Materials Procurement Conceptual Framework for Minimising Waste in the Egyptian Construction Industry

by

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ABSTRACT

The construction industry plays a crucial role in achieving the social and economic development of countries worldwide. However, construction projects are associated with materials waste, referred to as construction and demolition waste (CDW), generated at different stages of the construction process. In Egypt's particular case, the CDW problem has become a significant challenge, and the need to find sustainable solutions is overwhelming. Unfortunately, the Egyptian construction sector lacks a conceptual framework of materials procurement practices compounded by surrounding external factors of legislation, awareness measures, and culture & behaviour measures for CDW reduction (CDWR). Towards addressing the CDW problem, this study introduces a theoretical framework which was tested through a survey questionnaire distributed among a representative sample of Egyptian construction firms' total population. Through the survey questionnaire, this study was able to: (1) determine the current applicability and effectiveness levels of different CDWR factors' components in the Egyptian construction sector; (2) examine the effect of different practices, legislation, culture & behaviour measures, and awareness measures on CDWR; and (3) develop and introduce a conceptual framework consisting of the CDWR factors along with their components. The overall contributions of this study include (1) presenting CDWR factors along with their components needed for overcoming the CDW problem in Egypt via a conceptual framework; (2) demonstrating the importance of waste-efficient materials procurement practices, a rarely explored research area, in tackling CDW problem; (3) highlighting shortcomings in Egyptian CDWM legislation and the GPRS and proposing recommendations for their improvement; (4) encouraging more research on CDWM through waste-efficient materials procurement practices; and (5) promoting the application of the structural equation modelling (SEM) technique in the construction research domain in developing and introducing conceptual frameworks. Generally, a materials procurement conceptual framework to reduce CDW in the Egyptian construction sector is developed with recommendations and policy guidance for overcoming CDW problem in Egypt. While acknowledging issues of CDW can be country specific, it is expected that given the structural similarity of African construction industry, findings from this study can be of benefits to other African countries other than Egypt contending CDWR issues.

DECLARATION

"*And mankind have not been given of knowledge except a little*" (**Quran 17:85**)
"*My Lord, increase me in knowledge*" (**Quran 20:114**)

This thesis is an original work by the author, **Ahmed Osama Elsayed Daoud**, to the best of his knowledge, and it has not been submitted to any university or learning institute for the award of any academic degree. The research project, on which this dissertation is based, received research ethics approval from the Built Environment and Architecture Ethics Panel at **London South Bank University (LSBU)**, Project Name "Materials Procurement Conceptual Framework for Minimising Waste in the Egyptian Construction Industry", application ID: ETH1819-0067, approved on 16th of May 2019.

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- Daoud, A. O., Othman, A. A. E., Robinson, H. and Bayyati, A. (2020b) An Investigation into Solid Waste Problem in the Egyptian Construction Industry: A mini-review, *Waste Management & Research*, 38 (4), pp. 371–382. DOI:10.1177/0734242X20901568.
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The author,

Ahmed Osama Elsayed Daoud.

DEDICATION

This thesis is dedicated with love and sincerity to the four base corners of the challenge and achievement pyramid built through this PhD journey. These four years' journey would not have been completed without their tremendous and continuous support. I am dedicating this thesis to:

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GLOSSARY OF TERMS AND ABBREVIATIONS

Terms or Abbreviation	**Meaning**
AVE	Average variance extracted
AW	Awareness
BRE	Building Research Establishment
BREEAM	Building Research Establishment Environmental Assessment Method
BUA	Built-up area
R^2	Coefficient of determination value
CI	Composite index
CFA	Confirmatory factor analysis
CD	Construction and demolition
CDW	Construction and demolition waste
CDWG	Construction and demolition waste generation
CDWM	Construction and demolition waste management
CDWR	Construction and demolition waste reduction
CB-SEM	covariance-based structural equation modelling
CB	Culture & behaviour
DV	Dependent variable
f^2	Effect size
EMDM	Effective materials delivery management
EGGBC	Egypt Green Building Council
EES	Egyptian Engineers Syndicate
EFCBC	Egyptian Federation for Construction and Building Contractors
EMoE	Egyptian Ministry of Environment
EE	Energy Efficiency
EFA	Exploratory factor analysis
GCPM	General contractor procurement model
GoF	Goodness of fit
GC	Greater Cairo

Terms or Abbreviation	**Meaning**
GBPR	Green building practices representing green materials procurement
GBRSs	Green building rating systems
GBs	Green buildings
GPRS	Green Pyramid Rating System
HTMT	Hetrotrait-Monotrait ratio
IDVs	Independent variables
IEQ	Indoor Environmental Quality
IN	Innovation and Added Value
IPMA	Importance-Performance Map Analysis
km^2	Kilometres squared
LEED	Leadership in Energy and Environmental Design
LG	Legislation
LWPM	Low waste purchase management
MP	Management Protocols
M&R	Materials and Resources
MPCF	Materials procurement conceptual framework
MPMR	Materials procurement measures
MPMO	Materials procurement models
MENA	Middle East and North Africa
MW	Municipal waste
OPM	Owner procurement model
PFs	Palm fronds
PLS-SEM	Partial least squares method of structural equation modelling
β	Path coefficients
Q^2	Predictive relevance
RII	Relative importance index
R&D	Research and development
α	Significance level
SW	Solid waste

Terms or Abbreviation	**Meaning**
SWG	Solid waste generation
SWM	Solid waste management
SCPM	Specialty contractor procurement model
SPSS	Statistical Package for the Social Science
SEM	Structural equation modelling
SLWC	Suppliers' low waste commitment
SDGs	Sustainable development goals
SDS	Sustainable development strategy
SS	Sustainable Sites
TBL	Triple bottom line (i.e., social, economic, and environmental)
USGBC	U.S. Green Building Council
VIF	Variance inflation factor
WEBOQ	Waste-efficient bill of quantity
WM	Waste management
WE	Water efficiency
WR	Waste reduction

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CHAPTER 1: INTRODUCTION

1.1 Background

The construction industry is one of the most significant industries contributing to countries' social and economic development. It provides the community with high living standards by providing society with socio-economic projects and infrastructure facilities such as roads, hospitals, and schools. Unfortunately, construction and demolition waste (CDW) is a growing challenge that the whole globe faces (Hussin *et al.*, 2013). According to the latest report published by the World Bank in 2012, it is expected that the amount of solid waste (SW) generated worldwide will increase from 1.3 billion tonnes to 2.2 billion tonnes by 2025 (Hoornweg and Bhada-Tata, 2012). CDW constitutes about half of the annual generated SW worldwide (Yılmaz and Bakış, 2015; Redling, 2018). A report published by Transparency Market Research in 2017 claims that there will be a tremendous increase in the volume of the CDW generated over the coming years (Redling, 2018). Unfortunately, the dumping of CDW is a common global trend that negatively affects society and the environment (Slowey, 2018).

In 2015, a pile of CDW led to a landslide in Shenzhen, China, that killed more than 70 individuals and led to the displacement of 900 individuals. This slide also led to the destruction of many buildings, including houses and factories. Some analysts blamed the Chinese government for its reluctance to enforce laws and regulations regarding CDW disposal. In Minnesota, USA, CDW is negatively affecting the groundwater. Since SW regulations in Minnesota do not regulate disposed CDW, the Minnesota Pollution Control Agency (MPCA) is working hard to introduce stricter standards to landfills that lack barriers between deposited materials and groundwater (Slowey, 2018).

The main barriers to the proper management of CDW are the absence of standardisation and waste-efficient practices, lack of adequate policies and education, deficiencies in awareness, low-profit margins, and lack of technical and financial resources (Redling, 2018; Slowey, 2018). In the Middle East and North Africa (MENA) region, including Egypt, dumping is the dominant practice of dealing with CDW. This action has led to the escalation of the SW problem resulting in severe negative impacts on society, environment, and economy, which are the triple bottom line (TBL) of sustainability (United Nations Environment Programme (UNEP), 2009; El-Sherbiny *et al.*, 2011; Abdelhamid, 2014; Zafar, 2016; Nassour *et al.*, 2016; Aden, 2017). Accordingly, proper actions and strict measures need to be taken to alleviate the MENA region's CDW problem.

On the 14th of March 2015, the Egyptian government introduced the "Sustainable Development Strategy (SDS) – Egypt's Vision 2030" during the International Economic Conference in Sharm El Sheikh (State Information Service (SIS), 2015). Egypt's vision 2030 aims to improve Egyptian society's current economic, environmental, and social dimensions without depriving the next generations of enjoying their rights for a better life. Accordingly, Egypt's vision 2030 clearly stated the following:

"By 2030, Egypt will be a country with a competitive, balanced, and diversified economy, depending on knowledge and creativity, and based on justice, social integration, and participation, with a balanced and varied ecosystem, a country that uses the genius of the place and the citizens in order to achieve sustainable development and improve the quality of life for all. Moreover, the government looks forward to lifting Egypt, through this strategy, to a position among the top 30 countries in the world, in terms of economic development indicators, fighting corruption, human development, market competitiveness, and the quality of life." (Ministry of Planning, Monitoring, and Administrative Reform (MPMAR), 2016) (p.3).

One of the main pillars of Egypt's vision 2030 is "urban development", which is categorised under the environmental dimension. This is consistent with United Nations sustainable development goals (SDGs) in general, particularly goal no. (11) related to sustainable cities and communities through balanced development and management of land and resources. The non-existence of new areas, which can accommodate the continuous population growth in Egypt, has led to degradation of urban environment quality due to environmental pollution, traffic congestion, reduction in green spaces, and expansion of random construction on agricultural land (MPMAR, 2016). Based on that, the government is exerting great efforts towards decentralization by planning and constructing new communities and infrastructure projects all over Egypt, as shown in Figure 1.1. Examples of construction projects include the National Project for the Development of Sinai, National Projects for Roads, National Project for the Development of Upper Egypt, Establishment of New Cities (e.g., New Administrative Capital, East Port Said City, The New Ismailia City, The New Alamein City, and an Integrated City at Al-Galala), The Golden Triangle Project, and The National Project for Social Housing (Invest-gate, 2016). However, construction projects are associated with significant adverse environmental impact relating to the CDW generated at different stages. It is noted that at least 10% of materials cost is wasted in developing countries' construction projects (Hussin *et al.*, 2013).

Figure 1.1 *Construction of the New Administrative Capital*

Source: *(Prokeraia, 2018)*

In recent decades, research on construction and demolition waste management (CDWM) has explored different waste minimisation approaches during design and construction stages, but limited attention has been given to minimising waste during the materials procurement stage (Ajayi *et al.*, 2017a). Materials procurement is defined by Zeb *et al.* (2015) (p.171) as "purchasing of materials needed for execution of a project. Procurement is organising the purchasing and scheduling delivery of materials". Materials procurement is responsible for obtaining construction materials in terms of the right quantity, quality, time, cost, and place (Kamalaeaswari and Vedhajanani, 2015). The inefficient materials procurement process is one of the leading causes of CDW generation (CDWG), and it affects the total project cost (Formoso *et al.*, 2002; Ajayi *et al.*, 2017b). Ajayi *et al.* (2017a) further indicated that materials procurement affects 50% of the total project cost. Additionally, Fadiya *et al.* (2014) stated that inefficient materials procurement contributes up to 11.2% of total CDWG. Materials procurement, a critical interface between design and construction stages, plays a vital role in CDW reduction (CDWR) and saving project costs. Waste-efficient materials procurement practices include waste-efficient materials procurement measures, waste-efficient materials procurement models, and green materials procurement approach included in the green building rating systems (GBRSs) (Daoud *et al.*, 2018a; Daoud *et al.*, 2018b). Unfortunately, as aforementioned, these practices are rarely applied in the Egyptian construction sector due to the predominance of “dumping” as the sole solution of dealing with CDW (Abdelhamid, 2014; Azmy and El Gohary, 2017).

Moreover, Daoud *et al.* (2020b) investigated several studies about SW and CDW problems in the MENA region and Egypt. In addition to waste-efficient materials procurement practices, it has been reported that there are other external surrounding factors that affect CDWR. These factors are legislation, awareness, and culture & behaviour. These factors play an essential role in reducing CDWG and boosting CDWR through a series of defined measures that need to be applied through a framework for CDWR. Unfortunately, the Egyptian construction sector lacks waste-efficient legislation, appropriate culture & behaviour, and high awareness of the CDW problem, which results in an escalation of the CDW problem.

1.2 Problem Statement

The Egyptian construction industry lacks a framework for minimising CDW through waste-efficient materials procurement practices compounded by surrounding factors such as legislation, awareness measures, and culture & behaviour measures. As discussed in the background section, the literature is rich with different strategies for minimising CDW during the design and construction stages. However, limited research explored waste-efficient materials procurement practices as a practical and effective approach for CDWR despite the impact of materials procurement on project cost, project schedule, and CDWG. Besides, the CDWM research in Egypt lacks studies investigating the relationship between legislation, awareness measures, and culture & behaviour measures on the one hand and CDWR on the other hand. However, before a framework consisting of these abovementioned factors can be developed, there are five significant problems or knowledge gaps that must be addressed and investigated.

First, the Egyptian GBRS, named green pyramid rating system (GPRS), suffers from some limitations and shortcomings generally and its Materials and Resources (M&R) category specifically which need to be further improved to overcome environmental challenges in general and CDW challenge in specific. **Second**, CDWM research in Egypt lacks comparative studies quantifying CDW in terms of generation rates and costs among different construction projects (i.e., industrial, residential, commercial, and infrastructure). **Third**, CDWM research in Egypt lacks studies investigating the relationship between the abovementioned CDWR factors (i.e., practices, legislation, awareness, culture & behaviour) and CDWG. **Fourth**, CDWM research in Egypt lacks studies that explore the applicability and effectiveness of the abovementioned CDWR factors' components in the Egyptian construction sector. **Finally**, there is a lack of studies evaluating the effect of the abovementioned CDWR factors, either separately or in a multiple system (i.e., existing and acting together at the same time), on minimising CDW in the Egyptian construction sector to develop and introduce a conceptual framework needed for CDWR.

1.3 Research Questions

Therefore, the research will address the knowledge gaps and emerging issues using a different approach focusing on waste-efficient materials procurement practices to develop a conceptual framework that will incorporate elements to address the deficiencies in practices, legislation, culture & behaviour, and awareness. To address the CDW problem, the critical research questions to be investigated are as follows:

1) How could CDW be minimised in the Egyptian construction industry through waste-efficient materials procurement practices, legislation, culture & behaviour, and awareness?
2) How to overcome the deficiencies and shortcomings in the GPRS to improve its ability to minimise environmental hazards caused by CDWG?
3) How much is CDW generated among different types of construction projects in the Egyptian construction sector?
4) How do the CDWG rates change based on the different adopted waste-efficient materials procurement practices, legislation, measures of culture & behaviour, and awareness measures in the Egyptian construction sector?
5) What are the current applicability and effectiveness levels of waste-efficient materials procurement practices, legislation, measures of culture & behaviour, and awareness measures in the Egyptian construction sector needed for CDWR?
6) Are these waste-efficient materials procurement practices, legislation, culture & behaviour measures, and awareness measures effective towards solving the CDW problem in the Egyptian construction sector?

1.4 Research Aims and Objectives

The research's main aim is to develop a materials procurement conceptual framework (MPCF) to minimise CDW in the Egyptian construction industry in support of Egypt’s vision 2030. This framework will provide recommendations for improvement of practices, legislation, culture and behaviour, and awareness. Besides, this research aims to propose improvements to the GPRS to enhance its ability to minimise the CDW problem by addressing its current limitations and shortcomings.

In order to achieve the abovementioned aim, this study has to accomplish seven main objectives as follows:

1) To identify reasons behind CDWG and factors affecting CDWR by reviewing extant literature on different knowledge areas related to SW and CDW problems, focusing on the Egyptian context.
2) To propose and validate improvements to the GPRS generally and its M&R category specifically to overcome the environmental challenges in Egypt in general and the CDW problem in specific.
3) To quantify CDW among different project types in terms of generation rates and costs in the Egyptian construction sector.
4) To investigate the relationship between CDWG and different adopted CDWR factors in the Egyptian construction sector.
5) To investigate the current applicability and effectiveness levels of different CDWR factors’ components in the Egyptian construction sector.
6) To evaluate the effect of different waste-efficient materials procurement practices, legislation, culture & behaviour measures, and awareness measures on CDWR in the Egyptian construction sector.
7) To develop and validate the MPCF to reduce CDW in the Egyptian construction sector to support Egypt’s vision 2030.

1.5 Research Significance

This research will contribute to addressing the knowledge gaps identified in the literature review and make an original contribution to the existing body of knowledge to benefit industry practitioners, government policymakers, and academics as follows:

- **At the industry level**, this research will provide a conceptual framework that can guide the practitioners and professional organisations in the Egyptian construction industry on adopting key measures for (1) waste-efficient materials procurement practices; (2) CDWM legislation; (3) appropriate culture & behaviour; and (4) promoted awareness. Moreover, the importance of waste-efficient materials procurement practices, based on the TBL of sustainability, will be demonstrated.
- **At the governmental level**, this research will assist the Government of Egypt by providing recommendations and policy guidance to improve current practices, legislation, culture & behaviour, and awareness necessary to address the CDW problem. Moreover, it will provide a conceptual framework that acts as a roadmap to help the Egyptian government improve Egypt's current situation regarding CDWR.
- **At the academic level**, the research will provide a better understanding of how waste-efficient materials procurement practices can contribute to reducing CDW. It will also encourage more research on waste-efficient materials procurement practices as a research area for managing CDW rather than the predominant focus only on design and construction strategies for managing CDW. Furthermore, it will promote the application of the structural equation modelling (SEM) technique, a multivariate statistical technique, in the construction research domain to (1) test and validate theoretical frameworks; and (2) develop and introduce conceptual frameworks. It is worth mentioning that limited research in the construction domain applied this technique in statistical modelling.

1.6 Brief of Research Methodology

The study will employ a pluralistic methodological approach, as shown in Figure 1.2, in which the research will depend on qualitative and quantitative methods using different approaches for data collection such as grounded theory, case study, and survey. This approach helps develop a conceptual framework that integrates waste-efficient materials procurement practices, legislation, culture & behaviour measures, and awareness measures to minimise CDWG in the Egyptian construction industry. This framework shall act as a roadmap for solving the escalating problem of CDWG and tackling its challenges in Egypt. Moreover, this approach introduces a proposal of improvements to the current version of the Egyptian GPRS. The grounded theory will be used to achieve **objectives 1 & 2**. The case study will be used to achieve **objectives 3 & 4**. Finally, the survey will be used to achieve **objectives 5, 6, and 7**.

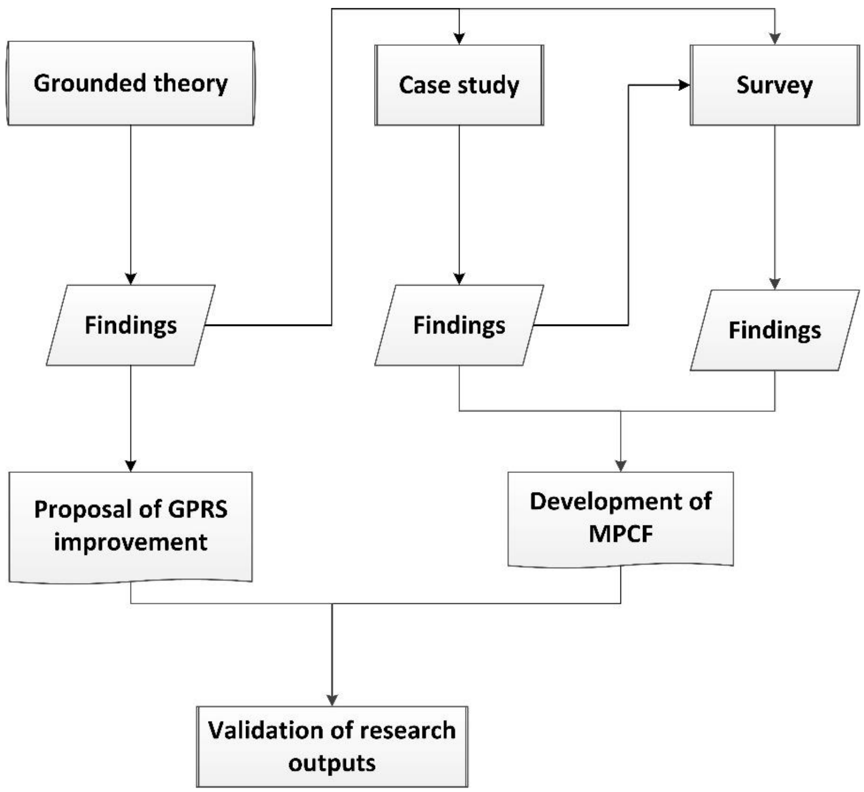

Figure 1.2 *Overview of the adopted research methodology*

1.7 Thesis Structure

Following this introductory chapter which presents the research scope and benefits, the rest of this thesis is structured as follows:

- **Chapter 2** investigates and explores different knowledge areas as follows: (1) SW problem on the regional and local levels and its main causes; (2) different approaches of CDWM in the construction industry; (3) current situation of CDW problem in the Egyptian construction industry; (4) main reasons behind CDW problem in the Egyptian construction industry; (5) main approaches for solving SW problem in general and CDW problem in Egypt in specific including practices, legislation, culture & behaviour, and awareness; (6) different types of waste-efficient materials procurement practices needed for CDWR; and (7) emerging issues and critical gaps based on the explored studies in the literature. Based on the explored literature, a theoretical framework is built along with the corresponding hypotheses at the end of chapter 2. This theoretical framework will be tested and validated during this study. Based on rigorous statistical testing, the theoretical framework shall be developed into a conceptual framework to act as a roadmap for CDWR.

- **Chapter 3** investigates the research philosophy, including the rationale behind the adopted research approach and the adopted research methods and strategies. Moreover, it sheds light on the design of primary data collection tools (i.e., interview and survey questionnaires) and the obstacles faced during data collection. Furthermore, it explains the adopted approaches and tools used for qualitative and quantitative data analysis. Finally, it investigates the validation process of the research outputs through a panel of experts.
- **Chapter 4** investigates the GPRS and compare it with its peers of well-known and well-established GBRSs, namely Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED), with a particular focus on M&R category. This approach is adopted to propose suggestions that may improve the GPRS on the categorical level in general and the criteria level of M&R category in specific. Moreover, the importance of M&R category is demonstrated by a detailed discussion of a case study through using palm fronds (PFs) as a green material for concrete reinforcement.
- **Chapter 5** presents the detailed results of the case study carried out in this research. This comparative case study explores the CDWG in terms of generation rates and cost and the adopted factors affecting CDWR in four different construction projects (i.e., industrial, residential, commercial, and infrastructure). This case study is carried out using structured interviews with a panel of project managers and procurement managers. Moreover, a comparison of results is presented in this chapter to highlight the most critical findings and discuss the relationship between CDWG and the adopted CDWR factors.
- **Chapter 6** presents the first part of the statistical analysis of the data collected via the survey questionnaire. It investigates data preparation, data examination, and descriptive and inferential statistical analysis of the data. Descriptive statistics are used to investigate respondents' demographic information, explore their perceptions towards the CDW problem in Egypt, and rank the CDWR factors’ components based

on their applicability and effectiveness levels. On the other hand, inferential statistics are used to investigate the relationship between applicability and effectiveness of CDWR factors and initially examine the relationships between independent variables (IDVs) (i.e., factors affecting CDWR) and dependent variable (DV) (i.e., CDWR) as listed in the defined theoretical framework in chapter 2.

