley & Sons. https://doi.org/10.1002/0470012668

Wilson, D. C. (2007). Development drivers for waste management. Waste Management & Research, 25(3), 198-207.

Winkler, G., 2010, Recycling Construction & Demolition Waste, A LEEDBased Toolkit, a green source book, McGraw-Hill Companies, Inc

Won, J., Cheng, J. C., & Lee, G. (2016). Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea. Waste Management, 49, 170-180.

Zheng, L., Wu, H., Zhang, H., Duan, H., Wang, J., Jiang, W., ... & Song, Q. (2017). Characterizing the generation and flows of construction and demolition waste in China. Construction and Building Materials, 136, 405-413.

APPENDICES

Appendix (A): Questionnaire Form

This questionnaire is a part of MSc thesis conducted by Mohammed Abdullah Mohammed H. Shubbar, entitled "Waste Management for Renovation Construction Projects in Iraqi".

Kindly fill in the questionnaire form considering your experience and viewpoint. The information given will be dealt with in confidence and used for the scientific research only. Thank you for your prompt response.

This questionnaire comprises two parts:

Part (1): General Information

Part (2): Factors affecting waste for renovation construction projects

Note: the ranking system is as follows:

Ranking				
1	**2**	**3**	**4**	**5**
Very Low important	Low important	Medium important	High important	Very high important

Part (1): General Information:

1. Governorate:

2. Profession:

Contractor or Representative	Owner or Representative	Supervising Engineer	Consultant

3. Work Sector:

Public	Private

4. Education Degree:

PhD	MSc	BSc	Others

5. Years of Experience:

(< 6)	(6 – 10)	(11 – 15)	(> 15)

Part (II): Factors affecting waste for renovation construction projects

Please tick (√) in the right impact field of the factors influencing waste for renovation construction projects. Your general explanations, notes, and opinions at the end of the questionnaire will be highly appreciated.

No.	Factor	Level of Importance				
		1	2	3	4	5
	Design, Planning & Documentation	**very low**	**low**	**medium**	**high**	**very high**
1	Frequent design changes					
2	Design errors					
3	Lack of design information					
4	Complicated design					
5	The conflict between design and other contract documents					
6	Document problems					
7	Not implementing green building practicing					
8	Mistake assessment of material quantities					
9	Errors in contract documents					
10	Poor design					
11	Carelessness during quantity analysis and measurement					
12	Inexperienced designer					
13	Ineffective planning and scheduling					
14	Lack of waste management plan					
	Material & Procurement	**very low**	**low**	**medium**	**high**	**very high**
15	Wrong material storage					
16	Damage of materials during transportation					
17	Poor quality of materials					
18	Delay during delivery of materials					
19	Ordering or supplier errors of materials					
20	Material quality problems					
21	Defective materials					
22	Damage to materials					
23	Packaging problem					
24	Lack of possibilities of ordering small quantities					
25	Shortage in materials					
26	Inadequate material handling					
27	Stored material far away from the construction site					

28	Carelessness of worker during materials handling					
29	Material transportation problem					
30	Material inventory not well documented.					
31	Materials supplied unbound					
32	Materials not fit to the specification					
	Construction Method	**very low**	**low**	**medium**	**high**	**very high**
33	Frequent demolitions due to rework and change orders					
34	Wasteful use of material on construction					
35	Poor site management					
36	Crews interfering					
37	Poor supervision					
38	Lack of coordination among parties					
39	Inappropriate construction method					
40	Tools and equipment misuse/malfunction					
41	Wrong team / subcontractor selection					
42	Construction errors					
43	On-site construction waste -sorting					
44	The magnitude and complexity of the construction					
45	Utilizing a product that does not fit					
46	Problems during fabrication					
47	Scarcity of equipment					
48	Equipment failure during construction					
49	Old used equipment					
50	Non-availability of equipment					
51	Extended project duration					
	Workers	**very low**	**low**	**medium**	**high**	**very high**
52	Workers not aware of construction waste					
53	Damage caused by workers					
54	Poor workmanship					
55	Worker mistakes					
56	Lack of experience					
57	Bad attitude of workers					
58	Shortage of skilled worker					
59	Excessive overtime for worker					