- **Chapter 7** presents the second part of the statistical analysis of the data collected via the survey questionnaire. It tests and validates (i.e., confirms) the hypotheses of the cause-effect relationships between the IDVs and the DV, as defined in the theoretical framework in chapter 2, via SEM technique. The SEM technique helps assess the proposed theoretical framework's predictive performance to ensure its capability to achieve the desired outcome of CDWR. Finally, based on the SEM technique's rigorous statistical analysis complemented by the results of chapter 6, a roadmap for the conceptual framework implementation is presented.
- **Chapter 8** presents the validation process of the research outputs. In this validation phase, a panel of experts is approached to validate the GPRS improvement proposal and the developed MPCF. The validation process helps to ensure that the research outputs are: (1) comprehensive; (2) logical; (3) valuable and applicable; and (4) required to be further improved (where necessary).
- **Chapter 9** summarises the research carried out in this thesis. Also, it presents the main research findings, detailed research contributions, research limitations, and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, a comprehensive literature review is carried out, which formed a base for and led to fulfiling this study's seven established research objectives. The literature review starts by investigating the solid waste problem on the regional level (i.e., MENA region). Then, it investigates the solid waste problem on the local level (i.e., Egypt). After that, it narrows down the topic by focusing on the CDW problem in Egypt. Besides, it presents solutions towards proper and efficient management of both SW problem in the MENA region in general and CDW problem in the Egyptian construction industry in specific. Finally, based on the reviewed studies in this chapter and the recommendations for proper and efficient SW management (SWM) and CDWM, a theoretical framework of this study is presented, which will be further tested and validated throughout the next chapters of this thesis.

2.2 The Solid Waste Problem in the MENA Region

2.2.1 The Current Situation in the MENA Region

The MENA region contains about 6% of the total world's population. The region's total population has boomed from around 100 million in 1950 to around 380 million in 2000. The total area of the MENA region is about 11.1 million km^2. Most of the MENA region countries can be classified as developing countries except Saudi Arabia, the United Arab Emirates, Qatar, and Kuwait, classified as developed countries (Nassour *et al.*, 2016). There is a massive gap between developing countries and developed countries in terms of disposal and management of SW materials (Zyoud *et al.*, 2015). The MENA region is noted for significant SW generation (SWG) worldwide, with a per capita municipal waste (MW) production of more than 2 kg per day on average in most of its countries (Zafar, 2016).

By 2020, SW is expected to exceed 200 million tonnes annually due to population and economic growth, accelerated urbanisation rate, the fast pace of industrialization, changing consumption patterns, and lack of public awareness (El-Sherbiny *et al.*, 2011; Zyoud *et al.*, 2015). MW is not the only or even the main reason for the SW problem in the MENA region, but CDW is the most influential and primary component of SW in the MENA region. For instance, due to the high boom of construction activities among the Gulf Cooperation Council (GCC), 55% of the total SW was estimated to be generated from construction and demolition (CD) operations (Aden, 2017).

MENA cities spend between 20 to 50% of their budgets on SWM. Unfortunately, there is no proper management of SW. Although 80% of the generated SW is decomposable; however, less than 5% is recycled, and less than 20% is adequately treated. The cost of the SW problem in the MENA region in terms of damage was equivalent to about 0.3% of the total GDP in 2006 (El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012). MENA's growing SW problem has started to urge officials and environmentalists to propose different solutions, such as the pay-as-you-throw policy (Aden, 2017). Most MENA region governments have recognised the SW problem and want to apply adequate solutions (Nassour *et al.*, 2016). The increasing environmental awareness nowadays in the region means that environmental protection is on the political agenda.

However, the MENA region's SWM sector is unorganised and inefficient, and the different WM strategies are still in their initial phases (El-Sherbiny *et al.*, 2011). Despite the expected increase in SWG in the MENA region by 2020, research on managing SW problems in the MENA region remains insufficient. A study carried out by Zyoud *et al.* (2015) indicated that a total of 382 research documents were published by authors in the MENA region in the SWM sector from 1982 up to 2012, and it was noted that the number of publications increased rapidly in the last ten years of this period. The highest number of publications focused on Egypt, followed by Tunisia and Jordan, and the most productive institution in terms of publications over the MENA region was the American University of Beirut (AUB) in Lebanon. It was recognised that Egypt is leading the Arab countries in SWM research.

2.2.2 Main Causes of Solid Waste Problem in the MENA Region

Different researchers have explored the main reasons for the SW problem in the MENA region. These reasons are divided into eight main clusters as a result of summarising and categorising the surveyed literature. The main reasons are tabulated and explained, where it needs further explanation, in Table 2.1.

Table 2.1a *Different reasons behind SW problem in the MENA region*

Main Reason	**Further Explanation**	**References**
Lack of strict measures and actions in the SWM sector	SWM is faced with a shortage of WM legislation and poor planning. There is a lack of legislative frameworks, policies, strategies, and enforced laws and regulations that may help mitigate and deal sustainably with the MENA countries' SW problem.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Zafar, 2016; Nassour *et al.*, 2016
Limited public awareness about environmental issues, WM practices and waste reduction (WR), and sustainable living	Public awareness is critically needed to help face the growing SW problem by changing habits and taking personal responsibility for environmental protection.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Zafar, 2016; Aden, 2017
Dumping of SW in open and uncontrolled spaces, deserts, and water	Dumping is the standard action of dealing with SW throughout the MENA region leading to hazardous environmental pollution. SW is often burnt in the open-air, wherever the dumpsites exist, leading to air pollution.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Zafar, 2016; Nassour *et al.*, 2016
Lack of proper means of SW collection, transport systems, and balanced and adequate coverage of WM		El-Sherbiny *et al.*, 2011; Zafar, 2016

Table 2.1b *Different reasons behind SW problem in the MENA region*

Main Reason	**Further Explanation**	**References**
Lack of integrated sustainable SWM plans	The MENA region lacks SWM plans which focus on the main 4R's of waste minimisation strategies (i.e., reduce, reuse, recycle, and recover). There is no focus on the prevention/reduction approach. Also, the reuse, recycling, and recovery approaches are still at their infancy stages in most MENA countries.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Zafar, 2016; Nassour *et al.*, 2016; Aden, 2017
Scarcity in reliable data of hazardous waste and waste-producing activities in the region	This data is needed to help in developing adequate policies and efficient WM plans nationally and regionally. Research is vital to obtain reliable data, and several reasons are cited for the low number of research publications as follows: (1) lack of funding and freedom; (2) lack of industry-academia and government-academia partnerships; (3) general weakness in scientific writing; and (4) lack of research promotion in the field of SWM.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Nassour *et al.*, 2016
Instability of political conditions in the MENA region	The unstable political conditions hinder the development and improvement of WM structures.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Nassour *et al.*, 2016

Table 2.1c *Different reasons behind SW problem in the MENA region*

Main Reason	**Further Explanation**	**References**
Others: insufficient allocated funds, lack of coordination among stakeholders, shortage of trained and qualified personnel, and shortage in technical and operational decision making		UNEP, 2009; El-Sherbiny *et al.*, 2011; Zafar, 2016; Nassour *et al.*, 2016; Aden, 2017

2.3 The Solid Waste Problem in Egypt

2.3.1 The Current Situation in Egypt

Like many countries in the MENA region, Egypt is facing a significant challenge regarding the SW problem. The SW became a severe threat to Egypt, which has to be handled correctly and with practical and effective solutions (El-Gamal, 2012). According to the latest report published by the Egyptian Ministry of Environment (EMoE), Egypt generates about 90 million tonnes of total SW annually, as shown in Table 2.2, in which 55 thousand tonnes are generated daily as MW (EMoE, 2017). Annually, about 21 million tonnes are generated as MW, and about 5.8 million tonnes are generated as CDW (EMoE, 2017). CDW is ranked the fourth among eight main reasons for SWG in Egypt.

Table 2.2 Classification of SW in Egypt

Source: (EMoE, 2017)

Type of Solid Waste	**Annual Generated Quantities (million tonnes)**
Municipal waste	21
Agricultural waste	31
Construction and demolition waste	5.8
Industrial waste	4.9
Hazardous waste	0.54
Health-care waste	0.52
Sludge and slurry waste	2
Waste resulting from canals' and drainages' purification	25
Total	90.76

In Egypt, the SWM system is weak and inefficient, where 81% of generated SW are dumped on streets of residential areas and at illegal dumping sites without any treatment, as indicated in Figure 2.1 (EMoE, 2017). In 2016, It was estimated that there were 18 million m^3 of dumped SW inside the different Egyptian governorates, in which most of it was CDW mixed with MW (EMoE, 2017). Cairo governorate possessed the highest amount of these dumped SW with an estimated quantity equal to 5 million m^3 out of the total 18 million m^3 of SW, as indicated in Table 2.3 (EMoE, 2017).

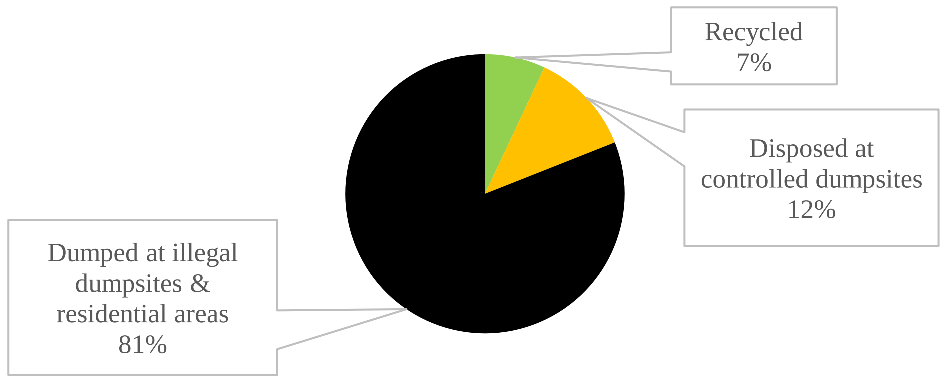

Figure 2.1 *Current status of SWM in Egypt*

Source: *(EMoE, 2017)*

Table 2.3a *Dispersion of dumped SW among Egyptian governorates*

Source: *(EMoE, 2017)*

Governorate	**Amount of Dumped SW (million m^3)**
Cairo	5.0
Alexandria	0.15
Giza	3.0
El-Qalyubia	0.50
Dakahlia	1.80
Gharbia	0.30
Menofia	1.20
El-Beheira	0.60
Kafr El-Sheikh	0.20
El-Sharkia	0.30
Damietta	0.40
Ismailia	0.35
Port Said	0.20
Suez	0.50
El-Fayoum	0.30
Beni Suef	0.15

__Table 2.3b__ Dispersion of dumped SW among Egyptian governorates

Source: *(EMoE, 2017)*

Governorate	**Amount of Dumped SW (million m^3)**
El-Minya	0.90
Assiut	0.25
Sohag	0.28
Qena	0.20
Aswan	0.20
Luxor	0.10
Red Sea	0.80
Matrouh	0.15
North Sinai	0.10
South Sinai	0.10
Total	18

The waste recycling industry in Egypt has financial and technical deficiencies, and it is not included in a legal framework. Moreover, most landfills in which the SW is dumped are open and exposed, as shown in Figure 2.2. Unfortunately, the common practice of dealing with the dumped SW is open burning instead of dealing adequately with the SW by recycling or sealing them within the landfills. Additionally, Egypt lacks the necessary equipment for covering SW (Japanese Ministry of Environment (JMoE), 2004; El-Gamal, 2012; Zaki and Khial, 2014; Azmy and El Gohary, 2017)

Figure 2.2 *Uncontrolled open landfill in El-Sharkia governorate in Egypt*

Source: *(Sharkiatoday, 2017)*

2.3.2 Main Causes of Solid Waste Problem in Egypt

In Egypt's local context, the factors contributing to the inadequacy of SWM are similar to the aforementioned ones in the MENA region. Besides, additional factors were identified by El-Gamal (2012) and National Solid Waste Management Programme (NSWMP) (2014) as follows: (1) conflicts in institutional structure, undefined roles, and deficiency in capacities; (2) lack of monitoring and evaluation mechanisms; and (3) inadequate social inclusion in centralised planning. It is also increasingly recognised that CDW contributes significantly to the general problems of SWM.

One of Egypt's most critical problems is that there are no specific laws and legislation for SWM. Legislation can be found as provisions within other laws. The legal framework of SWM in Egypt is dispersed into different pieces of legislation. These few pieces of legislation try to manage the process of SW transfer, charge and dumping without paying attention to WR. Unfortunately, these pieces of legislation are not strictly enforced and led to a dominant practice of dumping SW in public areas and on streets (El-Gamal, 2012; Zaki and Khial, 2014; Elsaid and Aghezzaf, 2015; Ibrahim and Mohamed, 2016; EMoE, 2017; Azmy and El Gohary, 2017).

An SWM system can be explained as the management of all practices, legislation, procedures, processes, responsibilities, and resources to build a system that deals with SW efficiently and follows environmental regulations (Elsaid and Aghezzaf, 2015; Ibrahim and Mohamed, 2016). An SWM system may include strategies that can be applied to avoid or reduce SWG as the preferable way. An SWM system is considered sustainable if it is economically affordable, environmentally significant, and socially acceptable (Elsaid and Aghezzaf, 2015). Unfortunately, Egypt lacks a sustainable SWM system to tackle the increasing SW problem.

2.4 Construction and Demolition Waste Problem in Egypt

2.4.1 Definition of Construction and Demolition Waste

The construction literature has defined CDW in various ways, and there is no absolute definition for it. For instance, Tchobanoglous *et al.* (1977) defined CDW as "*wastes from razed buildings, and other structures are classified as demolition wastes. Wastes from the* *construction, remodelling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes*" (cited in Elgizawy *et al.* (2016), p.2). Also, Koskela (1992) defined CDW as any inefficiency that leads to the use of materials in larger quantities than those needed to produce a building.

Alternatively, the US Environmental Protection Agency (EPA) (1995) defines CDW as "*waste that is generated from the construction, renovation, repair, and demolition of structures such as residential and commercial buildings, roads, and bridges*". On the other hand, Roche and Hegarty (2006) defined CDW as "*surplus and damaged products and materials arising in the course of construction work or used temporarily during the process of onsite activities*". Lu and Yuan (2011) claimed that the term CDW was mentioned in the literature as an integral term representing materials waste generated due to construction activities without being restricted to a specific construction or demolition stage. It is quite apparent that each study has its perspective towards the definition of CDW based on the addressed research question and objectives (Lu and Yuan, 2011).

2.4.2 Different Approaches to Construction and Demolition Waste Management

The literature review revealed several approaches to manage CDW used worldwide. For instance, Zaki and Khial (2014) stated that CDW could be managed using the WM hierarchy, which depends on the 4Rs' golden rule of reducing, reusing, recycling, and recovering waste. **Reducing** waste is defined by The Asia Foundation (2008, p.7) as "*any change in the design, manufacture, purchase, or use of materials or products (including packaging) to reduce their volume and amount of toxicity before they become municipal solid waste*". **Reusing** waste means using the same material in the construction process more than once, either for the same function or a new function (Yuan and Shen, 2011). **Recycling** waste is defined by Eurostat (2014) as "*any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes*". **Recovering** waste is defined by Environment Agency (2010, p.1) as "*using waste to replace other non-waste materials to achieve a beneficial outcome in an environmentally sound manner*". Yuan and Shen (2011) stated that CDW could be managed using WM hierarchy which depends on the following: (1) the 3Rs' principles of reducing, reusing, recycling; and (2) disposing of waste.

Disposing of waste is defined by Environment Agency (2010, p.2) as "*getting rid of waste in a safe and environmentally sound manner*".

The aforementioned WM hierarchies' components are arranged in ascending order according to their negative impact on the environment from low to high, as illustrated in Figure 2.3. Therefore, the WM hierarchy's main components tend to focus on reducing resource consumption and preventing environmental pollution, which both are two of the main pillars of sustainability (Yuan and Shen, 2011). It has been mentioned in several studies that the "reducing" approach is the most effective approach for managing waste due to many reasons outlined as follows: (1) protecting the environment from pollution; (2) reducing the cost assigned for waste transporting, recycling, and disposal; (3) increasing profit; (4) enhancing the company's corporate image; (5) saving the loss of construction time; and (6) providing cleaner and safer site condition (Yuan and Shen, 2011; Zaki and Khial, 2014; Eze *et al.*, 2017). Since 2000, many researchers focused on CDWR, which shows that CDWR is the preferable way to manage CDW from the perspective of saving resources and protecting the environment (Yuan and Shen, 2011).

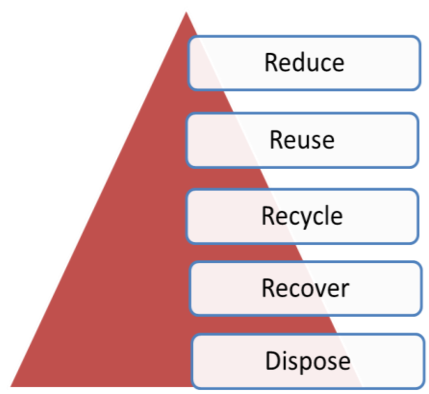

Figure 2.3 *Different CDWM approaches*

Several visions, strategies, methodologies, and action plans have been developed over the years to alleviate the CDW problem in construction sites. They include, for instance: industrialization, computer integrated construction, constructability, partnership, robotized and automated construction, lean construction (LC), building information modelling (BIM), value engineering (VE), and sustainable supply chain management (SSCM) (Hussin *et al.*, 2013; Marhani *et al.*, 2013; Othman *et al.*, 2014). These different approaches can reduce CDWG by 70% (Hussin *et al.*, 2013). Despite these solutions' valuable contributions, the

Egyptian construction industry's performance is considered inefficient and inadequate in adopting these solutions in CDWM (Abdelhamid, 2014).

2.4.3 The Current Situation in Egypt

The construction industry plays a prominent role in the growth of the Egyptian economy. It contributes 5% of the total gross domestic product (GDP) and employs about 11% of Egypt's total population (Esam and Ehab, 2015). Despite the unstable economic situations in Egypt through the past ten years, the Egyptian economy has experienced a development in the construction industry in which the real growth rate of the “construction and building” sector has increased from 9.7% in the fiscal year (FY) 2014/2015 (Central Bank of Egypt (CBE), 2015) to 11.2% in the FY 2015/2016 (CBE, 2016). The amount of investments in the “construction and building” sector has been tripled in the FY 2015/2016, in which the value of investments rose by 198.6% to reach EGP 11.7 billion in the FY 2015/2016 compared to a rise of 43.2%, reaching EGP 3.7 billion in the FY 2014/2015 (Barakat *et al.*, 2016; Barakat *et al.*, 2017). These investments prove that the Egyptian government is exerting great efforts in executing many construction megaprojects towards the implementation of Egypt’s SDS 2030 goals (Invest-gate, 2016). However, Barakat *et al.* (2017) stated that the Egyptian construction industry's progress could slow down in 2017, compared to the past two fiscal years, due to reduction in energy subsidies and devaluation of the Egyptian pound. Consequently, this may lead to many obstacles in the Egyptian construction industry regarding higher construction materials costs. Despite that, the Egyptian construction sector would remain in progress due to strong structural demand and increased investments in this sector (Barakat *et al.*, 2017).

The construction industry is noted for the CDWG and polluting effect on the environment (Azis *et al.*, 2012). Waste in construction materials represents a severe problem for the Egyptian construction industry (Garas *et al.*, 2001). In Egypt, up to 40% of total construction materials cost is wasted, and this is equivalent to 16% of total building cost (i.e., labour and materials cost). It is worth mentioning that the waste in total materials cost must not exceed 4% under any circumstances (Kholousy, 1991; Shamseldin, 2003). CDW is dumped on roads and in facilities that lack effective management, as shown in Figure 2.4. Most of the dumping sites are unsafe and marked by the non-existence of sufficient precautions to prevent the self-ignition of waste, leading to environmental pollution (Abdelhamid, 2014; Azmy and El Gohary, 2017).

Figure 2.4 *300 tonnes of CDW dumped on main roads of Mansoura city*

Source: *(Dot Msr, 2017)*

The biodegradation of CDW in landfills results in severe health and environmental problems (Azmy and El Gohary, 2017; Mahamid, 2020). Also, CDW negatively impacts the efficiency, effectiveness, value, and profitability of construction companies. CDW severely harms countries' economies and the TBL of sustainability (Memon *et al.*, 2015; Park and Tucker, 2017; Jalaei *et al.*, 2019). Caldas *et al.* (2014) claimed that construction materials and equipment constitute between 50 and 60% of total project cost and affect 80% of its schedule. Although the Egyptian Environmental Law regulates CDW disposal, these regulations lack clauses that foster CDWR (Azmy and El Gohary, 2017).

A recent study was carried out by Hany and Dulaimi (2014) to determine the composition of CDW for main construction materials in Greater Cairo (GC) based on 37 semi-structured interviews. The case study was based on a vast residential compound built on 33,600,000 m^2. It was found that timber is the highest wasted construction material, as listed in Table 2.4. This timber waste is because it is used in framework and shuttering for concrete. Moreover, labours do not have the high skills needed for using new tools to minimise timber waste, and there is a lack of using prefabricated elements, which can reduce timber waste significantly (Hany and Dulaimi, 2014).

However, different studies carried out by Garas *et al.* (2001) and El-Desouky *et al.* (2018) reported different statistics regarding the CDW composition for main construction materials. First, Garas *et al.* (2001) successfully collected 30 completed survey questionnaire from a representative sample of 1st-grade contractors, who are the most capable in Egypt, to determine CDW percentages for different construction materials. Second, El-Desouky *et al.* (2018) also successfully collected 28 completed survey questionnaire from a representative sample of 1st-grade contractors in Egypt to investigate the CDWG rates of different construction materials. Also, El-Desouky *et al.* (2018) reported another different statistics of CDWG rates for a study carried out by Ragab *et al.* (2001). The results of these studies are summarised in Table 2.4.

All these studies reported the CDWG rate of each material as a percentage of the total purchased amount. Comparing the abovementioned studies' results as listed in Table 2.4, the inconsistency among these studies' statistics can be easily detected. This is because they mainly depended on experts' knowledge and lacked any statistical records, which is the case in this study per the discussion in chapter three. In Egypt, almost no recorded data are available, based on regular feedback on previous projects, to predict the precise amounts and types of CDW generated during CD operations. Contractors tend to know approximately the amount of CDW generated during a given project according to previous experience (El-Desouky *et al.*, 2018). Both studies of Garas *et al.* (2001) and Hany and Dulaimi (2014) agreed that "timber" is the most wasteful material in Egypt. On the other hand, Ragab *et al.* (2001), as reported by El-Desouky *et al.* (2018), claimed that "sand" is the most wasteful material in Egypt. In contrast, El-Desouky *et al.* (2018) reported "bricks" as the most wasteful material in Egypt.

It is worth mentioning that the statistics of SWG and SW disposal, including CDWG and CDW disposal, in Egypt can be inaccurate due to lack of weighing facilities at disposal sites and the absence of SW sampling and analysis techniques (Zaki and Khial, 2014; Ibrahim and Mohamed, 2016). Also, the few studies of CDWM research in Egypt carried out by Garas *et al.* (2001), Ragab *et al.* (2001), Hany and Dulaimi (2014), and El-Desouky *et al.* (2018) lack comparative studies to quantify CDW in terms of generation rates and costs among various construction projects (i.e., industrial, residential, commercial, and infrastructure).

Table 2.4 *Results of different CDW quantification studies in Egypt*

Study	(Ragab *et al.*, 2001)	(Garas *et al.*, 2001)	(Hany and Dulaimi, 2014)	(El-Desouky *et al.*, 2018)
	Average Percentage of Waste			
Timber	--	13	40	20
Sand	7.2	9	17.5	8
Steel	3.9	5	3.5	6
Cement	3.8	5	4.5	10
Concrete	3.2	4	3.5	5
Bricks	5.9	6	5	35
Tiles	5.1	5	5	10

*Note: These studies did not investigate any CDWG rates for plastics, glass, or other metals, which indicate that these materials do not have a significant impact on CDW.

2.4.4 Main Causes of Construction and Demolition Waste Problem in Egypt

In addition to the aforementioned causes of the SW problem in the MENA region and Egypt, the behaviour of the Egyptian construction industry towards CDW has not improved for a long time resulting in a rapid and continuous increase of CDWG (Hany and Dulaimi, 2014; Azmy and El Gohary, 2017). Based on the SW statistics in 2016, it is worth mentioning that CDW represented about 6.4% of the total generated SW in Egypt (EMoE, 2017). SW statistics in 2012 showed that CDW represented about 4.5% of the total generated SW in Egypt (Zaki and Khial, 2014). This increase in CDWG proves that the boom of construction is associated with more CDWG. Nowadays, the Egyptian government is executing many megaprojects following the political agenda of Egypt's vision 2030, such as National Project for the Development of Sinai, National Projects for Roads, National Project for the Development of Upper Egypt, Establishment of New Cities, and The Golden Triangle Project (Invest-gate, 2016). It has been claimed that the increasing demand for executing megaprojects will necessarily require the use of more materials and resources, which consequently will lead to the generation of more CDW (Azis *et al.*, 2012; Nagapan *et al.*, 2012; Foo *et al.*, 2013; Ahmad *et al.*, 2014).

Moreover, few pieces of legislation manage CDW in Egypt (Zaki and Khial, 2014). Article 39 of the Environment Law 4/1994 and Article 41 of the executive regulations (Prime Minister Decree Number 338/1995) regulate CDWM. They require that all personnel engaged in the exploration, excavation, and CD activities should take necessary precautions to store, transport, and dispose the waste generated by these activities in a safe manner. These articles include the specifications and allow local authorities to include these specifications in the permits issued for the exploration, excavation, and CD activities. Moreover, Laws 106/1976 and 101/1996 authorise local governments to involve CDWM in the permits needed for construction activities. These laws also authorise local governments to gather fees from contractors and owners to provide or pay for CDW collection and disposal. However, contractors usually find it cheaper to transfer CDW to a nearby illegal site and neglect paid-for disposal services at an approved legal site.

In addition to the scarcity in the legislation of CDWM, these few legislation are ineffective due to several reasons as follows: (1) the existence of construction operations without a permit; (2) lack of regulations' enforcement in Egypt; (3) CDW collection and disposal are carried out by a limited number of local governments; and (4) the 1% building permit fee is dedicated to other services rather than CDWM (Zaki & Khial, 2014). The lack of enforced environmental legislation and laws negatively affects the WM system as people cannot comply with weak regulations. Also, the CDWM system in Egypt does not pay attention to WR as it focuses only on waste collection, transfer, and disposal. Moreover, the responsibility of SWM in Egypt is scattered among several authorities within the central government, leading to conflicts in roles and responsibilities (El-Gamal, 2012; Zaki and Khial, 2014; Elsaid and Aghezzaf, 2015; EMoE, 2017; Azmy and El Gohary, 2017).

Besides, in the study carried out by Hany and Dulaimi (2014) to explore the CDW problem in Egypt, specifically in GC, four main sources of CDWG were identified as follows: human source, technology source, an industry source, and process and governmental source. First, **the human source** is related to poor planning and design, which neglect the environmental best practices and standards such as BREEAM, LEED, GPRS or any other environmental measures. It is also related to the higher management's wrong perception regarding CDWR in which they consider the efforts exerted to minimise CDW as time and profit loss. Moreover, it is related to the client's lack of awareness and responsibility for not advising the designers and the project's supply chain to follow the GB concepts and practices. Second, **the technology source** is related to the low technology adopted by the Egyptian construction industry in executing most of its project. It worth mentioning that massive CDWG is associated with low technology. Third, **the industry source** is related to Egyptian construction companies' unwillingness to follow and implement new construction technologies, process management, waste-efficient procurement methodologies, and standards in their projects. Fourth, the **process and governmental source** is related to the lack of the Egyptian government's role in promoting the adoption of GB principles and waste-efficient practices through incentives and issuance of legislation. Unfortunately, the CDWM research in Egypt lacks studies investigating the relationship between the different CDWR factors (i.e., practices, legislation, awareness, culture & behaviour) and CDWG.

2.5 Towards Effective Solid Waste Management Systems in the MENA Region

After a critical review of the literature, some emerging issues at the global and regional levels regarding the SW problem become more severe and challenging. According to the study carried out by Transparency Market Research in 2017, global attention has to focus on the 4R policies of reducing, reusing, recycling, and recovering to minimise the amount of compiled CDW (Slowey, 2018). Different policies have been formulated to promote the application of the 4R policies of dealing with CDW. There are also various certifications, such as LEED and BREEAM, in place in different countries to encourage the proper CDWM.

According to lessons learnt from developed countries, there are two main approaches in tackling the problem of SW as follows: (1) by investing allocated funds to use advanced technologies to maximise SW diversion from landfills while gradually applying the 4R policies; or (2) by starting with the 4R policies to gradually reroute the SW away from landfills and avoid the dumping of SW. The second approach is the most convenient approach for developing countries, such as MENA countries, due to limited available capital (El-Sherbiny *et al.*, 2011). The most convenient way of dealing with SW, for the environmental and economic benefits, is to minimise generating it at its source, which is why WR is at the top of the well-known WM hierarchy. The main goal of WR is to disconnect economic growth from the negative environmental impacts caused by generated waste, often referred to as "decoupling" (Aden, 2017).

Several researchers suggested various approaches in structuring SWM sectors to solve the SW problem in the MENA region. These approaches are divided into eight main clusters as a result of summarising and categorising the surveyed literature. The main approaches are tabulated and explained, where it needs further explanation, in Table 2.5.

Table 2.5a *Different approaches to solving the SW problem in the MENA region*

Main Approach	**Further Explanation**	**References**
Adoption of WM hierarchy	MENA governments should encourage the different business sectors to adopt the WM hierarchy, focusing on the WR approach by offering incentives.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Aden, 2017
Boosting public awareness of citizens	MENA governments should increase their citizens' public awareness by implementing green behaviours in their societies and inform them of the consequences of inadequate WM. This step can be achieved through different governmental strategies as follows: (1) promote public awareness campaigns; (2) implement a "clean week" in which the public, service providers, and government officials participate in SWM activities; (3) foster a "Clean City" competition with financial incentives to encourage municipalities to act; (4) establish educational content about SWM in schools' curriculum; and (5) increase the awareness about SWM at the workplace of large waste generators.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Zafar, 2016; Aden, 2017

Table 2.5b *Different approaches to solving the SW problem in the MENA region*

Main Approach	**Further Explanation**	**References**
Developing policies, enforceable laws, strategic plans, and legislative and institutional frameworks	MENA governments should take this action to support the adoption of integrated sustainable SWM plans. This step can be achieved by different governmental strategies such as follows: (1) consider the SWM sector in the country's national development plan; (2) develop national guidelines for SWM; (3) construct a national SW task force to follow the progress of the SWM plans and guidelines; (4) identify the deficiencies in the current laws and regulations for SWM; and (5) develop specific laws for regulating CDWM.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Zafar, 2016; Nassour *et al.*, 2016
Promoting the industrial sector to adopt sustainable production practices	MENA governments should encourage different industries, including the construction industry and manufacturing, to adopt different cleaner and sustainable production practices. This can be achieved by building governments' capacity in cleaner production by establishing national cleaner production centres (NCPCs).	UNEP, 2009; El-Sherbiny *et al.*, 2011; Aden, 2017
Establishing a reliable database for SW in MENA countries	This strategy is needed to document the SW problem's current status in the MENA region to introduce appropriate solutions and strategies. This step can be achieved through different government strategies as follows: (1) develop mechanisms for gathering information on SW quantities and compositions on the national level; (2) set up an operational and environmental monitoring program in each SW facility; (3) unify the practices for gathering SW data among the SW facilities within the country and the MENA region; and (4) establish a government-run SW website and upload SW data on it regularly.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Nassour *et al.*, 2016

Table 2.5c *Different approaches to solving the SW problem in the MENA region*

Main Approach	Further Explanation	References
Promoting cooperation in research and development (R&D) between MENA countries	MENA governments need this step to help in exchanging knowledge and experience in the sector of SWM.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Nassour *et al.*, 2016
Developing financial frameworks for SWM	This strategy is needed to allocate adequate funds for efficient SW management and consider user-pays, polluter-pays, and landfill taxing principles. A sustainable financial plan should be developed for SWM, which has an allocated budget separate from the total budget to identify the total cost of SWM.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Zafar, 2016; Nassour *et al.*, 2016
Developing the institutional capacity of municipalities on SWM by investing in people, institutions, and practices.	This strategy can be achieved through different strategies to be adopted by MENA governments as follows: (1) implement training and educational programs about SWM and governance, including officials from central and regional governments; (2) arrange information exchange trips for SW officials in the MENA region to share their experiences and knowledge, improve policies, and learn about new green techniques and practices; (3) implement SWM education and research programs at universities; and (4) assign funds for capacity building in SWM.	UNEP, 2009; El-Sherbiny *et al.*, 2011; Arif and Abaza, 2012; Zafar, 2016; Nassour *et al.*, 2016; Aden, 2017

2.6 Waste-efficient Materials Procurement Practices for Reducing Construction and Demolition Waste in the Egyptian Construction Industry

Although CDWG occurs during the construction activities on-site, it is believed that it occurs due to various actions and activities at the design, materials procurement, and construction stages. Even though the literature is wealthy with design and construction strategies for minimising CDW as aforementioned, few efforts have been exerted to investigate materials procurement measures to reduce CDWG on-site (Ajayi *et al.*, 2017a). Zeb *et al.* (2015) defined procurement as "*purchasing of materials, equipment, labour and services needed for execution of a project. Procurement is organising the purchasing and scheduling delivery of materials*". Despite different studies (Formoso *et al.*, 2002; Ajayi *et al.*, 2017b) clearly stated that ineffective application of materials procurement process is a primary cause of CDWG; however, materials procurement measures for CDWR have neither been explored nor subjected to focused findings. As effective materials procurement process is efficient in reducing CDW and the total cost of construction projects, research attention must also be focused on the waste-efficient materials procurement process.

The literature review revealed different effective ways of waste-efficient materials procurement practices such as materials procurement measures, materials procurement models, and green materials procurement approach (Daoud *et al.*, 2018a; Daoud *et al.*, 2018b; Daoud *et al.*, 2020a; Daoud *et al.*, 2020b). For CDWR, the literature revealed 16 defined materials procurement measures, five defined criteria for the green materials procurement approach, and two preferred procurement models: the owner procurement model (OPM) and the specialty contractor procurement model (SCPM). These different practices are investigated in detail in the next subsections.

2.6.1 Waste-efficient Materials Procurement Measures

Daoud *et al.* (2018b) investigated the relationship between waste-efficient materials procurement and CDWR. It was concluded that efficient materials procurement measures could help in reducing CDW and financial loss of projects. According to a study carried out in the UK by Fadiya *et al.* (2014), it is claimed that inefficient materials procurement, among other eight factors, contributes about 11.2% towards total CDWG, as shown in Figure 2.5. Moreover, Eze *et al.* (2017) identified 20 main reasons for CDWG in construction sites, in which poor procurement management (i.e., wrong purchasing order – quality, number, time of order) had the sixth rank among other reasons. Also, Ajayi *et al.* (2017a) claimed that materials procurement is responsible for purchasing the wasted materials, and it was also claimed that materials procurement contributes up to 50% of the total project cost. Accordingly, Ajayi *et al.* (2017a) defined four clusters of materials procurement measures that could help in CDWR as follows: (1) suppliers' low waste commitment; (2) low waste purchase management; (3) effective materials delivery management; and (4) waste-efficient bill of quantity. Each cluster consists of a series of defined measures that should be applied to reduce CDW, as summarised in Table 2.6.

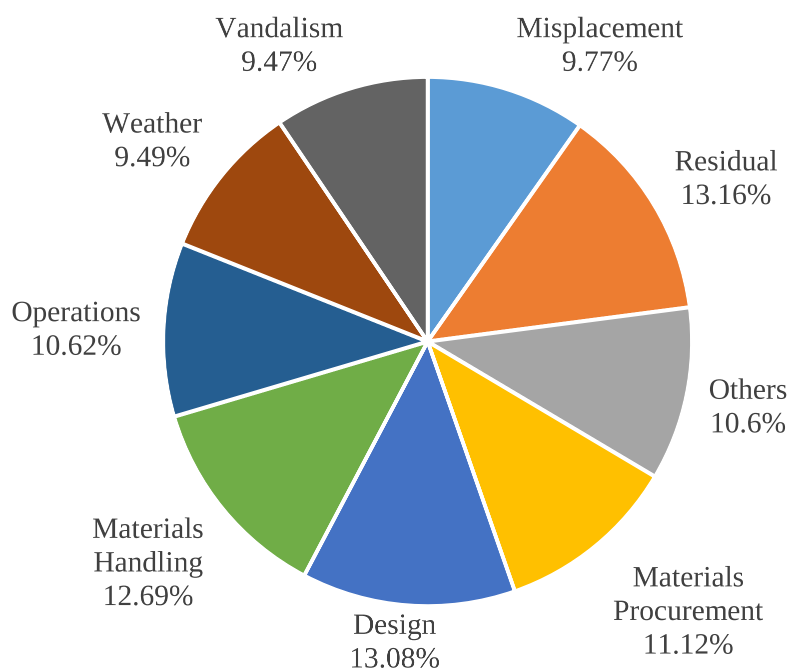

Figure 2.5 *Different factors contributing to CDWG in the UK*

Source: *(Fadiya et al., 2014)*

Table 2.6 *Different waste-efficient materials procurement measures for CDWR*

Source: *(Ajayi et al., 2017a)*

Main Cluster	Measures of Waste-efficient Materials Procurement
Suppliers' low waste commitment	• Suppliers' flexibility in supplying small quantities or modification to products in conformity • Commitment to take back scheme (packaging, unused, reusable, and recyclable materials) • Supply of quality and durable products • Usage of minimal packaging (without affecting materials safety)
Low waste purchase management	• Procurement of waste-efficient materials/technology (pre-assembled/cast/cut) • Purchase of secondary materials (recycled and reclaimed) • Purchase of quality and suitable materials • Avoidance of variation orders • Correct materials purchase
Effective materials delivery management	• Effective protection of materials (during transportation, loading & unloading) • Effective onsite access (for ease of delivery) • Efficient delivery schedule • Usage of Just in Time (JIT) delivery system
Waste-efficient bill of quantity	• Accurate materials take-off • Prevention of over/under ordering • Reduced waste allowance

2.6.2 Waste-efficient Materials Procurement Models

In the construction industry, there are different material procurement models. For instance, Daneshgari and Harbin (2003) investigated three materials procurement models in the construction industry as follows: specialty contractor procurement model (SCPM), general contractor procurement model (GCPM), and owner procurement model (OPM). In **SCPM**, a specialty contractor is responsible for procuring materials for the project owner. The procurement process takes place once the specialty contractor is assigned. In this model, the owner and general contractor of the project mainly depend on the specialty contractor to procure all the project materials. Nowadays, project owners use this model over 90% of the time for materials procurement (Daneshgari and Harbin, 2003). In this model, the specialty contractor has the privilege to review the design specifications, update the owner and general contractor of the project for any problem arising due to materials incompatibility with the design specifications, and give recommendations for any design changes. After finalizing the design, the materials order is issued by the specialty contractor to the vendors. Then, the materials are sent by the vendors to the specialty contractor at the jobsite.

In **GCPM**, the general contractor is responsible for procuring materials for the project owner. The procurement process takes place before the specialty contractor is assigned. In this model, the owner instructs the general contractor to procure all the project's required materials. Nowadays, project owners use this model about 2% of the time for materials procurement (Daneshgari and Harbin, 2003). Once the general contractor purchases the project's materials without inputs from the specialty contractor, s/he may assign the purchase order to the specialty contractor. In this case, the specialty contractor is responsible for receiving the materials on-site, sorting out inaccurate orders, and rectifying materials' incompatibility with specifications.

In **OPM**, the project owner directly procures the required materials from the vendors. The procurement process takes place before either a general contractor or specialty contractor is selected. Nowadays, project owners use this model about 10% of the time for materials procurement (Daneshgari and Harbin, 2003). In this model, the project owner depends on the engineering firm's design specifications and his/her own experience to procure the required materials. Since project owners may have individual relationships with specialty contractors, specialty contractors may give inputs and recommendations about materials procurement to the owner. Once the owner purchases the materials from the vendors, they are shipped directly to the site and stored by the specialty contractor until usage and installation.

Comparing the three models regarding CDWG, the **GCPM** was introduced to the supply chain to solve the CDWG problem. However, it has been proven to be more inefficient than **SCPM** (Daneshgari and Harbin, 2003). Both models suffer from inadequate materials management process, which leads to CDWG. The **OPM** is better than both models regarding the CDWG aspect. Comparing the three models regarding procured materials' cost, both models **GCPM** and **SCPM** are similar in materials cost. The **OPM** provides slightly less expensive costs of procured materials than GCPM and SCPM (Daneshgari and Harbin, 2003).

2.6.3 Green Buildings Practices and Green Materials Procurement

Another approach for rationalising and optimising materials procurement is by applying GB practices through defined guidelines named GBRSs (Daoud *et al.*, 2018a). So far, many countries worldwide have developed their rating standards and guidelines towards GB practices, named GBRSs, in a quest for the sustainable construction industry (Hussin *et al.*, 2013). GBRSs emphasise sustainable development of societies on three different levels as follows: (1) human level; (2) country level; and (3) global level (Karmany, 2016). Over the past 15 years, MENA countries looked at developing and applying their GBRSs (Attia, 2017). This step has taken place after the leading initiatives taken by the UK and US to develop their GBRSs respectively as follows: BREEAM in 1990, and LEED certification in 1998. Apart from the other sustainable goals of GBRSs, the emphasis on optimising the usage of materials through established guidelines for sustainable procurement of materials is prominent (Hussin *et al.*, 2013; Attia, 2017).

In 2011, the Egyptian Green Building Council (EGGBC) developed the Egyptian GBRS named GPRS in its first version, and it was revised in 2017 based on the third version of the LEED (Ammar, 2012; Ismaeel *et al.*, 2018). However, GPRS still needs more development (Ammar, 2012). One of the main weaknesses found in the GPRS is imitating the LEED without adapting to the local context, in which some criteria were adopted without considering local capacity and others were not adopted while being considered as promising solutions for solving the current challenges and needs in Egypt (Attia, 2017). Given a country’s specific nature and challenges, a rating system developed to suit a particular context or region needs to be tuned and adapted to local contexts (Karmany, 2016). The development of a rating system must reflect local capacity, constraints, opportunities, and above all, the local strategies and needs of the adopting countries. Indeed, the need to develop the structure and rating criteria of the GPRS to address the environmental, economic, and social needs in Egypt is overwhelming (Ammar, 2012; Ismaeel *et al.*, 2018). The GPRS is quite promising, but it cannot be considered comprehensive until it attunes to local needs (Ismaeel *et al.*, 2018; Daoud *et al.*, 2018a).

A category named "M&R" in the GPRS is responsible for indicating how to procure construction materials sustainably and in a green manner through several defined criteria as shown in Table 2.7 (Housing and Building National Research Center (HBRC), 2011); (HBRC, 2017). However, Daoud *et al.* (2018a) argued that the GPRS still needs improvement and development, especially its M&R category, in which two main limitations were highlighted in this study. The **first limitation** is related to the weight of the M&R category compared to other categories listed in the GPRS, given the escalating problem of CDW in Egypt. Although the weight of the "M&R" category increased by 2% in the second version of the GPRS; however, its weight is still low compared to most of the GPRS categories. This low weight indicates that low importance is given to this category regarding its environmental impact compared to most of the different categories listed in the GPRS. The **second limitation** is related to the non-existence of a list of GPRS certified materials, which can be used as a benchmark for assessment and a guide for users. There is no indication or examples of the different types of sustainable materials available within the Egyptian context. There should be a list of sustainable materials which are GPRS certified and follow the specifications set by national standards (e.g., Egyptian Organisation for Standards and Quality (EOS)) or international standards (e.g., International Organisation for Standardization (ISO)). This is needed to be used as a benchmark during the assessment and a guide by developers and construction companies.

Further shortcomings could be discovered in GPRS in general and its M&R category in specific if it is compared in detail to its peers in other well-established GBRS such as BREEAM and LEED. Accordingly, this step is taken into consideration and investigated in detail in chapter four of this thesis. This step is conducted for proposing improvements to the GPRS in general and its M&R category in specific as investigated by Daoud *et al.* (2020a). Unfortunately, The GPRS is not widely applied in Egypt due to several barriers as follows: (1) economic issues; (2) attitude and market; (3) information, knowledge, and awareness; (4) management and government; and (5) technology and training (Chan *et al.*, 2017). Moreover, Ismaeel *et al.* (2018) stated that Egyptian GPRS certification is not included in Egypt's national building law, making the green approach of materials procurement unfamiliar to most Egyptian construction industry practitioners.

Table 2.7a *Different criteria of the M&R category listed in the GPRS*

Source: *(HBRC, 2017)*

Main Criteria	**Requirements and Options**
Renewable materials and materials manufactured using renewable energy	• Option 1: using at least one construction material obtained from renewable resources such as natural stones, earth, etc. • Option 2: using at least one construction material which is manufactured using renewable energy sources such as solar energy, wind energy to reduce CO2 emission
Regionally procured materials and products	Credit points are gained when construction materials and products value have been extracted or manufactured within a distance of 500 km of the project site with no less than 50% of the total materials value based on cost
Reduction of overall material use	• Option 1: using standard assemblies and reducing customised spaces • Option 2: using materials that do not need finishing • Option 3: using materials that possess high durability and require low maintenance

Table 2.7b *Different criteria of the M&R category listed in the GPRS*

Source: *(HBRC, 2017)*

Main Criteria	**Requirements and Options**
Alternative building prefabricated elements	Credit points are gained for utilising totally or partially prefabricated elements. The quantity of prefabricated elements should not be less than 10% of the total element quantity. These prefabricated elements are used to reduce the need for construction skills and reduce materials waste.
Environment – friendly, sound and thermal insulation materials	Credit points are obtained for using materials that satisfy specific requirements as follows: (1) free from chlorofluorocarbons; (2) does not release toxic fumes when burned; (3) the percentage of volatile organic compound is less than 0.1; and (4) thermal insulation materials should have ozone-depleting materials of zero and a low global warming potential which does not exceed 5.

2.7 Emerging Issues and Key Gaps

In Egypt's local context, the construction industry lacks a framework for implementing waste-efficient materials procurement practices compounded by other surrounding external factors, such as legislation, culture & behaviour, and awareness, to minimise CDWG. It is increasingly recognised that CDW contributes significantly to the general problems of SWM. Based on the literature review, the critical gaps in CDWM are summarised as follows:

- There is a lack of **waste-efficient materials procurement practices** for minimising the CDW problem in Egypt. “Dumping” of CDW is the dominant practice like most of the countries all over the world. Moreover, most construction industry practitioners in Egypt are not familiar with the Egyptian GPRS because it is not included in the national building law.

- Existing **CDWM legislation and regulations** in Egypt are inadequate and ineffective as they focus mainly on CDW collection, transfer, and disposal and do not address the four golden rules (4Rs) (i.e., reduce, reuse, recycle, and recover) of SWM. Existing legislation and regulations do not address the source of the problem, which is at the early stages of the construction cycle, particularly at the procurement stages when critical decisions are made relating to the purchase of construction materials and how to minimise CDW at the source.

- Also, due to Egyptian society's **culture and behaviour** towards the SW problem, legislation are not appropriately enforced. There is a lack of **public awareness** about the severity of the SW problem, making society stand passively against the increasing SW problem.

- Finally, there is a lack of comparative studies that quantify CDW in terms of generation rates and costs among different construction projects (i.e., industrial, residential, commercial, and infrastructure). Besides, there is a lack of studies that explore the relationship between the different investigated CDWR factors (i.e., waste-efficient materials procurement practices, legislation, awareness, culture & behaviour) and CDWG.