	Site Situation	very low	low	medium	high	very high
60	Poor site conditions					
61	Unforeseen ground conditions					
62	Congestion at the site					
63	Difficulties accessing construction					
64	Vandalism					
65	Damages caused by third parties					
66	Accident at site					
	External Factors	**very low**	**low**	**medium**	**high**	**very high**
67	Effect of weather					
68	Stealing of materials					
69	Waste due to the nature of building, demolition or renovation works					
70	Absence of waste recycling programs					
71	Lightening problem at site					
72	Improper governmental role toward construction waste reduction					
73	Weak waste collection/transportation					
74	Delay due to official holidays					
75	Administrative corruption					
76	Lack of management legislations					

Appendix (B): Questionnaire Results

No.	Factor	Level of Importance					RII	Mean	St. Dev	Rank
		1	2	3	4	5				
	Design, Planning & Documentation	very low	low	medium	high	very high				
1	Frequent design changes	1	5	23	14	9	0.696	3.481	0.960	51
2	Design errors	1	2	8	25	16	0.804	4.019	0.896	11
3	Lack of design information	0	3	16	24	9	0.750	3.750	0.813	36
4	Complicated design	2	10	17	16	7	0.662	3.308	1.058	66
5	The conflict between design and other contract documents	2	9	14	17	10	0.692	3.462	1.111	52
6	Document problems	4	6	20	16	6	0.654	3.269	1.069	70
7	Not implementing green building practicing	0	9	20	10	13	0.704	3.519	1.057	50
8	Mistake assessment of material quantities	0	0	8	27	17	0.835	4.173	0.678	3
9	Errors in contract documents	1	5	16	20	10	0.727	3.635	0.971	41
10	Poor design	1	7	6	21	17	0.777	3.885	1.078	22
11	Carelessness during quantity analysis and measurement	0	1	4	33	14	0.831	4.154	0.638	5
12	Inexperienced designer	2	2	10	20	18	0.792	3.962	1.028	16
13	Ineffective planning and scheduling	1	1	16	23	11	0.762	3.808	0.864	31
14	Lack of waste management plan	0	3	8	18	23	0.835	4.173	0.901	3
	Material & Procurement	very low	low	medium	high	very high	RII	Mean	St. Dev	Rank
15	Wrong material storage		2	10	28	12	0.792	3.962	0.766	16
16	Damage during transportation of materials	0	7	13	25	7	0.723	3.615	0.889	42
17	Poor quality of materials	0	4	13	21	14	0.773	3.865	0.908	24
18	Delay during delivery of materials	2	13	23	12	2	0.596	2.981	0.896	75
19	Ordering or supplier errors of materials	2	11	19	16	4	0.635	3.173	0.985	72
20	Material quality problems	0	8	14	21	9	0.719	3.596	0.955	45
21	Defective materials	0	5	12	23	12	0.762	3.808	0.908	31
22	Materials Damage	1	3	7	23	18	0.808	4.038	0.949	10
23	Packaging problem	1	4	13	23	11	0.750	3.750	0.947	36
24	Lack of possibilities of ordering small quantities	3	4	19	18	8	0.692	3.462	1.038	52
25	Shortage in materials	5	11	21	11	4	0.592	2.962	1.066	76
26	Inadequate material handling	0	6	17	21	8	0.719	3.596	0.891	45
27	Stored material far away from the construction site	4	12	18	12	6	0.615	3.077	1.118	74
28	Carelessness of worker during handling materials	2	4	14	21	11	0.735	3.673	1.024	40
29	Material transportation problems	2	11	14	21	4	0.654	3.269	1.012	70