2.8 A Theoretical Framework for Minimising Construction and Demolition Waste in Egypt

Based on the detailed investigation of different key measures and solutions in sections 2.5 and 2.6 and the summarised critical gaps of CDWM in section 2.7, a theoretical framework was built for minimising CDW in Egypt. This framework depends mainly on six main factors, consisting of several items, as follows: (1) waste-efficient materials procurement measures; (2) waste-efficient materials procurement models; (3) green materials procurement approach of GB practices; (4) legislation; (5) culture & behaviour measures; and (6) awareness measures. All of these factors are considered as **IDVs,** which affects CDWR as a **DV**. In this study, the main aim is to understand and investigate the causes of a phenomenon (i.e., CDWR). In a cause-effect relationship, the presumed cause is called “IDV”, and the presumed effect is called “DV” (Flannelly *et al.*, 2014). In other words, an IDV is a variable that is assumed to affect another variable (i.e., DV). A DV is a variable that depends on IDVs. Researchers are usually interested in understanding and predicting the DV and how it is affected by IDVs (Flannelly *et al.*, 2014).

Each IDV and the DV, named constructs, are represented and measured by indicators or items. These indicators were extracted based on an extensive literature review as investigated in the previous sections. For the sake of straightforward representation of the theoretical framework, each indicator (i.e., item) is given an initial code which is used later on in chapters six and seven in data analysis. The IDVs, DV, relevant items, and corresponding codes are tabulated in Table 2.8, and the theoretical framework is shown in Figure 2.6.

As shown in Figure 2.6, this study's theoretical framework includes six main hypotheses to be tested and validated through this study in the Egyptian construction industry domain. As aforementioned, these hypotheses were built based on an extensive literature review as presented in the previous sections of this chapter. They will be tested and validated through a rigorous satistical analysis technique, namely **SEM**, as investigated in the next chapter. The main aim of this research is to test and validate the alternative proposed hypotheses (**H_n**) (i.e., there is a positive effect of the IDV on the DV) against the null hypotheses (**H_0**) (i.e., there is no effect of the IDV on the DV). In other words, the goal is to prove that there is sufficient evidence to reject the null hypothesis **H_0** in favour of alternative proposed hypotheses **H_n**. Accordingly, the alternative six proposed hypotheses **(H_n)** are as follows:

- **H_1**: waste-efficient materials procurement models have a positive effect on CDWR.
- **H_2**: waste-efficient materials procurement measures have a positive effect on CDWR.
- **H_3**: green materials procurement approach of GB practices has a positive effect on CDWR.
- **H_4**: CDWM legislation have a positive effect on CDWR.
- **H_5**: awareness has a positive effect on CDWR.
- **H_6**: culture & behaviour have a positive effect on CDWR.

Table 2.8a *Independent and dependent variables with their relevant items and corresponding codes*

Construct (i.e., variable)		Type	Indicator (i.e., item)	Code	References
Materials procurement models (MPMO)		IDV	Specialty contractor procurement model	MPMO.1	Daneshgari and Harbin, 2003
			Owner procurement model	MPMO.2	
Materials procurement measures (MPMR)	**Suppliers' low waste commitment (SLWC)**	IDV	Suppliers' flexibility in supplying small quantities or modification to products in conformity	MPMR.SLWC.1	Ajayi *et al.*, 2017a
			Commitment to take back scheme (packaging, unused, reusable and recyclable materials)	MPMR.SLWC.2	
			Supply of quality and durable products	MPMR.SLWC.3	
			Usage of minimal packaging (without affecting materials safety)	MPMR.SLWC.4	
	Low waste purchase management (LWPM)		Procurement of waste-efficient materials/technology (pre-assembled/cast/cut)	MPMR.LWPM.1	
			Purchase of secondary materials (recycled and reclaimed)	MPMR.LWPM.2	
			Purchase of quality and suitable materials	MPMR.LWPM.3	
			Avoidance of variation orders	MPMR.LWPM.4	
			Correct materials purchase	MPMR.LWPM.5	

Table 2.8b *Independent and dependent variables with their relevant items and corresponding codes*

Construct (i.e., variable)		Type	Indicator (i.e., item)	Code	References
Materials procurement measures (MPMR)	**Effective materials delivery management (EMDM)**	IDV	Effective protection of materials (during transportation, loading & unloading)	MPMR.EMDM.1	Ajayi *et al.*, 2017a
			Effective onsite access (for ease of delivery)	MPMR.EMDM.2	
			Efficient delivery schedule	MPMR.EMDM.3	
			Usage of Just in Time (JIT) delivery system	MPMR.EMDM.4	
	Waste-efficient bill of quantity (WEBOQ)		Accurate materials take-off	MPMR.WEBOQ.1	
			Prevention of over/under ordering	MPMR.WEBOQ.2	
			Reduced waste allowance	MPMR.WEBOQ.3	
Green building practices representing green materials procurement (GBPR)		IDV	Utilising renewable materials and materials manufactured using renewable energy.	GBPR.1	HBRC, 2011; HBRC, 2017
			Using regionally procured materials and products extracted or manufactured within a distance of 500 km of the project site with no less than 50% of the total materials value based on cost.	GBPR.2	

Table 2.8c *Independent and dependent variables with their relevant items and corresponding codes*

Construct (i.e., variable)	**Type**	**Indicator (i.e., item)**	**Code**	**References**
Green building practices representing green materials procurement (GBPR)	IDV	Reducing overall material use by: (1) using standard assemblies and reducing customised spaces, (2) using materials that do not need finishing, or (3) using materials that possess high durability and require low maintenance.	GBPR.3	HBRC, 2011; HBRC, 2017
		Using alternative building prefabricated elements not less than 10% of the total element quantity.	GBPR.4	
		Using environment – friendly, sound and thermal insulation materials which have specific requirements as follows: (1) free from chlorofluorocarbons, (2) does not release toxic fumes when burned, (3) the percentage of volatile organic compound is less than 0.1, and (4) thermal insulation materials should have ozone-depleting materials of zero and a low global warming potential which does not exceed 5.	GBPR.5	

Table 2.8d *Independent and dependent variables with their relevant items and corresponding codes*

Construct (i.e., variable)	**Type**	**Indicator (i.e., item)**	**Code**	**References**
Legislation (LG)	IDV	Local governments are authorised to involve CDWM in the permits needed for construction activities. These laws also authorise local governments to gather fees from contractors and owners to provide or pay for CDW collection and disposal.	LG.1	Zaki and Khial, 2014
		When carrying out exploration, digging construction, or demolition work, or while transporting waste substances or soil, all bodies and individuals shall take necessary precautions to store or transport this waste in a safe way to prevent it from being dispersed.	LG.2	
Awareness (AW)	IDV	Promoting public awareness campaigns about SW and its negative impacts.	AW.1	UNEP, 2009; El-Sherbiny et al., 2011; Zafar, 2016; Aden, 2017
		Encouraging cooperation between the public, service providers, and government officials to participate in SWM activities.	AW.2	

Table 2.8e *Independent and dependent variables with their relevant items and corresponding codes*

Construct (i.e., variable)	Type	Indicator (i.e., item)	Code	References
Awareness (AW)		Increasing the awareness about SWM at the workplace.	AW.3	UNEP, 2009; El-Sherbiny et al., 2011; Zafar, 2016; Aden, 2017
Culture & behaviour (CB)	IDV	Fostering WR via financial incentives to encourage municipalities and industry practitioners to act.	CB.1	UNEP, 2009; El-Sherbiny et al., 2011; Arif and Abaza, 2012; Zafar, 2016; Nassour et al., 2016; Aden, 2017
		Establishing educational content about SWM in schools' curriculum.	CB.2	
		Implementing training and educational programmes about SWM and governance, including officials from central and regional governments.	CB.3	
		Arranging information exchange trips for SW officials to share their experiences and knowledge, improve policies, and learn about new green techniques and practices.	CB.4	
		Implementing SWM educational and research programmes at universities.	CB.5	

__Table 2.8f__ Independent and dependent variables with their relevant items and corresponding codes

Construct (i.e., variable)	**Type**	**Indicator (i.e., item)**	**Code**	**References**
Construction and demolition waste reduction (CDWR)	DV	Reducing unnecessary wasted project cost and eliminate project cost overruns.	CDWR.1	Hussin *et al.*, 2013; Caldas *et al.*, 2014; Memon *et al.*, 2015
		Delivering the project within the specified schedule with minimal possible delays.	CDWR.2	
		Delivering the project according to the desired quality and specifications.	CDWR.3	

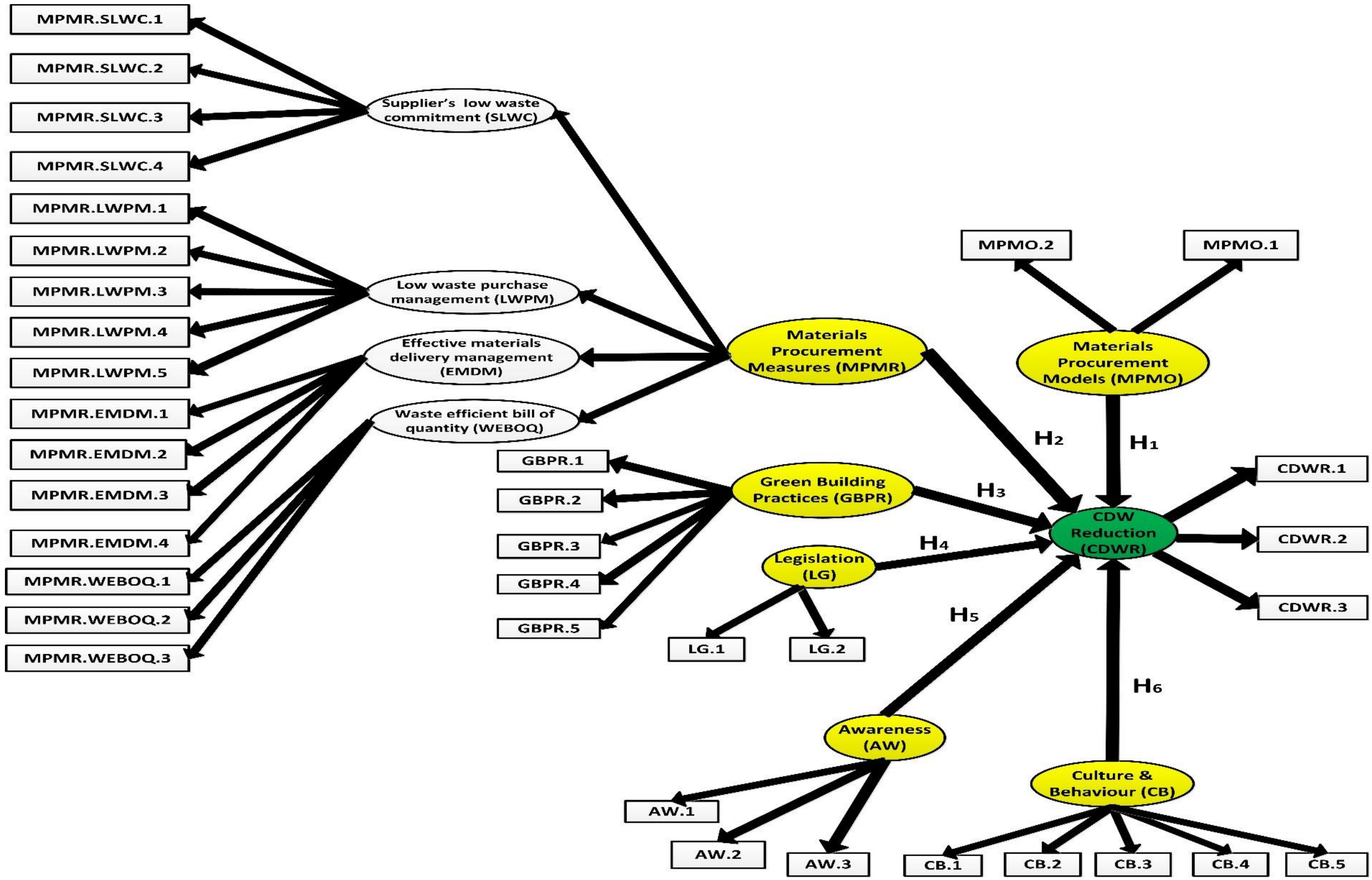

Figure 2.6 *The theoretical framework of the study*

2.9 Summary

This chapter presented a comprehensive literature review about the SW problem in the MENA region and Egypt, focusing on Egypt's CDW problem. It was demonstrated that the SW and CDW problems are growing challenges in the MENA region and Egypt, and urgent solutions need to be found for solving them. This can be explained by the fact that SWG is expected to exceed 200 million tonnes annually in the MENA region, in which most of the SW components are CDW. Based on Egypt's recent statistics in 2017, 90 million tonnes of SW are generated annually, of which 5.8 million tonnes are CDW. Examples of the reasons behind SW and CDW problems in the MENA region and Egypt are (1) absence of strict measures and actions in the SWM sector; (2) lack of public awareness about environmental issues; (3) dumping of SW in open and uncontrolled spaces; (4) lack of sustainable SWM plans; (5) absence of proper means of SW collection and transport systems.

Based on the extensive literature review carried out in this chapter about critical measures and solutions for solving SW in general and CDW in specific, a theoretical framework was built consisting of six IDVs (i.e., factors contributing to CDWR) and one DV (i.e., CDWR) for solving the growing CDW challenge. These six IDVs are as follows: (1) waste-efficient materials procurement measures; (2) waste-efficient materials procurement models; (3) green materials procurement approach of green building practices; (4) legislation; (5) awareness; and (6) culture & behaviour. Six hypotheses were proposed in this framework, which will be tested and validated throughout this study. In the next chapter, the adopted research methodology is investigated in detail in which the discussion includes the following: research paradigm (i.e., research philosophy and approach), research design (i.e., research methods, research strategies, and time horizon of the study), data collection and analysis techniques, and results' validation.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology adopted to address the research questions, aims, and objectives investigated in chapter one. In order to achieve meaningful results, any study requires a methodological approach for data collection and analysis. This chapter outlines the research methodology adopted in this study. This study employed grounded theory, structured interviews, and survey questionnaires. As aforementioned in chapter one, this research focuses on developing an MPCF and improvements proposal to the Egyptian GPRS. Finally, the chapter justifies the adopted research methods and explains the different applied data collection methods and analysis.

3.2 Research Paradigm

Before starting to think of research design and adopted methods, the research paradigm should be first defined. The research paradigm is an overall structure consisting of perceptions, beliefs, and awareness of different theories and methods to conduct research. Defining the research paradigm includes identifying the **research philosophy** and **research approach** adopted in the problem investigation to address the research question(s) (Saunders *et al.*, 2009). It is worth mentioning that both qualitative and quantitative methods can be used with any research paradigm. Accordingly, the concern of research methods is secondary compared to the paradigm's concern, which portrays the beliefs and world view that lead the investigation (Guba and Lincolin, 1994). Both research philosophy and research approach represent the first two layers of the research onion, shown in Figure 3.1, that should be peeled away to build the research map. The highlighted rectangles in Figure 3.1 show the adopted philosophy, approach, methods, strategies, and time horizon in this research investigated in detail in this chapter's next sections.

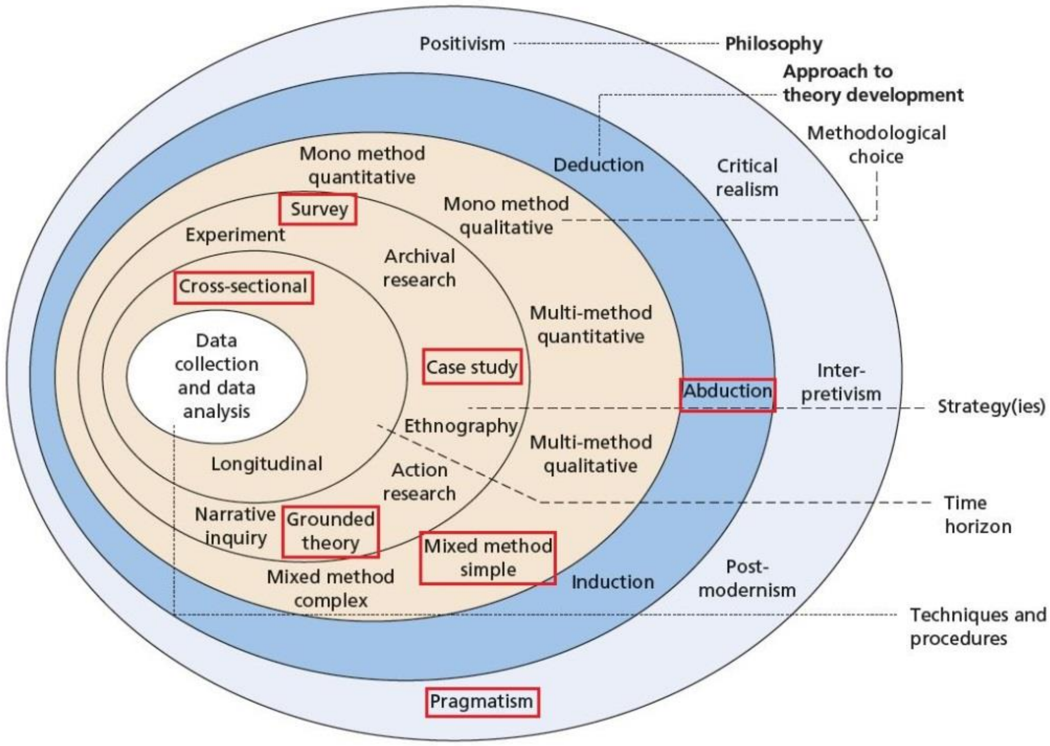

Figure 3.1 *Research onion*

Source: *adapted from (Saunders et al., 2016)*

3.2.1 Research Philosophy

The term "research philosophy" refers to developing research assumptions, knowledge, and nature. It includes critical assumptions about the researcher's view of the world. These assumptions influence and direct the choice of research strategy(ies) and methods. The researcher's view of the relationship between knowledge and its development influences the research philosophy's choice. Therefore, no research philosophy is better than another, as each philosophy is dedicated to doing a specific thing better. In the end, the choice of suitable research philosophy mainly depends on the research question(s) that the researcher is trying to answer (Saunders *et al.*, 2009).

The adopted philosophical position in this study is "pragmatism". Pragmatism argues that the research question(s) is the most crucial determinant of epistemology, ontology, and axiology (Saunders *et al.*, 2009). According to Tashakkori and Teddlie (1998), the pragmatism position is attractive because it encourages the researcher to focus on what they see away from being true or real. The pragmatists believe that reality is not fixed and constant and that the best knowledge is gained through the application of their thoughts and experiences to problems. An advice was given by Tashakkori and Teddlie (1998, p.30) to every researcher in support of the philosophical pragmatism position as follows "*study what interests you and is of value to you, study in the different ways in which you deem appropriate, and use the results in ways that can bring about positive consequences within your value system*". The researcher's epistemology, ontology, and axiology are the key actors in choosing the pragmatism position in this study.

The ontology describes reality's nature, indicated by the researchers' views and assumptions about how the world operates (Saunders *et al.*, 2009). The researcher's ontological assumptions define his/her view of the matter under investigation and how it will be investigated. Ontology has two aspects which are **objectivism** and **subjectivism**. Objectivism argues that both social actors (i.e., us and others) and social reality under research investigation are independent. On the other hand, subjectivism argues that social reality is a result generated by social actors' actions (Saunders *et al.*, 2009). Given the nature of this study's research questions, both objectivism and subjectivism aspects are adopted to address these questions.

Epistemology refers to the researcher's assumptions and views about what seems to be acceptable and valid knowledge in the research and how can this knowledge be transferred to others (Saunders *et al.*, 2009). Different types of knowledge, such as numerical data, textual and visual data, facts, interpretations, and narratives, can be considered valid and acceptable based on the researcher's vision. In this research and based on the research questions, different types of knowledge gained through the research are considered correct and valid. There is no black and white between right and false; however, the researcher assumes a grey area between different types of knowledge where every type of knowledge can be somewhat right and somewhat false because human beings have limits of knowledge, and this knowledge keeps changing all the time.

The axiology is concerned with the role of the researcher's values in the research process (Saunders *et al.*, 2009). Values are a critical role in all human actions. A researcher can shape and define his/her values as a guide for taking decision regarding the research to be conducted and how it will be conducted (Heron, 1996). In value-free research, the researcher is liberated from being involved in the data and remains neutral to the research investigation. In value-laden research, the researcher is influenced by world views and experiences, which may lead to research bias. However, the researcher works on minimising bias and errors and tries to remain objective as much as possible. In value-bound research, the researcher is involved in what is being investigated in the research, and s/he cannot be liberated or isolated and adopts a subjective stance. In value-driven research, the research process is started and maintained by the researcher's beliefs and doubts in which the researcher adopts both objective and subjective stances (Saunders *et al.*, 2016). In this study, the research is value-driven in which values are a key role actor in discussing results and data.

After discussing the researcher's ontology, epistemology, and axiology in this study, this explains why this research's philosophical pragmatism position is adopted. To summarise this section, the philosophical pragmatism position and its associated ontology, epistemology, and axiology are summarised in Table 3.1. The philosophical pragmatism position influences the research approach choices and research methods, as discussed in the following sections.

Table 3.1 *Reasons behind choosing philosophical pragmatism position*

Source: *adapted from (Saunders et al., 2009; Saunders et al., 2016)*

	Pragmatism
Ontology: the researcher's view of the nature of reality or being	External, complex & rich, multiple, and view is chosen to enable the research question's best answering. Reality is the practical consequences of ideas. It is a flux of processes, experiences, and practices.
Epistemology: the researcher's view regarding what constitutes acceptable knowledge	Either or both observable phenomena and subjective meanings can provide sufficient knowledge dependent upon the research question. Focus on practical applied research, problems, and practices by integrating different perspectives to interpret the data. The main contribution to knowledge is problem-solving and informed future practice.
Axiology: the researcher's view of the role of values in research	Value-driven research in which values play a large role in interpreting results, the researcher adopts both objective and subjective points of view. The research is initiated and sustained by the researcher's doubts and beliefs.
Data collection techniques most often used	Mixed or multiple method designs, quantitative and qualitative. Different methods can be adopted to help in solving the research problem and addressing research questions. The main focus is on practical solutions and outcomes.

3.2.2 Research Approach

The research design mainly depends on the degree to which a researcher is clear about the theory at the beginning of the research process. Based on his vision to theory, a researcher may adopt one of three research approaches as follows: **deductive**, **inductive**, and **abductive** (Saunders *et al.*, 2016). In the deductive approach, the research process is initiated with theory, which is developed from the literature review, and the research strategy is designed to test this theory in which it can be either true or false. In the inductive approach, the research process is initiated by collecting data and then analysing it to build or develop a theory. In the abductive approach, the research process goes back and forth between data and theory. The research is initiated by collecting data to: explore a specific phenomenon, define themes and investigate patterns, then develop and build a new theory or modify an existing theory that will be further tested through additional data collection methods (Saunders *et al.*, 2016). The abductive approach was adopted in the course of this study because the research topic seems to include rich information in one context (i.e., developed countries) but far less in the context under investigation (i.e., Egypt as a developing country). Therefore, the researcher needed to adopt the **abduction approach** to go back and forth between data and existing theories to explore their suitability in the local context through data collection and analysis. Other reasons for adopting the abduction approach are listed in Table 3.2 which shows this approach's features.

Table 3.2 *Features of abduction research approach*

Source: *adapted from (Saunders et al., 2009; Saunders et al., 2016)*

	Abduction
Logic	Known assumptions are used in an abductive inference to draw relevant conclusions.
Generalisability	Generalising the relationships between the specific and the general.
Use of data	Data collection is used for phenomenon examination, identification of subjects and trends, development of conceptual frameworks and testing using appropriate data collection methods.
Theory	Generation or adjustment of theory; integrating existing theory, if necessary, to construct new theory or adjust and upgrade existing theory.

3.3 Research Design

Research design is the process of setting a plan for answering the research questions included in the study (Saunders *et al.*, 2009). It consists of three main layers in the research onion as follows: research methods, research strategies, and time horizon of the study. The research questions influence the choice of (1) research methods; (2) research strategies; and (3) the time horizon of carrying out the research. The research design will include crystal clear objectives drawn from the research questions, different sources for data collection, and expected challenges (i.e., access to data, time, location and money) and ethical issues (Saunders *et al.*, 2009).

Given the nature of the research problem, questions, and objectives of this study, the research process adopted three main phases, as indicated in Figure 3.2, as follows: (1) exploratory research to achieve objectives 1 and 2; (2) a mix of exploratory and descriptive research to achieve objectives 3 and 4; and (3) a mix of descriptive and explanatory research to achieve objectives 5, 6, and 7. In **exploratory** research, the researcher tries to search for the problem's reasons (Saunders *et al.*, 2009). It helps discover the precise nature of the problem. In **descriptive** research, the researcher tries to investigate the accurate profile of situations. It is necessary to have a deeper understanding and a clear view of the phenomenon on which data need to be collected before collecting the necessary data. In **explanatory** (i.e., causal) research, the researcher investigates the causal relationships between independent and dependent variables through different statistical analysis techniques (Saunders *et al.*, 2009). Each phase was sequentially adopted in this study to aid in initiating the next phase. The adopted research methods and research strategies are used to help achieve each phase's desired aim, as discussed in the next sub-sections.

3.3.1 Research Methods

This study adopted mixed-method research in which quantitative and qualitative data collection tools and analysis procedures were used. However, quantitative data were analysed quantitatively, and qualitative data were analysed qualitatively. A simple mixed research method was adopted to answer the different questions in each research phase and achieve the research objectives. The main reasons for using mixed-method research in this study are summarised and explained in Table 3.3.

Table 3.3 *Reasons for choosing mixed-method research*

Source: *adapted from (Saunders et al., 2009; Saunders et al., 2016)*

Reason	**Explanation**
Triangulation	Usage of two or more different sources of data or data collection methods to validate and confirm the results of the analysis in a study.
Complementarity	Usage of two or more research strategies to combine various aspects of the study.
Aid interpretation	Usage of qualitative data to clarify correlations between quantitative data.
Study different aspects	Quantitative methods are used for investigating macro aspects, and qualitative methods are used for investigating micro aspects.

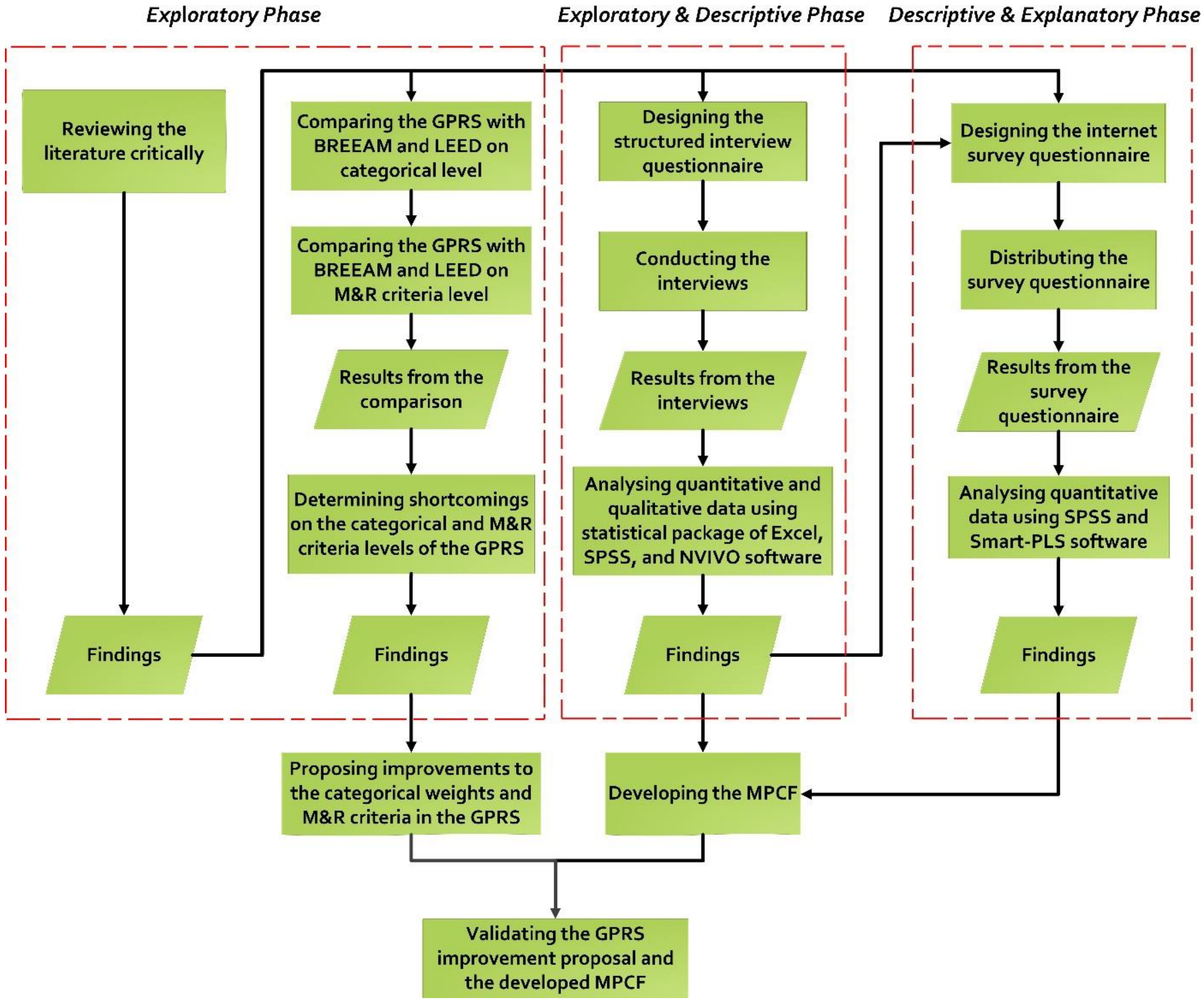

Figure 3.2 *Research design*

Source: *developed by the author*

3.3.2 Research Strategies

3.3.2.1 Grounded Theory

In the exploratory phase, the "**grounded theory**" strategy was used. Grounded theory was developed to help develop and build a theory based on qualitative data analysis. Different stages of collecting, refining, and categorising data are used (Strauss and Corbin, 2008). In this study, data are collected through reviewing different documents (e.g., publications, theses, governmental reports, green building codes) to gain a broader understanding and experience. After that, data analysis was carried out, including the refining and categorising of the qualitative data. Data refining includes reducing the data by selection, simplification, and abstraction of the raw data. In other words, it means reducing data in main categories (i.e., themes) (Miles and Huberman, 1994). Categorising includes coding the raw data under the main categories. In other words, it means assigning data in subcategories (i.e., subthemes) to main categories (Strauss and Corbin, 2008).

Constant comparative method and theoretical sampling are crucial strategies to develop a grounded theory (Creswell, 2007). The constant comparative method is adopted to generate concepts from the data by coding and analysing data simultaneously. It includes four main stages as follows: "*(1) comparing incidents applicable to each category; (2) integrating categories and their properties; (3) delimiting the theory; and (4) writing the theory*" (Glaser and Strauss, 1967, p. 105). This strategy is beneficial as the researcher starts with raw data, and a theory shall be developed through continuous comparisons included in data collection, refining, and categorising. The theoretical sampling includes additional cases in the investigation of constant comparison method to gain new insights or widen and clarify concepts already captured. Theoretical sampling helps in validating relationships among the data and ensuring that the categorical findings are robust and precise (Kolb, 2012).

Grounded theory was used in the **literature review** to refine and categorise the literature data to develop a theory(ies) that are to be investigated and tested in the descriptive and explanatory phases, respectively. A critical literature review was carried out to explore different knowledge areas (i.e., themes), as presented in chapter two. Based on the shortcomings found in the GPRS through literature review, grounded theory was also used to develop a **proposal (i.e., theory) of improvements to GPRS**, which was validated through experts in academia and industry as discussed later in this chapter, through comparing it with the well-established BREEAM and LEED. This was carried out by comparing the GPRS with BREEAM and LEED on the categorical level and on the criteria level of M&R category to overcome shortcomings and limitations existing in the current version of the GPRS. This helped in proposing new weights to the GPRS categories to overcome Egypt's environmental challenges in general. In specific, this helped in proposing improvements to the M&R category of the GPRS by suggesting modifications to its existing criteria or additions of missing criteria. This is needed to help in minimising the hazard of the CDW problem in Egypt. The results of the comparison and the GPRS improvement proposal are introduced in chapter four of this thesis.

3.3.2.2 Case Study

In the exploratory and descriptive phase, a “case study” strategy was used. A case study is defined by (Robson, 2002, p. 178) as “*a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence*”. The case study strategy helps the researcher capture a deeper understanding of the researcher context and its processes (Morris and Wood, 1991). It is used when the researcher tries to investigate opinions, attitudes, and organisational practices. Different data collection tools can be used separately or in combination while conducting a case study, such as interviews, observation, documentary analysis, and survey questionnaires (Saunders *et al.*, 2009).

A multiple case study was conducted, in which multiple cases were included in this study’s investigation. The reason behind choosing this type of case study strategy was to determine the differences and similarities between the cases under investigation (Saunders *et al.*, 2009). The case study conducted in this research helps in: (1) quantifying CDW in terms of costs and generation rates among different types of projects (i.e., industrial, residential, commercial, and infrastructure) in the Egyptian construction industry; and (2) exploring the relationship between CDWG and different factors affecting CDWR such as waste-efficient materials procurement practices, awareness, culture & behaviour, and legislation. Different data collection methods are being adopted in the case study as follows: (1) analysis of documents collected from different projects; and (2) structured interview questionnaire.

Structured interviews, which are interviewer-administered questionnaires, were used in this multiple case study to ensure that the respondent is the one who is wanted to be included in the study (Saunders *et al.*, 2009). For instance, the researcher wants answers from industry professionals who deal closely with construction materials in the construction project. Accordingly, the selection criterion was interviewing project managers and procurement managers of the selected four construction projects. Consequently, the collected data shall have high reliability.

Based on the literature review findings, as discussed in the previous chapter, the interview questionnaire was designed for data collection from the targeted participants. It was divided into four main sections, as shown in appendix A. Section one investigates the respondents' demographic information and their firms. Section two aims to determine: (1) the CDWG rates in main common building materials (i.e., timber, sand, concrete, cement, reinforcement steel, tiles, bricks/blocks) in the selected construction projects; and (2) a brief description of these projects. Section three aims to explore: (1) the current adopted materials procurement models and measures; and (2) GB practices regarding green materials procurement approach in the selected construction projects. Finally, section four aims to investigate and examine the current status of awareness, practices, culture & behaviour, and adopted CDWM legislation at the respondents' firms.

A mix of open and close-ended questions was used in the different sections of the interview questionnaire. Open-ended questions allow the respondents to answer the questions in their way or wording (Saunders *et al.*, 2016). This questions' type helps the researcher seeking a detailed answer or when s/he wants to explore what is uppermost in the respondent's mind. This questions' type was used to allow the respondents to talk openly about the project nature and details, CDWG rates, limitations/advantages of current applied practices, and their perception of Egypt's CDW problem. On the other hand, close-ended questions or forced-choice questions allow the respondent to choose his/her answer from a list of alternative predetermined answers. This questions' type helps the researcher make sure that the respondent has considered all possible answers while responding (Saunders *et al.*, 2016).

For closed-ended questions, ordinal (i.e., rating) scales, namely Likert scales, were developed to investigate the different factors affecting CDWR at the respondents' firms. Likert scales are suitable for collecting attitudinal information about the subjective matter (Rea and Parker, 1997). All five-point Likert scales were adopted from studies carried out by Vagias (2006) and Brown (2010). Five-point Likert scales were used to increase response rate and quality and reduce respondents' frustration (Babakus and Mangold, 1992). For instance, awareness was evaluated on a Likert scale, in which "1" means "not aware at all", and "5" means "extremely aware". Also, different practices were evaluated on a Likert scale to assess the frequency of their application. In this case, "1" means "never", and "5" means "always". Moreover, culture & behaviour was evaluated using different five-point Likert scales. Two evaluating questions used the "interest" Likert scale to assess the degree of interest in reducing CDW, in which "1" means "not interested at all", and "5" means "extremely interested". One evaluating question used the "frequency" Likert scale to assess the extent of encouraging labours and employees to reduce CDW during project execution. One evaluating question used the "agreement" Likert scale to assess the degree of agreement on the fact that the respondents' firms are implementing and developing the culture & behaviour of CDWR at their firms. In this scale, "1" means "strongly disagree", and "5" means "strongly agree". Finally, legislation were evaluated using "agreement" Likert scale to assess the degree of agreement on the fact that the respondents' firms are abiding by the Egyptian legislation.

3.3.2.3 Survey

In the descriptive and explanatory phase, a "survey" strategy was used. The survey strategy, which is a self-administered questionnaire, is helpful when the researcher tries to investigate both following aspects: (1) attitudes, opinions, and organisational practices; and (2) relationships between different variables, mainly cause-effect relationships (Saunders *et al.*, 2016). It helps collect data from a sufficient sample size to allow generalisation of the findings. The survey conducted in this research helps in investigating: (1) the current applicability level of different factors affecting CDWR and their level of effectiveness towards solving the CDW problem in Egypt; and (2) the cause-effect relationships between the different aforementioned defined factors and CDWR in Egypt.

There are three methods of a survey as follows: (1) internet questionnaire; (2) postal (mail) questionnaire; and (3) delivery and collection questionnaire. **Internet questionnaire** was used as a survey method in this study, in which questionnaires were sent electronically to respondents through the internet. Respondents can access the questionnaire via a hyperlink through their web browser or mobile. This method was adopted in this study due to its feasibility and efficiency as follows: (1) it can be used for a large sample size; (2) high confidence that the right person is targeted and contacted; (3) suitable with close-ended questions; and (4) automated data input (Saunders *et al.*, 2016).

Based on the literature review findings supplemented with the interview questionnaire's results, the internet survey questionnaire was designed for data collection from the targeted sample size. It was divided into five sections main sections, as shown in Appendix B. Section one investigates demographic information of the respondents and their firms. Also, it investigates the CDW problem in Egypt and its current status. Section two evaluates: (1) the current applicability of materials procurement models and measures and green building practices within the Egyptian construction industry; and (2) their effectiveness towards CDWR. Section three evaluates the applicability of Egyptian CDWM legislation and their effectiveness towards CDWR. Section four evaluates the applicability of awareness and culture & behaviour measures in Egypt and their effectiveness towards CDWR. In other words, sections two, three, and four evaluate the factors affecting CDWR in terms of current applicability and effectiveness in reaching the goal of CDWR. Finally, section five evaluates the agreement on the expected improvement of different project dimensions (i.e., cost, time, and quality) via CDWR. In other words, the last section (i.e., section five) evaluates the expected outcomes or goals of CDWR, which would result from the **effectiveness** of the factors behind it.

All the questions used in the survey questionnaire are close-ended. Three types of five-point Likert scales were developed, based on studies of Vagias (2006) and Brown (2010), to answer the sections mentioned above. First, the "applicability" Likert scale was used to assess the current degree of applicability of different factors contributing to CDWR in the Egyptian construction industry as defined by the literature and investigated in the "theoretical framework" in chapter two. In this scale, "1" means "not applicable at all", and "5" means "extremely applicable". Second, "effectiveness" Likert scale was used to assess the degree of effectiveness of these different factors towards CDWR, in which "1" means "not effective at all", and "5" means "extremely effective. Finally, "agreement" Likert scale was used to assess the degree of agreement on the expected outcomes of CDWR towards project dimensions' improvement.

3.3.2.4 Ethics Approval

As discussed in the adopted research strategies, this study requires the collection of data from human subjects. Accordingly, the study was submitted to the Built Environment and Architecture Ethics Panel at London South Bank University (LSBU) for ethical review before data collection. The panel approved the ethics application on the 16th of May 2019, and the researcher collected the data after this date.

3.3.3 Time Horizon of the Study

The time horizon of this study was cross-sectional as the research focuses on studying a specific phenomenon (or phenomena) within a particular time (i.e., the duration of the investigation). This time horizon was chosen because the research was taking place through an academic course within a specified time frame (i.e., four years).

3.4 Primary Data Collection & Analysis Techniques

3.4.1 Structured Interview Questionnaire

3.4.1.1 Validation of the Interview Questionnaire

The interview questionnaire's face and content validation was done by reviewing by ten experts to ensure that the questions are clear, focused, and match the addressed objectives. The number of selected experts satisfies the recommended maximum number for face and content validation, as stated by (Wai Lam *et al.*, 2018; Saiful and Yusoff, 2019). This step is critically important to ensure that the questions are clear, focused, contextually relevant, and match the addressed objectives before using it in data collection from the four construction projects. Face validation aims to ensure that the questions of the survey are easy to understand, clear, and readable, while content validation aims to ensure that the measurement questions included in the questionnaire are covering and representing the investigative research questions and aims of the questionnaire (Saunders *et al.*, 2009; Burton and Mazerolle, 2011).

The ten experts were chosen as follows: (1) five industry professionals who hold managerial positions in the construction industry; and (2) five academics who are professors of construction engineering and management. All experts have more than 15 years' experience of industrial work or teaching and research, respectively. Feedback was received from the selected experts, and the interview questionnaire was modified accordingly. The average time taken to complete the questionnaire was approximately 45-60 minutes based on the respondents' feedback. Also, there was a consensus among the selected experts that the interview questionnaire should be conducted using Arabic or a mix between Arabic and English. This suggestion was introduced due to the complexity of some used terminologies and concepts and the fact that English is not the first language in Egypt. Accordingly, this recommendation was taken into consideration during the administration of the interviews.

3.4.1.2 Selection of Cases & Participants

This study was conducted as a multiple case study (i.e., comparative case study) of four different construction projects (i.e., industrial, residential, commercial, and infrastructure project) located in Egypt. The number of cases included in this study satisfies the recommended number of cases in a comparative case study, as stated by Eisenhardt (1989) and Creswell (2013). Moreover, the number of these cases is convenient due to the local construction industry's nature and resources constraints in data collection from the targeted participants. The cases were selected via direct contact with the researchers in this study. The direct contact facilitated the data collection from the targeted four construction projects based on his referrals to procurement managers and project managers of these projects, referred to as “snowball sampling” (Naderifar *et al.*, 2017). The demographic information of the participants is investigated in detail in chapter five.

3.4.1.3 Administration of Interview Questionnaire

A project manager and a procurement manager of each project were invited to participate in this study given the nature of their roles in controlling and dealing with project resources (i.e., materials, labours, and equipment). Every single case consists of two participants, and the comparative case study in total consists of eight participants, in which the participants have more than ten years’ experience. The number of interviews included in the comparative case study is sufficient given the study's nature as a phenomenological study and the homogeneity among the participants’ roles and experiences (Dukes, 1984; Parse, 1990; Ray, 1994; Kuzel, 1999; Smith *et al.*, 2009). It was made sure that the participants get brief information about the study aim at the beginning of the interview. It was also ensured that the participants carefully read and signed the consent form before starting the interview. A mix of Arabic and English was used during the whole interviews.

3.4.1.4 Checking Consistency and Reliability – Cronbach's alpha

A measure of consistency, called Cronbach's alpha coefficient, is statistically derived to verify that the responses of the participants towards the evaluation of the different CDWR factors (i.e., awareness, practices, culture & behaviour, and legislation) are consistent and the used measurement tools (i.e., Likert scales) are reliable. The value of Cronbach's alpha coefficient ranges between 0 and 1, in which the closer the Cronbach's alpha coefficient is to 1, the greater the internal consistency of the data collected from the participants towards the evaluation of the different abovementioned factors (George and Mallery, 2003). Interpretations of Cronbach's alpha coefficient values towards consistency measurement are summarised, as seen in Table 3.4.

Table 3.4 *Determining consistency through Cronbach's alpha coefficient value*

Source: *(George and Mallery, 2003)*

Cronbach's Alpha Coefficient Value (α)	**Interpretation of Consistency**
$1.0 \geq \alpha \geq 0.9$	Excellent consistency
$0.9 > \alpha \geq 0.8$	Good consistency
$0.8 > \alpha \geq 0.7$	Acceptable consistency
$0.7 > \alpha \geq 0.6$	Questionable consistency
$0.6 > \alpha \geq 0.5$	Poor consistency
$\alpha < 0.5$	Unacceptable consistency

Cronbach's alpha coefficient was calculated via **Statistical Package for the Social Science (SPSS) V26**© software for the different abovementioned factors, and it has been noticed that all the values exceeded 0.7, as shown in Table 3.5. This result means that the consistency among the responses exceeded the minimum limit of being acceptable, and the used measurement scales for data collection are reliable. This result confirms that there is no need to redesign the questionnaire and recollect the data or exclude any responses. Finally, the overall Cronbach's alpha coefficient was calculated for the whole section of the factors resulting in a value of 0.95. This result indicates an excellent overall level of internal consistency and reliability of scales.

Table 3.5 *Calculation of Cronbach's alpha for different factors*

Evaluated Factors	**Number of Items**	**Number of the Questions in the Interview Questionnaire**	**Cronbach's Alpha Coefficient Value (α)**
Awareness	4	Q11 – Q14	0.79
Practices	3	Q15 – Q17	0.85
Culture & behaviour	5	Q18 – Q22	0.91
Legislation	2	Q23 – Q24	0.83
Total	14	Q11 – Q24	0.95

3.4.1.5 Approach to Qualitative and Quantitative Data Analysis

Thematic analysis of qualitative data, obtained from open-ended questions, was carried out using **NVivo 12©** software, which helped organise the collected textual data and interpret it. The thematic analysis helps analyse large and small qualitative data sets resulting in detailed descriptions, explanations, conclusions, and theories. Its primary purpose is to explore themes and patterns among a textual data set through data coding into subthemes and themes (Saunders *et al.*, 2016). The thematic analysis was carried out through three sequential steps. First, the qualitative responses of each respondent were entered separately in **NVivo 12©** software. Second, thematic analysis was conducted via **NVivo 12©** software by "coding" the related textual data and assigning them to "child node" (i.e., subtheme). Third, the "child nodes" are assigned later to their relevant "parent nodes" (i.e., theme), which represent the "themes" investigated in the questionnaire, leading to detailed descriptions and conclusions. The results of qualitative data analysis are investigated in chapter five.

Quantitative data collected via the interview questionnaire are classified into: (1) ranges of CDWG rates; and (2) scores given on Likert scales to evaluate the different factors (i.e., awareness, practices, culture & behaviour, and legislation). For CDWG rates, the weighted arithmetic mean is calculated using **Microsoft Excel 2016©** software to consider an average CDWG rate, presented as a percentage, taking into consideration the weight of each expert's opinion based on the number of years spent in the industry as indicated in the following equation:

$$\boldsymbol{CDWG\ rate} = \frac{CDWG1 \times years\ of\ experience + CDWG2 \times years\ of\ experience}{sum\ of\ years\ of\ experience\ of\ both\ respondents}$$

The quantities of materials used in the project and cost per materials unit were retrieved from projects' documents as introduced by the interviewed managers. Accordingly, the total costs of used materials were calculated following the next equation:

$$\boldsymbol{Total\ cost\ of\ procured\ material} = total\ quantity\ of\ procured\ material \times cost\ per\ material\ unit$$

After that, the cost of wasted material is estimated based on the calculated CDWG rate for each material, as indicated in the following equation:

$$\boldsymbol{Cost\ of\ wasted\ material} = \frac{CDWG\ rate\ \times total\ cost\ of\ procured\ material}{100}$$

Finally, the percentage of total wasted materials cost in relation to total procured materials cost in a project is calculated using the following equation:

$$\boldsymbol{Percentage\ of\ total\ wasted\ materials'\ cost} = \frac{total\ cost\ of\ wasted\ materials}{total\ cost\ of\ procured\ materials} \times 100$$

For the Likert scales scores, these scores are first normalised for each respondent using the minimum-maximum normalisation approach using **Microsoft Excel 2016©** software. Since different types of scales were sometimes used to measure the metrics (i.e., questions) and in order to maintain consistency in evaluating the different factors, each appropriate response was "normalised" by assigning it an equivalent normalised value ranging from 0 to 1 in order to enable aggregation on the factor level and to get a representative "composite index" (CI) representing the overall evaluation of the factor (Mazziotta and Pareto, 2013; Hudrliková, 2013). All aggregation processes were carried out using **Microsoft Excel 2016©** software.