30	Material inventory not well documented.	1	10	20	15	6	0.658	3.288	0.977	68
31	Materials supplied unbound	1	6	23	17	5	0.673	3.365	0.886	62
32	Materials not fit to the specification	3	2	9	26	12	0.762	3.808	1.030	31
	Construction Method	**very low**	**low**	**medium**	**high**	**very high**	**RII**	**Mean**	**St. Dev**	**Rank**
33	Frequent demolitions due to rework and change orders	0	1	8	25	18	0.831	4.154	0.751	5
34	Wasteful use of material on construction	1	3	10	27	11	0.769	3.846	0.894	28
35	Poor site management	0	1	5	24	22	0.858	4.288	0.723	1
36	Crews interfering	3	5	17	19	8	0.692	3.462	1.056	52
37	Poor supervision	0	1	9	23	19	0.831	4.154	0.777	5
38	Lack of coordination among parties	0	0	11	29	12	0.804	4.019	0.671	11
39	Inappropriate construction method	0	1	10	29	12	0.800	4.000	0.714	14
40	Tools and equipment misuse/ malfunction	0	2	12	29	9	0.773	3.865	0.742	24
41	Wrong team / subcontractor selection	0	4	7	25	16	0.804	4.019	0.874	11
42	Construction errors	0	0	6	33	13	0.827	4.135	0.595	8
43	On-site construction waste -sorting	1	5	20	15	11	0.715	3.577	0.997	47
44	The magnitude and complexity of the construction	2	4	21	21	4	0.681	3.404	0.891	60
45	Utilizing a product that does not fit	0	0	14	31	7	0.773	3.865	0.627	24
46	Problem during fabrication	1	4	25	19	3	0.673	3.365	0.793	62
47	Scarcity of equipment	0	7	21	18	6	0.688	3.442	0.873	58
48	Equipment failure during construction	0	10	17	18	7	0.685	3.423	0.957	59
49	Old used equipment	1	4	24	20	3	0.677	3.385	0.796	61
50	Non-availability of equipment	0	3	17	23	9	0.746	3.731	0.819	38
51	Extended project duration	3	9	16	18	6	0.658	3.288	1.073	68
	Workers	**very low**	**low**	**medium**	**high**	**very high**	**RII**	**Mean**	**St. Dev**	**Rank**
52	Workers not aware of construction waste	0	3	13	23	13	0.777	3.885	0.855	22
53	Damage caused by workers	1	4	15	22	10	0.738	3.692	0.940	39
54	Poor workmanship	0	4	14	22	12	0.762	3.808	0.886	31
55	Worker mistakes	0	5	12	23	12	0.762	3.808	0.908	31
56	Lack of experience	0	3	10	26	13	0.788	3.942	0.826	19
57	Bad attitude of workers	0	3	11	24	14	0.788	3.942	0.850	19
58	Shortage of skilled worker	1	1	10	29	11	0.785	3.923	0.813	21
59	Excessive overtime for worker	2	5	18	16	11	0.712	3.558	1.056	48

	Site Situation	very low	low	medium	high	very high	RII	Mean	St. Dev	Rank
60	Poor site conditions	0	3	20	23	6	0.723	3.615	0.771	42
61	Unforeseen ground conditions	0	6	19	20	7	0.708	3.538	0.874	49
62	Congestion at the site	2	4	20	20	6	0.692	3.462	0.939	52
63	Difficulties accessing construction	2	9	13	25	3	0.669	3.346	0.968	64
64	Vandalism	1	6	5	27	13	0.773	3.865	0.991	24
65	Damage caused by third parties	0	5	18	21	8	0.723	3.615	0.867	42
66	Accident at site	1	8	17	18	8	0.692	3.462	0.999	52
	External Factors	**very low**	**low**	**medium**	**high**	**very high**	**RII**	**Mean**	**St. Dev**	**Rank**
67	Effect of weather	0	12	18	16	6	0.662	3.308	0.961	66
68	Stealing of materials	1	9	17	15	10	0.692	3.462	1.056	52
69	Waste due to the nature of building demolition or renovation works	0	6	14	14	18	0.769	3.846	1.036	28
70	Absence of waste recycling programs	1	4	10	16	21	0.800	4.000	1.048	14
71	Lightening problem at site	0	11	21	12	8	0.665	3.327	0.985	65
72	Improper governmental role toward construction waste reduction	1	3	11	19	18	0.792	3.962	0.989	16
73	Weak waste collection/transportation	0	3	16	20	13	0.765	3.827	0.879	30
74	Delay due to official holidays	3	9	23	10	7	0.635	3.173	1.061	72
75	Administrative corruption	1	2	9	14	26	0.838	4.192	0.991	2
76	Lack of management legislation	2	1	8	18	23	0.827	4.135	1.010	8

Appendix (C): Permissible Limits of Construction Material Wastage

Material	Percentage (%)	Material	Percentage (%)
Concrete	4-5	Precast Units	3-5
Sand	6-9	Concrete Tiles	5-10
Gravel	6-9	Masonry	5-8
Non-packed Cement	6-7	Marble	5-7
Subbase	15-20	Angle	3-4
Brick	10-20	Galvanized Steel (Ducts)	3-4
Reinforcement Steel	4-6	Binding Wires	3-5
Forms	5-7	Lime & Gypsum	10-15
Insulation Layers	5-8	B.R.C	5-7
Ceramic Tiles	4-7	Mosaic Tiles	10-15
Thermo-Stone	10-18	Casting In Situ	5-10
Electrical Materials			
Wires	4-5	Electrical Pipe	4-5
Wall Socket Box	1	Plug Socket	1-2
Plumbing Materials			
Galvanized Pipe	4-6	Fittings	4-5
Taps	1-2	Washbasins	1