The Likert scales used in the interview questionnaire were five-point (i.e., 1–5) scales. Score (1) is represented by normalised score (0), score (2) is represented by normalised score (0.25), score (3) is represented by normalised score (0.5), score (4) is represented by normalised score (0.75), and score (5) is represented by normalised score (1). Then, the normalised responses for the metrics measuring a specific factor were aggregated on the metric level using simple arithmetic mean in which all metrics (i.e., indicators) measuring the same factor are assumed to have equal weights and to be independent of each other. Simple arithmetic mean was used in aggregation on the metric level as it is the most common and transparent method used in aggregating different variables (Salzman, 2003). The result of aggregation on the metric level indicates each respondent's evaluation towards the factor which the metrics are measuring as demonstrated in the following equation:

$$\boldsymbol{Respondent's\ (R)\ evaluation\ towards\ a\ factor} = \frac{Sum\ of\ metrics'normalised\ responses}{number\ of\ metrics}$$

After that, the aggregation process took place on the factor level using the respondents' aggregated scores on the metric level. Weighted arithmetic mean was used in aggregation on the factor level to consider the experience of the respondents in the weight of the responses, as demonstrated in the following equation:

$$\boldsymbol{CI} = \frac{R1 \times years\ of\ experience + R2 \times years\ of\ experience}{sum\ of\ years\ of\ experience\ of\ both\ respondents}$$

CI represents the result of aggregation on the factor level, a score ranging from 0 to 1, divided over a five-point rating scale to indicate the respondents' overall evaluation of each factor as shown in Table 3.6 (Daoud *et al.*, 2017). Finally, the CIs of all factors are aggregated together using simple arithmetic mean to give an overall evaluation of WM at the construction firm executing the investigated project. The results of quantitative data analysis are investigated in detail in chapter five.

Table 3.6 *Interpretation of the overall evaluation of the factor based on the value of the CI*
Source: *(Daoud et al., 2017)*

Mean Value of CI for the Factor	**Interpretation of the Value Towards the Overall Evaluation of the Factor**
0.00 – 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Good
0.61 – 0.80	Very Good
0.81 – 1.00	Excellent

3.4.2 Online Survey Questionnaire

3.4.2.1 Pilot Testing of the Survey Questionnaire

An initial pilot study was carried out to assess the survey questionnaire's comprehensiveness, clarity, and feasibility (Ruel *et al*., 2018). The recommended minimum sample size for pilot testing is 10 participants (Saunders *et al.*, 2016). The sample included in this pilot test consisted of 30 participants, of which 15 participants are industry professionals, and the other 15 participants are academics with more than ten years' experience of industrial work and teaching & research, respectively. Face and content validation were achieved through piloting with the experts mentioned above. Feedback was received from the selected experts, and the survey questionnaire was modified accordingly. The average time taken to complete the questionnaire was approximately 45-60 minutes based on the respondents' feedback.

Similarly, like the interview questionnaire, there was a consensus among the selected experts that the survey questionnaire should be designed in Arabic and English. This is due to the complexity of some used terminologies and concepts and that the English language is not the first language in Egypt. Accordingly, this recommendation was taken into consideration. The survey questions were translated, and the survey questionnaire was redesigned to include Arabic and English questions.

As the survey questionnaire was going to be distributed among a large sample size, as discussed later in this chapter, it is difficult to repeat the process to get a second round of responses. Accordingly, the internal consistency and reliability of the survey questionnaire were checked before conducting the actual study. It was essential to ensure that the expected responses will be consistent and the used measurement tools (i.e., Likert scales) are reliable before actual data collection (Daoud *et al.*, 2017). Through the pilot testing of the survey questionnaire, Cronbach's alpha was calculated for the different variables included in the questionnaire using **SPSS V26**© software to check consistency and reliability. All the values exceeded the threshold value of 0.7, as stated by George and Mallery (2003). This result ensures the consistency among responses and the reliability of the used Likert scales. It is worth mentioning that all the factors (i.e., independent variables) contributing to CDWR had two values of Cronbach's alpha: one for applicability Likert scale and the other for effectiveness Likert scale, as shown in Table 3.7. On the other hand, CDWR (i.e., dependent variable) had one value of Cronbach's alpha for the agreement Likert scale.

Table 3.7 *Calculation of Cronbach's alpha for the different variables in the pilot survey*

Category	**Subcategory (if applicable)**	**Number of Items**	**Number of the Questions in the Survey Questionnaire**	**Cronbach's Alpha**
MPMO		2	Q9a – Q9b	0.722 / 0.711
MPMR	SLWC	4	Q10.1.a – Q10.1.d	0.706 / 0.758
	LWPM	5	Q10.2.a – Q10.2.e	0.811 / 0.724
	EMDM	4	Q10.3.a – Q10.3.d	0.892 / 0.885
	WEBOQ	3	Q10.4.a – Q10.4.C	0.713 / 0.706
GBPR		5	Q11.a – Q11.e	0.772 / 0.764
LG		2	Q12.a – Q12.b	0.708 / 0.710
AW		3	Q14.a – Q14.c	0.917 / 0.714
CB		5	Q15.a – Q15.e	0.726 / 0.715
CDWR		3	Q16.a – Q16.c	0.746

3.4.2.2 Sample Size – Targeted Participants

The Egyptian Federation for Construction and Building Contractors (EFCBC) currently includes 28,000 construction companies as active members (Sada Elbalad, 2018). These firms are classified into seven grades based on eight main criteria as follows: (1) invested financial capital; (2) contractor's years of experience; (3) number of technical staff; (4) financial structure; (5) administrative and legal structure; (6) the highest value of the work carried out during the last five years; (7) the value of the largest operation completed during the five years before the submission of the upgrade application; and (8) the upper limit of the allowable value of the tender (El Ehwany, 2009; EFCBC, 2017). Grades one, two, and three are considered "large firms", grades four and five are considered "medium firms", and grades six and seven are considered "small firms" (El Ehwany, 2009). According to El Ehwany (2009), more than 80% of the registered firms belong to the sixth and seventh grades. This statistic means that most Egyptian construction firms are small-sized ones that carry out small-scale and simple construction activities and depend mainly on the workforce more than advanced construction techniques.

In this study, the population considered for sample size calculation was the construction firms registered at EFCBC and located in Greater Cairo (GC). GC was chosen as the central area of investigation for this study for the following reasons: (1) it includes all similarities and contradictions; (2) diversity in levels of education; (3) large number of construction projects; (4) it is political, financial, commercial, and administrative governance; and (5) it includes more than 60% of Egypt's CDW (Hany and Dulaimi, 2014). According to the data provided by EFCBC (2019), it was indicated that GC includes 1400 construction firms with different grades, as summarised in Table 3.8.

Table 3.8 *Number of different construction firms in Greater Cairo*

Source: *(EFCBC, 2019)*

Classification of Firms	Number of Firms
1st-grade	79
2nd-grade	57
3rd-grade	62
4th-grade	154
5th-grade	161
6th-grade	100
7th-grade	787

First, the representative sample size was calculated from the total population (i.e., 1400 construction firms) in GC using a sample size calculator provided by **SurveyMonkey**©. This calculator needs three inputs to calculate the sample size as follows: (1) population; (2) confidence level %; and (3) margin of error (i.e., confidence interval) %. The margin of error is a percentage that indicates how much the survey results (i.e., sample mean) can be expected to be higher or lower compared to the actual views (i.e., mean) of the population. The confidence level is a percentage that represents how confident the researcher can be that the population would choose an answer within the confidence interval (Smith, 2013). Based on a study carried out by Conroy (2006), 95% is the most recommended confidence level in survey research. Also, it was recommended to adopt a confidence interval between 5% and 10%. Accordingly, this research adopted a confidence level of 95% and a confidence interval of 7.5%, leading to a sample size equal to 153 firms approximately.

Second, stratified random sampling was done for the seven grades to determine the number of companies that need to be chosen from each category of the total sample size (i.e., 153 firms). The main advantages of stratified sampling are as follows: (1) decreasing the occurrence of bias in the selection of cases to be involved in the sample, and this means that the sample will be highly representative to the population under investigation; (2) permitting the generalisation (i.e., statistical inferences) from the sample to the population because the cases chosen to be involved in the sample are selected based on probabilistic methods, and this is a tremendous advantage as such generalisation seems to have external validity; and (3) ensuring the involvement of sufficient sample points to help in a separate analysis of any strata (Sharma, 2017; Stat Trek, 2018). The following formula calculates the sample size for each stratum (i.e., grade):

$$\boldsymbol{Stratum\ sample\ size} = \frac{size\ of\ entire\ sample}{\text{population size}}\ X\ stratum\ size$$

The stratified sample size for each stratum is summarised in Table 3.9. Finally, simple random sampling was done using random numbers generated by **Microsoft Excel 2016©** software to randomly choose the number of companies from each grade resulting from the stratified sampling.

Table 3.9 *Stratified sampling of construction firms in Greater Cairo*

Classification of Firms	**Stratified Sample Size**
1st-grade	9
2nd-grade	7
3rd-grade	7
4th-grade	17
5th-grade	18
6th-grade	11
7th-grade	87

3.4.2.3 Distribution of Survey Questionnaire

Based on the construction firm's contact information provided by EFCBC (2019), the construction firms chosen using stratified random sampling were contacted via different communication channels (e.g., Fax, emails, WhatsApp messages). It was required from each company to provide the researcher with at least one response. This is based on the availability of engineers who are working in project management and procurement management departments, architects, or civil engineers. The first month passed with no responses sent by any of the targeted companies. Accordingly, reminders were sent once and twice to these companies. Unfortunately, another month passed with no willingness of these companies to participate in the survey questionnaire.

Accordingly, the researcher had to adopt a new way to collect the data needed to test the proposed hypotheses in this study. The researcher distributed the survey questionnaire among different Egyptian industry professionals via different social media channels like Linkedin, Twitter, ResearchGate, emailing list of Co-operative Network of Building Researchers (CNBR), and Facebook groups of civil engineers and architects. For Linkedin, different keywords were used in the search to target Egyptian industry professionals who are related to the topic such as "Egypt", "procurement management", "project management", "construction management", "civil engineer", "architect", "technical office engineer". They were added by the researcher on Linkedin, and messages were sent to them explaining the topic with the survey questionnaire link. For Twitter, ResearchGate, and the emailing list of CNBR, a post including a survey link with topic explanation was written via these channels to kindly ask industry professionals who have experiences in the Egyptian construction industry to provide the researcher with their responses. For Facebook groups, a search was done to explore the groups, including the largest number of Egyptian architects and civil engineers. The survey questionnaire was posted through these different groups. Finally, 244 valid and complete responses were collected through the different channels mentioned above. An initial check of the respondents' collected demographic information ensured that the collected responses covered the different classification grades of construction firms, as investigated later in chapter six.

3.4.2.4 Approach to Quantitative Data Analysis

The quantitative analysis of the collected responses from the survey questionnaire was divided into two main sections: (1) descriptive and inferential statistical analysis; and (2) multivariate statistical analysis. First, descriptive and inferential statistical analysis was carried out before proceeding to multivariate statistical analysis. Descriptive statistics (e.g., mean, frequency, standard deviation, cross-tabulation, and relative importance index (RII)) is useful in describing, summarising, and visualising collected data in numerical and graphical formats to show different patterns coming out from the data (Sutanapong and Louangrath, 2015). It helps understand the data's nature in a meaningful way with simple interpretations before proceeding to statistical modelling using multivariate techniques. Descriptive statistics were used to determine respondents' demographic information, the perspectives towards the CDW problem in Egypt, and ranking the different factors affecting CDWR based on their applicability and effectiveness. Different descriptive statistical analysis operations were carried out using **SPSS V26©** software, and the results are discussed in detail in chapter six. However, RII analysis was carried out using **Microsoft Excel 2016©** software to develop an excel sheet, including the formula of RII as investigated in chapter six, to rank the different factors.

On the other hand, inferential statistics (e.g., chi-square test of independence and correlation analysis) helps in making predictions or inferences from the collected data, which helps in reaching conclusions about the relationships between different separated variables from the collected data and generalising them to general conditions (Sutanapong and Louangrath, 2015). A Chi-square test was carried out to examine the dependence and association between the current applicability and effectiveness levels of the different factors affecting CDWR. Also, bivariate correlation analysis was carried out to examine the relationships between the different factors (i.e., IDVs) and CDWR (i.e., DV). This step is conducted to determine the effect of each IDV on the DV separately before proceeding to multivariate statistical analysis. This step is a matter of checking the significance of the cause-effect relationship between each IDV and DV without being affected by any other surrounding variable (i.e., IDV). Different inferential statistical analysis operations were carried out using **SPSS V26©** software, and the results are discussed in detail in chapter six.

The findings of both descriptive and inferential statistics are critically important to support and enrich the conclusions resulting from multivariate statistical analysis.

Second, SEM, a multivariate statistical analysis, was carried out to test the theoretical framework, including the different six hypotheses, as investigated in chapter two. For this purpose, the SEM was applied to test the hypotheses and determine the relationships between IDVs and DV in a multivariate statistical approach. The SEM is a general linear model technique for examining associations between IDVs and DVs. These variables can be observed directly as measured variables (i.e., indicators or items) or not as latent variables (i.e., constructs) (Ullman, 2010; Garson, 2012). The SEM is a combination of factor analysis and multiple regression that includes a series of statistical approaches that allow for composite relationships between IDVs and DVs. It can be applied theoretically for answering questions exploring the indirect or direct influence of IDVs on DVs. However, the SEM's primary goal is to explain and validate a proposed causal theoretical framework. The SEM is a validation or confirmation procedure that depends on two steps. The first step is to validate the measurement model through confirmatory factor analysis (CFA) to test how well the measured indicators represent their relevant constructs. The second step is to fit the structural model and test the research hypotheses through path analysis between constructs. The SEM has been applied a lot in the social sciences and psychology research domain, but limited research has applied it in the construction research domain (Xiong *et al.*, 2015).

For five reasons, the SEM method was considered an effective data analysis technique for this study. First, the SEM uses a confirmatory approach for data analysis instead of using an exploratory approach (Byrne, 2009). Second, the SEM could examine the relationship between CDWR with the IDVs. Third, the SEM provides unique characteristics over other multivariate techniques since it is better than multiple regression for a similar goal (Ullman, 2010; Garson, 2012). By creating an SEM model, various but interdependent multiple regression equations can be analysed simultaneously. Fourth, the SEM allows the measurement error estimation by considering error variance parameter estimates. Fifth, the sufficient sample size of the data collected in this study exceeds the minimum sample size needed for using the SEM technique. According to a study carried out by do Valle and Assaker (2016), 42 out of 44 investigated studies recommend using a sample size of 100 cases or more to use the SEM technique. In this main study, 244 responses were collected via the survey questionnaire, in which these responses were considered more than sufficient for using the SEM technique.

The literature suggests that the partial least squares (PLS) method of SEM (PLS-SEM) is suitable for studies involving more realistic settings in social science research (Kline, 2005; Tenenhaus *et al.*, 2005). A PLS analysis is an efficient alternative to ordinary least squares regression or covariance-based SEM (CB-SEM) for models which include IDVs and DVs. The PLS-SEM analysis can deal with multicollinearity among IDVs and generates IDVs based on cross-products and more robust predictions. It can simultaneously test both the measurement and path models to develop more realistic assumptions (Abdi, 2010; Hair *et al.*, 2017). Unlike PLS regression models, the PLS-SEM method entails path models with some variables that may affect others but still act as causal factors for the following variables in the hypothesized causal sequence. Accordingly, the PLS-SEM method is typically considered an efficient alternative to CB-SEM. The PLS-SEM analysis was conducted via **SmartPLS 3.3.2**© software because it offers the most widespread PLS-SEM method application (Garson, 2016). With the data collected from the questionnaire survey, the PLS-SEM was used for hypotheses testing in this study. The results of PLS-SEM analysis and the evaluation tests of the theoretical framework are presented in chapter seven. As proposed in this study, the PLS-SEM helped test and validate the theoretical framework of different hypotheses efficiently. A final developed conceptual framework is presented as a roadmap for bettering the current situation in Egypt.

The PLS-SEM consists mainly of seven sequential steps, as illustrated in Figure 3.3. The first stage involves developing the structural model (i.e., theoretical model), also known as the inner model. The structural model illustrates the relationships between the factors. The structural model is developed based on an extensive literature review, and the order of the constructs must be based on theory, logic, or observations (Hair *et al.*, 2016). The relationships in the structural model of this study are cause-effect relationships. Causal links or relationships are direct relationships between factors in which one factor predicts the other. The structural model for this study was specified in chapter two in the theoretical framework. The model consists of first-order constructs except for only one construct (i.e., MPMR), a second-order construct. The first-order constructs have observed variables (i.e., items) as indicators of the construct. On the other hand, second-order constructs have other unobserved constructs as their indicators, while these unobserved constructs have observed variables (i.e., indicators). In other words, first-order constructs are measured at one level of abstraction, while second-order constructs are measured at two levels of abstraction (Hair *et al.*, 2017a).

Secondly, the measurement models, which are also known as the outer models, describe the relationships between the constructs and their indicators (i.e., items). The measurement models for this study were also specified in chapter two in the theoretical framework. Measurements models could be reflective or formative (Hair *et al.*, 2016). Reflective measurement models are commonly used in social science research. The indicators in such models reflect the effect of the underlying construct. This means the causal effect is initiated from the construct to its indicators. As the same construct causes all of the indicators measuring it, there must be a high correlation between them. Moreover, all of the indicators measuring a specific construct must be interchangeable so that if one of the indicators is removed, as long as the reliability is acceptable, the meaning of the construct will not change.

On the other hand, formative measurement models are found to assume that causal indicators create the construct. Opposite to the reflective measurement models, the formative measurement models' indicators are not interchangeable because each variable captures a different dimension of the construct. Therefore, when constructing a formative measurement model, it is critically important to ensure that each indicator captures an aspect of the construct and that all of the construct's aspects are covered by the indicators (Hair *et al.*, 2016). In the course of this study, reflective measurement models have been adopted for all constructs (i.e., first-order and second-order constructs) based on an extant literature review, the conceptualisation of constructs, and the objectives of the study (Hair *et al.*, 2017a). Moreover, all the variables and their attributes were extracted from literature and supplemented by interviews; accordingly, there was no need to carry out exploratory factor analysis (EFA) before testing the different hypotheses via PLS-SEM in order to identify constructs' underlying set of measured variables (Nga, 2019). EFA should be used when the researcher has no a priori hypothesis about factors or patterns of measured variables (i.e., indicators).

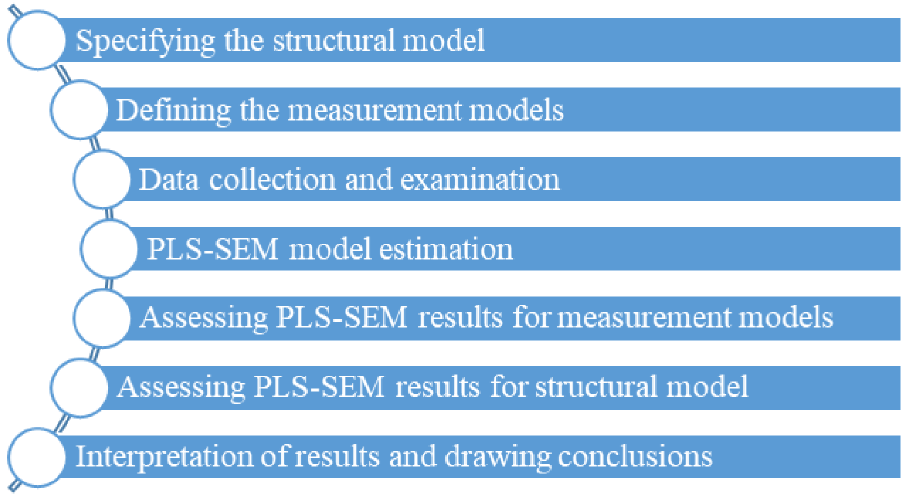

Figure 3.3 *A systematic procedure for applying PLS-SEM*

Source: *adapted from (Hair et al., 2017a)*

Third, data must be examined before conducting multivariate statistical analysis using the SEM technique to ensure valid results and conclusions. This is investigated in detail in chapter six, in which collected data are examined for missing data, outliers, common method bias, and normality. The fourth, fifth, sixth, and seventh steps are investigated and discussed in detail in chapter seven. These steps include running the model via **SmartPLS 3.3.2**© software, assessing the quality of measurement and structural models, and interpreting the results and drawing conclusions.

3.5 Expert Validation of the Proposed Improvements to the GPRS and the MPCF

After developing the proposal of improvement to GPRS and testing and statistically validating the developed MPCF, expert validation was carried out to assess these outputs if they are: (1) robust and comprehensive; (2) logical and acceptable; (3) valuable and applicable; and (4) strong and complete. This step was necessary to ensure that the research outputs are thorough, detailed, and unbiased. Research outputs can be validated via interviews, survey questionnaires, and focus groups (Lucko and Rojas, 2010). Due to the hazards of Coronavirus disease of 2019 (COVID-19), a structured survey questionnaire was the preferable option adopted to validate the research outputs, as shown in Appendix E.

From the 30 experts who participated in the pilot study, ten experts were interested in being updated with the final study's outputs, as discussed in chapter eight. Accordingly, these ten experts were contacted to participate in the validation process. A copy of the MPCF and the GPRS improvement proposal, accompanied by the survey questionnaire consisting of four simple close-ended questions and one open-ended question, were sent to the participants. All the questions were designed to address the objectives of the validation process. The respondent had to answer the validation questions using an "agreement" Likert scale to assess comprehensiveness & robustness, acceptability, applicability, and the necessity for improvement areas (if needed). One open-ended question was asked to indicate the areas of improvement suggested by the respondent (if existing).

3.6 Summary

This chapter investigated the research methodology adopted in this study in details. A mixed-method approach was adopted in this study, in which grounded theory, structured interviews, and survey questionnaires were used. Grounded theory was used to help in: (1) exploring and categorising the literature review; and (2) proposing improvements to the Egyptian GPRS. Eight structured interviews were conducted among different construction projects to (1) explore the relationship between different CDWR factors and CDWG; and (2) quantify CDW in terms of costs and generation rates. Besides, 244 completed responses to the survey questionnaire were successfully collected via an online system to (1) investigate the applicability and effectiveness of different factors affecting CDWR; and (2) test and evaluate the theoretical framework for developing a final developed conceptual framework. Finally, ten completed responses to the additional validation survey questionnaire were successfully collected via an online system to validate the research outputs of both the GPRS improvement proposal and the developed MPCF.

In the next chapter, the developed improvement proposal to GPRS is presented. The categorical weights and the criteria of M&R category of the GPRS are investigated thoroughly. Improvements to categorical weights and M&R criteria were proposed based on an in-depth investigation of GPRS along with the current Egyptian challenges and a critical comparison with the well-established BREEAM and LEED. Results of the investigation and comparisons are listed in detail in the next chapter.

CHAPTER 4: OVERCOMING THE LIMITATIONS OF THE EGYPTIAN GPRS: A CRITICAL ANALYSIS

4.1 Introduction

Based on the shortcomings of GPRS as investigated in the literature review, this chapter aims to examine the GPRS and compare it with its peers BREEAM and LEED with a particular focus on M&R category as investigated in the research methodology chapter specifically in section 3.3.2.1. The investigation and comparison results helped to propose suggestions that may improve the GPRS on the categorical level and the criteria level of M&R category. Moreover, the importance of M&R category is demonstrated through a case study by using PFs as a green material for concrete reinforcement to prove the positive impact of this category on the TBL of sustainability.

4.2 Research Steps

This chapter adopted a four-sequential steps approach, as shown in Figure 4.1, to investigate the GPRS and analyse its shortcomings, especially the M&R category, to suggest better improvements and developments. **First**, a systematic internet search was conducted via different databases, such as Scopus, Web of Science (WOS), JSTOR, ProQuest, to review various research papers and theses related to the research topic. This step was conducted using specific keywords, either separately or in combination, such as “GPRS”, “BREEAM”, “LEED”, “materials and resources”, “materials waste”, “comparative study”, “waste reduction”. Also, rating manuals of GPRS, BREEAM, and LEED were thoroughly reviewed to capture their components and detailed structure. **Second**, the GPRS was compared with BREEAM and LEED quantitatively and qualitatively in general, on the categorical level, and the criteria level of M&R category. This step is needed to highlight similarities, differences, and current shortcomings in the GPRS.

Third, improvements to GPRS categorical weights were proposed based on the investigation's outcome and the critical comparison with BREEAM and LEED rating systems that revealed some of the GPRS's weaknesses. Besides, an in-depth analysis was carried out on the criteria level of M&R category to identify its shortcomings in the GPRS either by criticising existing criteria or by highlighting missing criteria compared to M&R category of BREEAM and LEED. **Finally**, a case study, which focuses on using chemically treated PFs as a reinforcement material for concrete members, was employed to demonstrate the importance of M&R category and its impact on the TBL of sustainability.

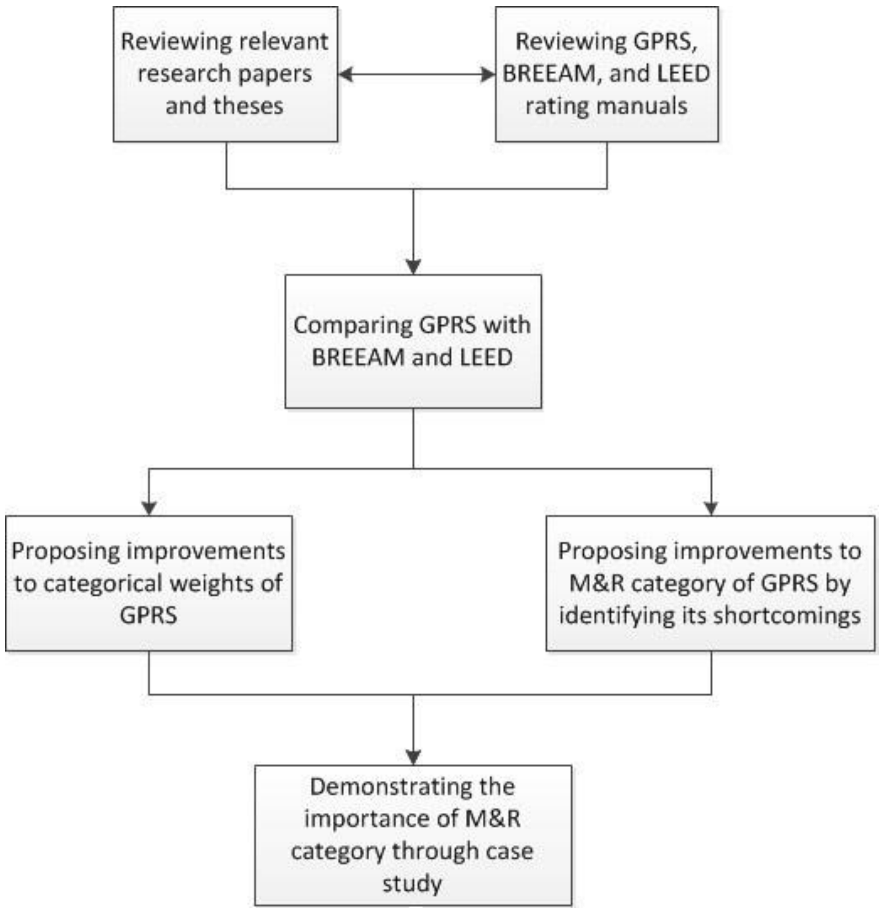

Figure 4.1 *Research flowchart*

Source: *developed by the author*

4.3 A Comparison between GPRS, BREEAM, and LEED

This section presents an overall comparison between GPRS, BREEAM, and LEED. Also, it offers a categorical weights' comparison between the three GBRSs in their most recent versions (i.e., GPRS V2, BREEAM International New Construction 2016, and LEED V4).

4.3.1 An Overall Comparison between GPRS, BREEAM, and LEED

The main characteristics of GPRS, BREEAM, and LEED are summarised in Table 4.1. It is noticed that the three rating systems recently released their latest updated versions. This demonstrates that the three GBRSs try to modify and update their contents, either criteria or weightings, to address the changing needs and new challenges towards achieving a sustainable construction industry (Doan *et al.*, 2017).

Table 4.1a *Comparing GPRS with BREEAM and LEED*

Source: *(HBRC, 2011; Building Research Establishment (BRE), 2016; Karmany, 2016; Doan et al., 2017; HBRC, 2017; U.S. Green Building Council (USGBC), 2019)*

Points of Comparison	**GPRS V2**	**BREEAM International New Construction 2016 V2**	**LEED V4**
Country	Egypt	UK	US
Organisations	EGGBC	BRE	USGBC
Flexibility	1 country	77 countries	160 countries
First version	2011	1990	1998
Latest version	2017	2016 (updated in 2017)	2013 (updated in 2019)

Table 4.1b *Comparing GPRS with BREEAM and LEED*

Source: *(HBRC, 2011; Building Research Establishment (BRE), 2016; Karmany, 2016; Doan et al., 2017; HBRC, 2017; U.S. Green Building Council (USGBC), 2019)*

Points of Comparison	**GPRS V2**	**BREEAM International New Construction 2016 V2**	**LEED V4**
Main categories	• Management Protocols • Indoor Environmental Quality • Energy Efficiency • Water Efficiency • Materials and Resources • Sustainable Sites • Innovation and Added Value	• Management • Health & Wellbeing • Energy • Transport • Water • Materials • Waste • Land Use & Ecology • Pollution • Innovation	• Integrative Process • Indoor Environment Quality • Energy & Atmosphere • Location & Transportation • Water Efficiency • Materials & Resources • Sustainable Sites • Regional Priority • Innovation
Rating approach	Additive credits	Pre-weighted categories	Additive credits
Rating levels	• Certified ≥ 40 • Silver Pyramid ≥ 50 • Gold Pyramid ≥ 60 • Green Pyramid ≥ 80	• Pass ≥ 30 • Good ≥ 45 • Very good ≥ 55 • Excellent ≥ 70 • Outstanding ≥ 85	• Certified ≥ 40 • Silver ≥ 50 • Gold ≥ 60 • Platinum ≥ 80
Certified buildings	2	561,600	79,100

It is evident from the comparison that the GPRS's applicability is limited to the Egyptian context only with a limited number of certified buildings. This can be explained by that fact that GPRS was developed nine years ago, and it is still at the early stages of development and improvement compared to the well-established BREEAM and LEED (Karmany, 2016). BREEAM and LEED are characterised by a large number of certified buildings worldwide. Despite the different contexts, countries other than the UK and the US use BREEAM and LEED to certify green buildings. This is because GBRSs could be classified as international standards or local standards. Based on the comparison, it is evident that the number of BREEAM certified buildings is almost seven times the number of LEED-certified buildings. However, LEED has higher applicability and popularity in worldwide countries than BREEAM (Doan *et al.*, 2017).

Regarding the number of categories in the three GBRSs, BREEAM has the largest number (i.e., ten categories), which is higher than those of LEED and GPRS with nine categories and seven categories, respectively. However, the three GBRSs share some common features of categories. This is because of the direct influence of BREEAM on LEED (Doan *et al.*, 2017) and the direct influence of LEED on GPRS (Ismaeel *et al.*, 2018; Daoud *et al.*, 2018a), which consequently means that BREEAM has an indirect influence on GPRS. Although the effect of BREEAM and LEED on GPRS, there are some discrepancies in GPRS categories compared to BREEAM and LEED. As discussed later in this chapter, some categories are missing or named with different terminologies in the GPRS. These discrepancies, between the GPRS on one hand and BREEAM and LEED on the other hand, may have resulted because GPRS was developed by Egyptian governmental bodies and Egyptian and non-Egyptian academics. The three GBRSs have common categories, such as **Energy**, **Water**, **Materials**, and **Sustainable Sites**, tailored to their local contexts (Ismail *et al.*, 2015; Karmany, 2016). This demonstrates that these categories attract global attention, and they should be prioritised (Doan *et al.*, 2017). Regarding the rating approach of the three GBRSs, GPRS and LEED sum all credit points to get the final grade while BREEAM pre-weight the categories before summing them to get a final BREEAM score. The rating approach of BREEAM is more complicated than LEED and GPRS (Karmany, 2016; Doan *et al.*, 2017).

4.3.2 Categorical Weights' Comparison between GPRS, BREEAM, and LEED

In this section, the three GBRSs' categories are compared to investigate their weights and importance according to each GBRS. By examining the three GBRSs as shown in Table 4.2, it has been noticed that most of the categories listed in them have the same meaning or aim but with different terminology (Ismail *et al.*, 2015). For instance, Land Use & Ecology category in BREEAM is equivalent to the Sustainable Sites category in LEED and GPRS. However, the categories' requirements or criteria may differ from one rating system to another (Karmany, 2016). Also, the criteria or requirements of a category sometimes are listed under different categories (Menting, 2016).

Table 4.2 *Comparing the categories of GPRS, BREEAM, and LEED*

Source: *(BRE, 2016; HBRC, 2017; USGBC, 2019)*

GPRS Categories	**BREEAM Categories**	**LEED Categories**
Management Protocols (10%)	Management (11%)	Integrative Process (≈0.91%)
Indoor Environmental Quality (16%)	Health & Wellbeing (19%)	Indoor Environment Quality (≈14.55%)
Energy Efficiency (32%)	Energy (20%)	Energy & Atmosphere (30%)
	Transport (6%)	Location & Transportation (≈14.55%)
Water Efficiency (20%)	Water (7%)	Water Efficiency (10%)
Materials and Resources (12%)	Materials (13%)	Materials & Resources (≈11.82%)
	Waste (6%)	
Sustainable Sites (10%)	Land Use & Ecology (8%)	Sustainable Sites (≈9.09%)
	Pollution (10%)	Regional Priority (≈3.64%)
Innovation and Added Value (5% bonus)	Innovation (10% bonus)	Innovation (≈5.45%)

It is worth mentioning that GPRS categories' weights are the same for all types of buildings (HBRC, 2017). Conversely, LEED and BREEAM categories' weights differ according to the building type (BRE, 2016; USGBC, 2019). For instance, LEED building types are classified as follows: New Construction, Core and Shell, Schools, Retail, Data Centres, Warehouses and Distribution Centres, Hospitality, and Healthcare. The weight of M&R Category is 12.73% for Core and Shell, 17.27% for Healthcare, and 11.82% for all other types of buildings, including new construction. On the other hand, the building types in BREEAM are classified as follows: Non-residential (fully fitted, shell only, shell and core), and Single and Multiple Residential Dwellings and Multiple Residential Dwellings (partially fitted, and fully fitted). The weight of Materials category ranges between 12.50 to 18.41% according to the building type. Accordingly, for the sake of thoroughness in this comparison, New Construction and Non-residential Fully Fitted building types are chosen for LEED and BREEAM, respectively. This is because the chosen LEED and BREEAM building types fit most of the construction projects, making it a fair comparison with the GPRS, as shown in Table 4.2.

It can be noticed that the Energy Efficiency (EE) category has the highest weight in the three GBRSs. In the GPRS case, this demonstrates the growing energy crisis in Egypt mirrored by electricity supply interruptions in the country (Ismail *et al.*, 2015). Besides, the Water Efficiency (WE) category is accorded the second highest weight in the GPRS, reflecting the growing water poverty due to the construction of the Renaissance Dam, leading to a reduction in Egypt’s share of the Nile River (Ismail *et al.*, 2015). It is noticed that the weight of the M&R category in the three GBRSs is almost the same. However, in the case of the GPRS, the M&R category should be accorded a higher weight compared to BREEAM and LEED. This is because Egypt still relies heavily on traditional construction methods, which is not the case in advanced construction industries of the UK and US. This has implications for material use, which is not as efficient as in modern construction, leading to increased CDWG, resulting in escalations of total project cost and depletion of natural resources (Elattar and Ahmed, 2014; Ismail *et al.*, 2015).

Indeed, Say and Wood (2008) highlighted that although some categories within rating systems have a more significant positive impact on sustainability, they are assigned lower weights. Furthermore, Dev (2017) argued that optimising the construction sector's materials consumption should be the GPRS's priority given that it was developed to promote GBs in Egypt, minimise ecological footprints of the built environment, and boost economic development. This step can be achieved by constructing entire societies in the deserts to meet the life needs of accelerating population growth. Accordingly, in the specific case and local context of the GPRS, the weighting allocated to M&R category need to be revised as investigated in the next section of this chapter.

In particular, GPRS and LEED have no specific Waste category, unlike BREEAM. In the Waste category of BREEAM, the management of both operational waste (i.e., waste resulting from the operation of the building by its occupants) and construction materials waste (i.e., waste of materials resulting from construction operations) is addressed (BRE, 2016). Although there is no specific category addressing issues of waste in LEED, it nevertheless addresses the management of both operational and construction materials waste through defined pre-requisites and requirements in its M&R category (USGBC, 2019). In GPRS, only operational waste management has been addressed through defined criteria in the Management Protocols category (HBRC, 2017). In other words, GPRS paid no attention to the escalating problem of CDW generated by the Egyptian construction sector (Hassan, 2012; Elattar and Ahmed, 2014). Accordingly, CDWM has to be incorporated in the GPRS, as investigated later in this chapter.

4.4 A Proposal for Improving the Categorical Weights of the GPRS

This section presents modified categorical weights proposed by this study, as shown in Table 4.3, for GPRS based on the Egyptian construction industry's current challenges. Based on Egypt's challenges regarding electricity supply shortage, water scarcity, and CDW, new categorical weights of the GPRS are proposed to address the current problems. Accordingly, EE, WE, and M&R categories are given the highest priorities to reflect their importance. Categorical weights are carefully modified to ensure that the rest of the modified categories are assigned reasonable new weights compared to their old ones in GPRS V1 and their current ones in GPRS V2. The summation of all newly proposed categorical weights, without the bonus category, has to be 100. Accordingly, weights modification started by suggesting new weights to the abovementioned three critical categories, then modifying other categorical weights.

It is worth mentioning that WE category is accorded a new higher weight similar to its old one in GPRS V1 given the expected negative impacts of Renaissance Dam on Egypt. On the other hand, the electric power supply problem has been improved since H.E. President Abdel Fattah El Sisi was elected president. Total capacity in Egypt's power sector increased by 80% between June 2013 and June 2018 to 55.5 gigawatts (GWs), and there is a power surplus over demand in Egypt (Castlereagh Associates, 2019). Accordingly, the EE category is accorded a bit lower weight to match its old one in GPRS V1, given the importance of this category and the current improvements in the Egyptian power sector. M&R category is accorded a higher weight than its old one in GPRS V1 and the current one in GPRS V2 given the growing challenge of CDW problem in Egypt. The new proposed weight is accorded to M&R category while paying attention to other remaining categorical weights. For instance, the IEQ category is accorded the same weight as its old one in GPRS V1. Also, the SS category's weight is kept as its current weight in GPRS V2 without changes. Finally, the weight of MP category is reduced by 5% compared to its current weight in GPRS V2 given the fact that most of its criteria are listed under other categories and to make sure that the summation of all proposed categorical weights is 100%.

4.5 Towards Improving M&R Category of the GPRS

In this section, the shortcomings in the criteria of the M&R category are considered. This step has been achieved based on an in-depth investigation of the M&R category's criteria in the three GBRSs. Shortcomings either in existing criteria or criteria missing in the GPRS, compared to BREEAM and LEED, are listed in Table 4.4 together with corresponding analysis.

Table 4.3a *New proposed weights for GPRS categories*

Categories	Old weights in GPRS V1	Current weights in GPRS V2	New Proposed Weights	Comment
Management Protocols (MP)	10%	10%	5%	The weight was modified as most category elements are included in other categories (Ismail *et al.*, 2015).
Indoor Environmental Quality (IEQ)	10%	16%	10%	This category is essential as much as Sustainable Sites (SS) category, given the importance of enhancing the TBL of sustainability. Accordingly, they were assigned similar weights.
Energy Efficiency (EE)	25%	32%	25%	This category is crucial, given the current electricity supply interruptions in Egypt. Careful attention has to be paid to reduce and optimise energy consumption. Accordingly, it is assigned an average weight between the new proposed weights of both WE category and M&R category.
Water Efficiency (WE)	30%	20%	30%	A higher weight is proposed to overcome the water crisis resulting from Renaissance Dam's construction on the Nile River. Careful attention has to be paid to save water resources and optimise their usage.

Table 4.3b *New proposed weights for GPRS categories*

Categories	**Old weights in GPRS V1**	**Current weights in GPRS V2**	**New Proposed Weights**	**Comment**
Materials and Resources (M&R)	10%	12%	20%	A higher weight is proposed to save raw materials from depletion, avoid high project cost, and reduce CDW given the current construction boom in Egypt. This new proposed weight considers integrating the missing criteria, as highlighted in the previous section, in the future version of the GPRS.
Sustainable Sites (SS)	15%	10%	10%	This category demonstrates the importance of protecting agricultural land from urban sprawl (Ismail *et al.*, 2015).
Innovation and Added Value (IN)	5% (bonus)	5% (bonus)	5% (bonus)	

Table 4.4a *Shortcomings in M&R category of the GPRS V2*

Criteria	Status	Comment	References
Renewable materials and materials manufactured using renewable energy.	Existing	• Lack of database for the available green materials in Egypt and their suppliers. • Lack of green materials certification in Egypt using national or international standards. • Lack of specification ensures that renewable materials should be obtained from a rapidly renewable source by specifying a time frame. • For materials manufactured using renewable energy, it is not effectively applied due to the high initial renewable energy costs.	Eldeeb, 2013; Ismail *et al.*, 2015; HBRC, 2017; Khalifa *et al.*, 2018; Ismaeel *et al.*, 2018; Daoud *et al.*, 2018a
Regionally procured materials and products.	Existing	• The maximum distance between the construction site and the suppliers needs to be minimised below the specified distance of 500 km. This distance is specified as 160 km in the LEED. This step is necessary to minimise the negative impacts of materials' transportation on the environment.	Eldeeb, 2013; HBRC, 2017; USGBC, 2019
Reduction of overall material use.	Existing	• Not effectively applied due to the lack of contractor's awareness.	HBRC, 2017; Khalifa *et al.*, 2018
Alternative building prefabricated elements.	Existing	• Not effectively applied due to high initial costs of prefabricated elements and lack of highly qualified contractors.	HBRC, 2017; Khalifa *et al.*, 2018

__Table 4.4b__ Shortcomings in M&R category of the GPRS V2

Criteria	**Status**	**Comment**	**References**
Environment – friendly, sound and thermal insulation materials.	Existing	• Lack of data about life cycle costs and information about these materials. • Not effectively applied due to the lack of contractor's awareness.	BRE, 2016; HBRC, 2017; Khalifa *et al.*, 2018; USGBC, 2019
Construction waste management	Missing	• Lack of requirements and instructions regarding the diversion of CDW from landfills by applying reduction, reuse, and recover techniques. The GPRS requires only the presentation of a schedule for principal project materials. Also, it is worth mentioning that the recycling industry lacks in Egypt. Accordingly, recycling is not mentioned here as a solution for CDWM.	Hassan, 2012; Elattar and Ahmed, 2014; Ismail *et al.*, 2015; BRE, 2016; HBRC, 2017; USGBC, 2019
Building and material reuse	Missing	• Lack of requirements and instructions to indicate the reuse of an existing building structural elements (e.g., floors, roof decking), enclosure materials (e.g., skin, framing), and permanently installed interior elements (e.g., walls, doors, floor coverings, ceiling systems). This step should help in reducing CDW.	Elattar and Ahmed, 2014; BRE, 2016; HBRC, 2017; USGBC, 2019

Table 4.4c *Shortcomings in M&R category of the GPRS V2*

Criteria	Status	Comment	References
Material efficiency	Missing	• Lack of requirements and instructions to reduce the amount of materials used in building design without compromising the structural stability and other performance factors.	BRE, 2016; HBRC, 2017

4.6 Case study: Palmocrete© - Replacement of Steel Rebars by Chemically Treated Palm Fronds as Concrete Reinforcement

The main goal of this case study is to prove the importance of M&R category and its impact on the TBL of sustainability and support the rationale behind proposing a higher weight to it, as investigated in this chapter. This case study adopted only one criterion of the M&R category, which is "using renewable materials", by using PFs as concrete reinforcing material. Due to the relatively high mechanical properties of PFs, PFs are considered an attractive replacement to steel rebars in concrete members. PFs can improve the ductility, strength, and resistance to cracking of composite material, and they are responsible for converting the sudden brittle failure of concrete in tension into more gradual and ductile failure. PFs can be used in the concrete medium after being coated with a polyester chemical compound to preserve its mechanical and physical properties from deterioration and preserve its durability (Daoud, 2013). This technique of using PFs as concrete reinforcement is intended to produce lightweight concrete members for low-income one-story housing, and it is named by Daoud (2013) as Palmocrete©. Accordingly, this section demonstrates the benefits of using chemically treated PFs, a green material, to replace steel rebars in concrete members.

4.6.1 Availability of Palm Fronds in Egypt and their Positive Impacts on Sustainability

As reported in (Daoud, 2013), palm trees are widespread in Arab countries, with over 100 million trees. Egypt owns more than 10% of the palm trees in Arab countries, in which it has 11 million palm trees distributed among its governorates. Studies on Egyptian palm trees showed that every palm tree yields 15 to 20 PFs due to the annual healthy pruning process. This means that Egypt has a rich availability of PFs, which ranges from 165 million to 220 million PFs annually (Daoud, 2013).

Palmocrete© has significant impacts on the TBL of sustainability in Egypt. Based on research and field pilot experiments carried out by Daoud (2013), the impacts can be summarised as follows:

- **Economic impact**: PFs can be used instead of steel rebars in concrete reinforcement, leading to a reduction in the building cost. PFs may reduce the cost of reinforcement (materials and placement) by 80-90%. One tonne of steel costs about 10,000 EGP, according to the Egyptian market in 2019. On the other hand, PFs reinforcement costs 10-20% of steel rebars reinforcement cost, in which most of the cost goes to the coating compounds of the chemical treatment. It is worth mentioning that PFs possess high ultimate tensile strength (UTS), which may reach 70% of the steel rebars' UTS.

- **Environmental impact**: PFs produced from the healthy pruning of palm trees are rarely used in construction despite their huge potentials as a replacement for steel reinforcement. They can be buried in a concrete medium, and as a result, the indiscriminate disposal as SW on the streets and dumpsites can be mediated. This is to lessen the environmental pollution resulting from the current means of disposal, which is open incineration. Above all, and unlike the finite resources used in steel manufacture, palm trees are renewable materials.

- **Social impact**: Palmocrete© has a substantial social impact through the boost to self-esteem associated with employment and income-generating opportunities in Egypt. The Palmocrete© technique's affordability can provide tremendous employment and income-generating opportunities due to reduced construction costs. It can stimulate and sustain rural income and wealth by developing desert and remote areas in Egypt.

4.6.2 Pilot Experiment: Constructing a Small House in Egypt Using Palmocrete© Technique

Palmocrete© technique is used for reinforcing one-way and two-way solid slabs and beams. These concrete members are reinforced using chemically treated PFs as aforementioned. The design of these concrete members using the Palmocrete© technique is carried out via the Egyptian code of practice for concrete structures and Response-2000 programme, in which the UTS of PFs replaces the UTS of steel rebars. Slabs and beams rest on bearing walls constructed according to the Egyptian code of practice for concrete structures. These bearing walls rest on ground beams which act as foundations for the building (Daoud, 2013).