Appendix (D): Data of (30) Projects

No. Project	Cement (CE)	Sand (SA)	Gravel (GR)	BRC (BR)	Mosaic Tile (MT)	Cement Plastering (CP)	Waste Cost IQD (WC)
P1	0.0700	0.2500	0.1400	0.1100	0.1250	0.0475	2,401,900
P2	0.0400	0.2000	0.0330	0.0660	0.1000	0.1800	2,550,000
P3	0.0550	0.0715	0.0625	0.1430	0.0700	0.0293	6,476,000
P4	0.0723	0.1375	0.0466	0.0592	0.1029	0.1937	2,937,653
P5	0.1168	0.0549	0.0606	0.1085	0.1067	0.195	3,595,325
P6	0.0938	0.0747	0.0616	0.109	0.1146	0.2216	2,746,132
P7	0.1313	0.0546	0.0573	0.0757	0.0883	0.1398	4,884,641
P8	0.1251	0.0788	0.0501	0.0496	0.0774	0.1088	5,360,421
P9	0.1423	0.0395	0.0555	0.063	0.0735	0.0796	6,264,792
P10	0.1338	0.0469	0.0602	0.093	0.0944	0.1484	4,696,841
P11	0.1374	0.0397	0.0662	0.1198	0.1026	0.1813	4,257,025
P12	0.0754	0.111	0.0544	0.0914	0.1143	0.2221	2,687,359
P13	0.1078	0.0898	0.0496	0.0558	0.0866	0.1338	4,444,040
P14	0.1242	0.0656	0.0542	0.0668	0.087	0.1371	4,823,490
P15	0.1266	0.0696	0.0506	0.0551	0.0796	0.1084	5,365,756
P16	0.0832	0.0885	0.0607	0.1068	0.1171	0.2286	2,597,604
P17	0.1287	0.0539	0.0611	0.0897	0.0959	0.1722	4,223,824
P18	0.1372	0.0519	0.0498	0.0551	0.0756	0.0833	5,989,339
P19	0.1416	0.0347	0.066	0.1177	0.0959	0.1427	5,168,015
P20	0.1201	0.062	0.0594	0.0851	0.0981	0.1773	3,828,495
P21	0.0925	0.1172	0.0475	0.0496	0.0871	0.1497	4,022,497
P22	0.1329	0.0451	0.0628	0.1088	0.1003	0.1747	4,371,379
P23	0.1252	0.0708	0.0505	0.0554	0.0803	0.1102	5,280,032
P24	0.0709	0.1321	0.0531	0.0788	0.1139	0.2258	2,581,481
P25	0.1421	0.0371	0.0642	0.0936	0.0838	0.118	5,669,454
P26	0.0836	0.1057	0.0541	0.0774	0.1061	0.2056	2,948,084
P27	0.117	0.0763	0.0493	0.0596	0.0846	0.1231	5,074,816
P28	0.1087	0.0734	0.0569	0.0833	0.1	0.1867	3,677,187
P29	0.1236	0.0737	0.0505	0.0551	0.0806	0.114	5,222,090
P30	0.1078	0.0726	0.0575	0.0842	0.1013	0.1871	3,476,493

RESUME

Mohammed Abdullah Mohammed H. SHUBBAR

EDUCATION:

- Graduated from University of Baghdad / College of Engineering / civil engineering department. In 2000
- Master: MCE From Istanbul Gedik University - Engineering Management

EXPERIENCES:

- **2001- 2006:** Site engineer overseeing the construction of the University building, supervising and monitoring project progress.
- **2006-2008:** Site engineer of luxury villas in "Rabwa project" in Egypt, as well as responsible of the finishing works.
- **2008-2022:** Project manager of the building in a variety places in Baghdad University, taking responsibility of preparing tenders, cost estimation, turn key of the building
- **2022-present:** consultant of tenders, prices, specifications of construction method and materials.

SKILLS:

- Office programming skills like word program, excel, power point
- Well organized
- Leadership
- Communication skill and work under pressure
- Primavera program
- Auto Cad
- Bim skill