In June 2011, a one-story building was built in Aswan governorate with dimensions 8 m in length by 6 m in width. The building's construction was funded by the British University in Egypt (BUE) and executed through ENACTUS-BUE as a part of a community development programme. The ground beams were reinforced using chemically treated PFs as a flexural reinforcement, while shear reinforcement was steel stirrups. After the concrete casting of ground beams, bearing walls were built over them. After the construction of bearing walls, wooden formwork was installed for slab construction. The two-way solid slab was reinforced using chemically treated PFs in the two directions, as shown in Figure 4.2. The slab's beams were reinforced using chemically treated PFs for flexural reinforcement and steel stirrups of 6 mm diameter as shear reinforcement, as shown in Figure 4.3. Besides the four beams of the slab, there was an intermediate beam in the midway of the slab dividing the long direction into two halves, as shown in Figure 4.4, because the length of PFs was ranging between 4 to 5 m while the long direction was 8 m (Daoud, 2013).

The final stage was the concrete casting of the slab and its curing for 28 days. Local people and builders were provided with the knowledge of applying the Palmocrete© to help them construct or add value to their low-income houses. Palmocrete© is cost-effective, uses available locally produced PFs treated with available and affordable chemical compounds, and may dramatically prolong the active life span for such slabs. The constructed building, shown in Figure 4.5, is used until now for nine years without any cracks in the slab or settlement in the ground beams (Daoud, 2013).

Figure 4.2 *Slab reinforcement*

Source: *(Daoud, 2013)*

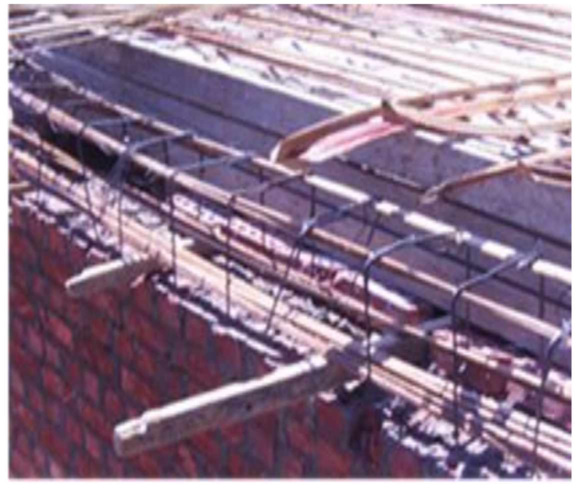

Figure 4.3 *Beam reinforcement*

Source: *(Daoud, 2013)*

Figure 4.4 *Intermediate beam*

Source: *(Daoud, 2013)*

Figure 4.5 *Final constructed building*

Source: *(Daoud, 2013)*

4.7 Summary

This chapter presented an investigation of current shortcomings and limitations in the GPRS's categorical weights and the criteria of its M&R category. Based on the detailed investigation and the comparison with the well-established BREEAM and LEED, a proposal of improvements was introduced to develop the categorical weights and the M&R criteria. Recommendations were stated as a roadmap for improving the abovementioned two aspects of improvements to face the current challenges in Egyptian society regarding CDW, water scarcity, and energy conservation. Furthermore, a case study was discussed in this chapter to demonstrate the importance of M&R category and prove the importance of according it a higher weight. In the next chapter, the analysis results of the case study are presented. This comparative case study investigates four different construction projects in the Egyptian construction sector. It shall help in (1) quantifying CDW among various Egyptian construction projects in terms of costs and generation rates; and (2) exploring the relationship between CDWR factors and CDWG.

CHAPTER 5: QUANTIFYING CDW IN THE EGYPTIAN CONSTRUCTION INDUSTRY: A CRITICAL ANALYSIS OF RATES AND FACTORS

5.1 Introduction

This chapter presents the case study results as investigated in the research methodology chapter, specifically in section 3.4.1.5. The comparative case study was conducted using a structured interview questionnaire, in which industrial, residential, commercial, and infrastructure projects were investigated. This chapter revealed that the rates and associated costs of CDWG differ from one project to another. Analysis of results demonstrated that CDWG rates and costs do not depend only on the project's nature, size, and complexity, but also on the applied CDWR factors such as waste-efficient materials procurement practices, awareness, culture & behaviour, and legislation. On average, it was found that "timber", "sand", and "bricks/blocks" are the most wasteful materials, and "practices" and "legislation" are the least applied factors towards CDWR. This case study's findings offer an understanding of the CDW problem in the Egyptian construction sector and demonstrate the relationship between different CDWR factors and CDWG to improve Egypt's current situation regarding CDWR.

5.2 Demographic Information of Participants

The interviews were conducted with four project managers and four procurement managers in total, in which their industrial experiences range between 10 and 36 years, as summarised in Table 5.1. Each interview took place face-to-face for around 45 to 60 minutes. The participants did not sign for audio or video recording of the interviews on the consent form. Their preferences were respected, and these tools were not used during the interview. Instead, the answers of the participants were written on the interview transcript. It was also made sure that the participants, their firms, and the investigated projects in the case study are kept anonymous in the publications based on the participants' preferences in the consent form. The four selected construction projects were executed by four "1st-grade" firms per the classification of the EFCBC. The four firms can also carry out different construction projects in general (i.e., industrial, residential, commercial, and infrastructure).

Table 5.1 *The profile of different participants in the case study*

Respondent number	**Type of the investigated project**	**Position**	**Number of years' industrial experience**	**The highest degree of education**	**Professional designations (if applicable)**
1	Industrial	Project manager	36	BSc	Member of the Egyptian Engineers Syndicate (EES)
2	Industrial	Procurement manager	30	BSc	Member of the EES
3	Residential	Project manager	10	BSc	Member of the EES
4	Residential	Procurement manager	23	BSc	Member of the EES
5	Commercial	Project manager	27	MSc	Member of the UK Institution of Civil Engineers (ICE)
6	Commercial	Procurement manager	23	BSc	Member of the EES
7	Infrastructure	Project manager	27	BSc	Member of the EES
8	Infrastructure	Procurement manager	10	BSc	Member of the EES

5.3 Data Analysis and Results

As previously discussed in chapter 3, this section presents the qualitative data analysis of the different projects represented by the managers' responses. Moreover, the quantitative data analysis regarding CDWG rates and costs and the evaluation of the adopted CDWR factors are presented. Each subsubsection presents the qualitative and quantitative data analysis of each project type of the four investigated projects.

5.3.1 Industrial Project

Table 5.2a *Qualitative analysis of the industrial project*

Theme	Subtheme	Response
Project description	Size	The project consists of four mega military factories. The main works were infrastructure and buildings construction. The total size of the land is around 1360 acres.
	Specifications and challenges	Both managers stated that this project's main difficulties were the undulating land surface and its large size. It took a great effort to level the ground surface and execute the infrastructure works in this large area. Also, they added that significant challenges were faced due to rapid changes and variation orders in the project. The variation orders were mainly because of the foreign vendors. There was a lack of coordination between the project owner and the vendors. Moreover, they said that there were many price changes due to the currency devaluation during this decade.

Table 5.2b *Qualitative analysis of the industrial project*

Theme	**Subtheme**	**Response**
Project description	Duration	This project started in 2009, and it was delivered by June 2019.
	Contractual agreement	The project was delivered on a turnkey basis.
Materials procurement models	Adopted materials procurement model/s	✓ GCPM
	Reasons behind choosing the adopted model/s	Both managers said that this type of procurement model was stated in the contract. The project consultant only specifies the vendor list. The firm was responsible for materials procurement. Moreover, this model was adopted in order to maximise the firm's profit in the project. The firm calculated the margin profit based on procured materials. The aim was to procure materials with low prices and high quality, which suits the project nature. They added that this model is used to control the delivery schedule of materials based on the project timeline and to control the project budget regarding the procured materials.

Table 5.2c *Qualitative analysis of the industrial project*

Theme	**Subtheme**	**Response**
Materials procurement models	Relationship between the adopted model/s and CDWR	Both managers confirmed that this model was the best option. They said that the firm made a bid among materials vendors and chose the best of them based on those who can provide materials with low costs, high quality, and flexible payment intervals. Both managers claimed that this model gave them full control of materials procurement aspects like budget and schedule. Moreover, they stated that it helped them to track the usage of materials onsite and optimise it. They said that adopting this model allowed them to reduce CDW, delays, and cost overrun.

Table 5.2d *Qualitative analysis of the industrial project*

Theme	**Subtheme**	**Response**
Materials procurement measures	Adopted materials procurement measures	✓ Suppliers’ flexibility in supplying small quantities or modification to products in conformity. ✓ Supply of quality and durable products. ✓ Procurement of waste-efficient materials/technology (pre-assembled/cast/cut). ✓ Purchase of quality and suitable materials. ✓ Correct materials purchase. ✓ Effective protection of materials (during transportation, loading & unloading). ✓ Effective onsite access (for ease of delivery). ✓ Efficient delivery schedule. ✓ Accurate materials take-off. ✓ Prevention of over/under ordering. ✓ Reduced waste allowance. ✓ Usage of Just in Time (JIT) delivery system. ✓ Avoidance of variation orders. ✓ Other: meeting with products’ manufacturers to carry out a quality test to ensure that the written materials specifications are accurate.

***Table 5.2e** Qualitative analysis of the industrial project*

Theme	**Subtheme**	**Response**
Materials procurement measures	Sufficiency of adopted materials procurement measures towards CDWR	Both managers stated that the adopted measures were sufficient towards CDWR. A plan was in place to efficiently store the materials onsite. Furthermore, they commented on the adopted measures. Regarding the measure named "supply of quality and durable products", they said that sometimes the firm is subjected to vendors who supply low-quality materials. Accordingly, these vendors are struck from the vendor list. Regarding the measure named "procurement of waste-efficient materials/technology (pre-assembled/cast/cut)", both managers stated that pre-cast concrete floors and walls were used in this project. Regarding the measure named "correct materials purchase", both managers confirmed that detailed specifications of the materials were sent along with the materials order. Also, they said that the additional measure, which is not listed in the 16 defined measures, was necessary to confirm that the written materials specifications are accurate.

Table 5.2f *Qualitative analysis of the industrial project*

Theme	**Subtheme**	**Response**
Green building practices	Application of green materials procurement approach	Both managers said that the different criteria were not fully adopted in this project. Only one criterion, which is "usage of alternative building prefabricated elements", was adopted in this project. Prefabricated reinforcement steel of columns, beams, and foundation cages was used. They said that they exceeded the minimum requirement (i.e., 10% of the total quantity) as stated by the GPRS. Both managers stated that they had used 100% of the total quantity as prefabricated reinforcement steel with 0% waste. Moreover, they stated that green building practices are not a familiar concept in the Egyptian construction industry, and it is still in the infancy stages.

Table 5.2g *Qualitative analysis of the industrial project*

Theme	**Subtheme**	**Response**
CDW problem in the Egyptian construction industry	Different reasons for CDWG	Both managers claimed that the main reasons behind such a problem are lack of waste-efficient practices in the industry, poor and careless behaviour, lack of awareness towards the problem, and lack of knowledge among project participants on different levels. Also, there is a lack of coordination among different project parties, which plays an essential role in CDWG. In addition, there is a lack of adequate practices for dealing with materials, whether during the procurement or onsite. Moreover, there are no strict laws that can reduce CDW and penalise those who dump CDW at unassigned illegal landfills. Also, there is a lack of awareness towards the Egyptian legislation concerned with CDWM. This indicates that the existing legislation are weak and ineffective.
	Negative impacts of CDW problem	Both managers stated that this is a huge problem in Egypt. They believe that it leads to a high financial loss of firms, especially in megaprojects. It leads to project delays because raw materials are wasted, resulting in waiting for other materials to be brought on-site. Consequently, this leads to a delay in the project schedule. It negatively impacts well-being and the environment. They said that this increasing CDW problem is deteriorating lives, the environment, and the economy.

Table 5.3 *Quantification of CDW in the industrial project*

Material type (unit)	**Weighted mean value (%)**	**Standard deviation (%)**	**The quantity used in the project (unit)**	**Cost per unit (EGP/unit)**	**Total cost (EGP)**	**Cost of wasted materials (EGP)**	**Percentage of total wasted materials cost (%)**
Timber (m3)	11.77	7.42	1500	2500	3750000	441477.3	
Sand (m3)	2.68	1.06	25000	17	425000	11397.7	
Concrete (m3)	1.95	0.71	176000	300	52800000	1032000.0	
Cement (tons)	3.23	0.35	3500	450	1575000	50829.5	1.89
Reinforcement steel (tons)	0.00	0.00	14000	5000	70000000	0.0	
Tiles (m2)	3.59	1.41	14500	500	7250000	260340.9	
Bricks/blocks (m3)	2.95	0.71	180000	400	72000000	2127272.7	

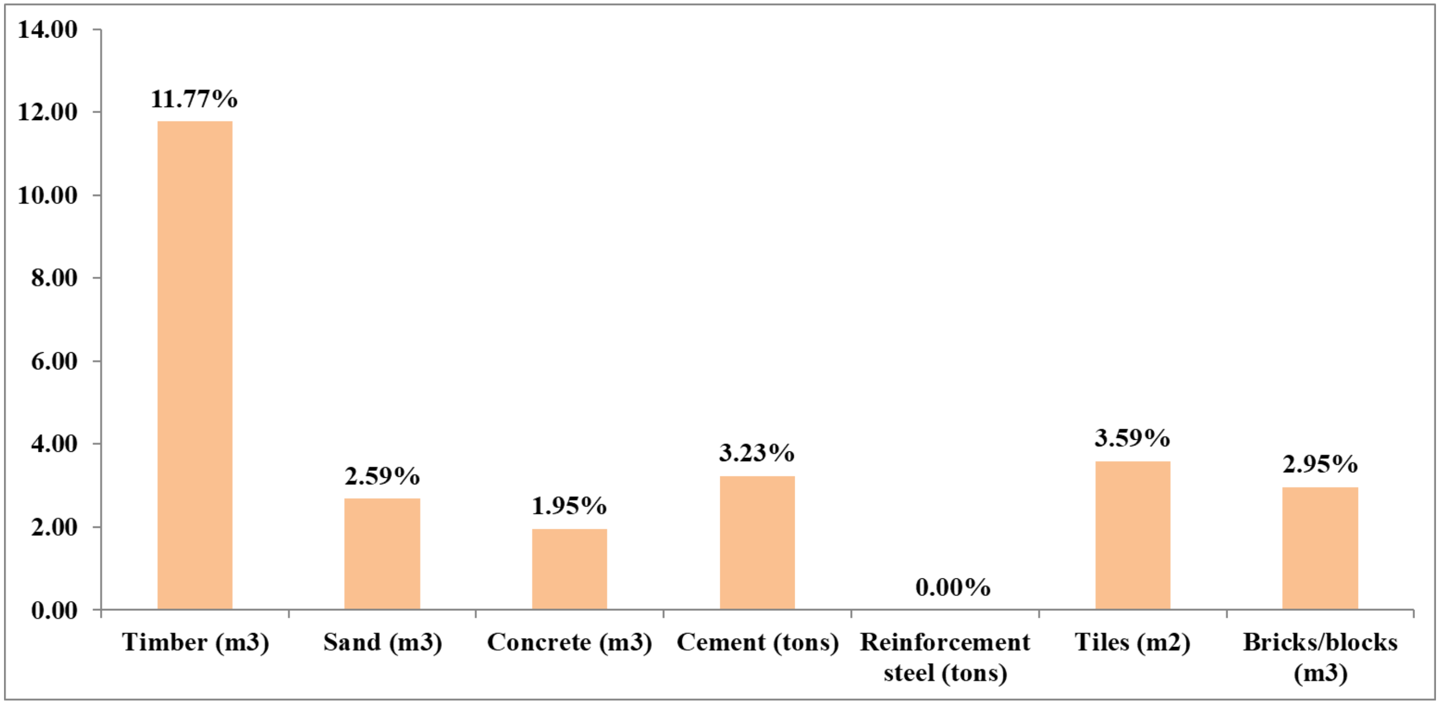

Figure 5.1 *Percentage of waste in each type of materials in the industrial project*

Table 5.4 *Evaluation of different CDWR factors at the firm executed the industrial project*

Factor	**The composite index of the factor**	**Standard deviation among respondents' evaluations**	**Interpretation of the index**	**The total final score of the project's waste management (WM)**	**Interpretation of the score**
Awareness	0.63	0.09	Very good	0.63	Very good
Practices	0.54	0.06	Good		
Culture & behaviour	0.83	0.04	Excellent		
Legislation	0.50	0.00	Good		

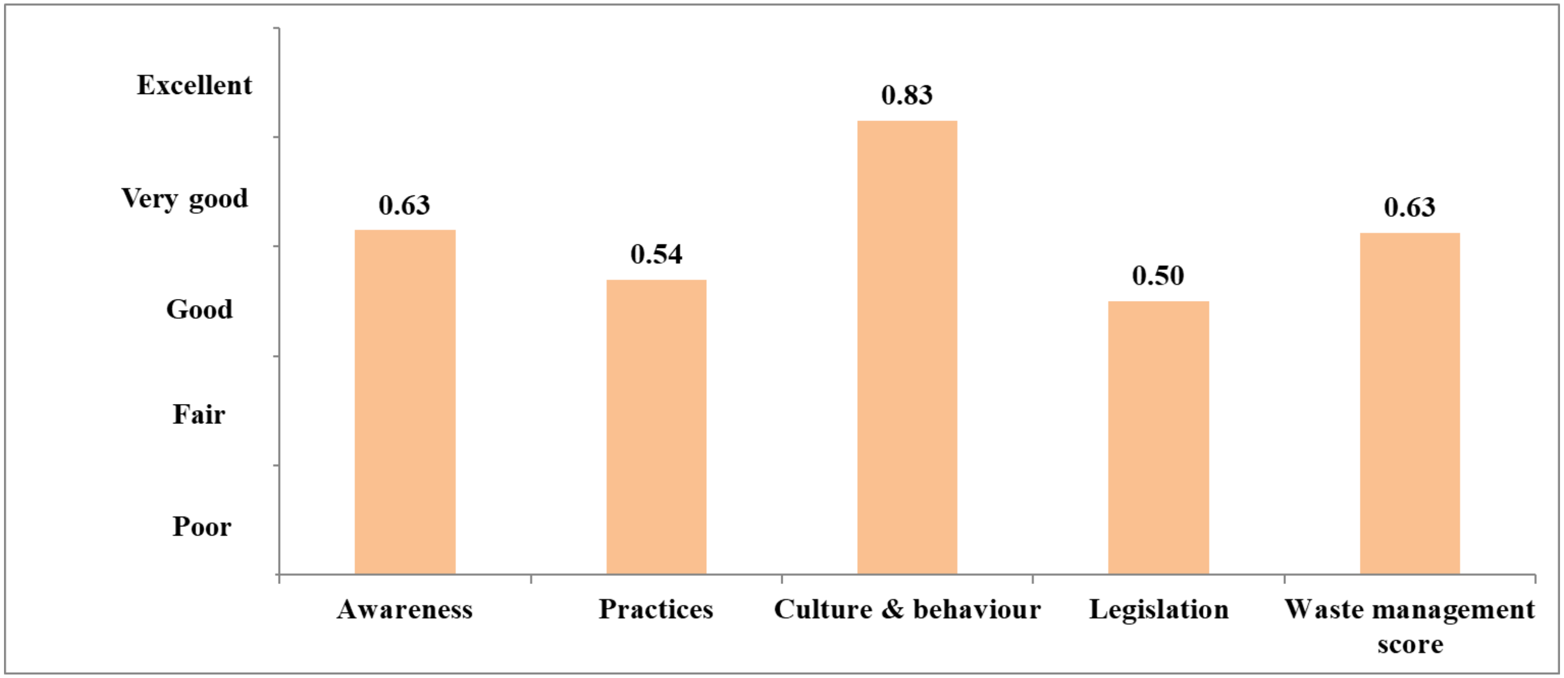

Figure 5.2 *Factors' evaluation and total WM score in the industrial project*

5.3.2 Residential Project

Table 5.5a *Qualitative analysis of the residential project*

Theme	**Subtheme**	**Response**
Project description	Size	The project consists of six buildings. Each building consists of 11 floors with a built-up area (BUA) of 1250 m^2. The total number of units is 337 apartments.
	Specifications and challenges	Both managers stated that this project's main challenge was its location near the Nile River, so the underground water was a significant problem. Accordingly, they constructed large piles and caps. Moreover, huge retaining walls were constructed to avoid any deterioration to the near old buildings.
	Duration	The project started in 2008, and it was delivered in 2013.
	Contractual agreement	The apartments were delivered semi-finished.
Materials procurement models	Adopted materials procurement model/s	✓ GCPM
	Reasons behind choosing the adopted model/s	Both managers stated that most of the financial profit is in this model. The firm calculated its overhead and profit based on the procured materials. They added that this model helped in executing the project on a fast track. They stated that using this model helped in tracking the usage and procurement of materials. Accordingly, materials were procured and used economically and efficiently to increase the firm's profit margin.

Table 5.5b *Qualitative analysis of the residential project*

Theme	**Subtheme**	**Response**
Materials procurement models	Relationship between the adopted model/s and CDWR	Both managers confirmed that the adopted model was the best option as it helped reduce CDW to maximise the firm's profit.
Materials procurement measures	Adopted materials procurement measures	✓ Suppliers' flexibility in supplying small quantities or modification to products in conformity. ✓ Supply of quality and durable products. ✓ Usage of minimal packaging (without affecting materials safety). ✓ Purchase of quality and suitable materials. ✓ Correct materials purchase. ✓ Effective protection of materials (during transportation, loading & unloading). ✓ Effective onsite access (for ease of delivery). ✓ Accurate materials take-off. ✓ Prevention of over/under ordering. ✓ Reduced waste allowance.

Table 5.5c *Qualitative analysis of the residential project*

Theme	**Subtheme**	**Response**
Materials procurement measures	Sufficiency of adopted materials procurement measures towards CDWR	Both managers stated that the adopted measures were sufficient for CDWR compared to the project's complexity, large size, location, and unstable political conditions during its execution. Political conditions at this time in Egypt were unstable, so the project was exposed to several interruptions. The main focus was on delivering the project as fast as possible without considering every single measure. They believe that the CDWG rates could have been greater, but they tried hard to minimise them by applying these measures as much as they could.
Green building practices	Application of green materials procurement approach	Both managers stated that the different criteria were not adopted in the project, and these criteria are not applicable in their firm. They believe that these criteria are also not applicable in most of the construction projects in Egypt. Moreover, they said that they are slightly aware of them.

__Table 5.5d__ Qualitative analysis of the residential project

Theme	**Subtheme**	**Response**
CDW problem in the Egyptian construction industry	Different reasons for CDWG	Both managers stated that the main reason behind the CDW problem is that the culture of CDWR does not exist within most of the Egyptian construction firms. The awareness of people towards the severity of the problem and developing innovative solutions to face this problem is lacking. They claimed that recycling and reuse strategies for CDWR does not exist in Egypt. This could help in reducing CDW significantly. They added that the Egyptian construction firms do not adequately adopt waste-efficient practices of dealing with materials. Moreover, they said that labours in Egypt are not dealing carefully with materials. Additionally, they stated that the nature of project execution affects CDWG. If the project's timeline is compressed and the project is executed on a fast-track basis, it can be expected to have a high rate of CDWG. They claimed that this is the nature of construction projects nowadays in Egypt. Most of the projects are executed on a fast-track basis. Furthermore, they said that the Egyptian legislation are weak towards solving this problem. No strict laws exist in the industry to enforce construction firms to minimise CDW.
	Negative impacts of CDW problem	Both managers stated that the CDW problem has severe adverse effects on society, the environment, and Egypt's economy.

Table 5.6 *Quantification of CDW in the residential project*

Material type (unit)	**Weighted mean value (%)**	**Standard deviation (%)**	**The quantity used in the project (unit)**	**Cost per unit (EGP/unit)**	**Total cost (EGP)**	**Cost of wasted materials (EGP)**	**Percentage of total wasted materials cost (%)**
Timber (m3)	7.05	1.06	2200	800	1760000	124000.00	
Sand (m3)	6.74	1.77	60000	121	7260000	489500.00	
Concrete (m3)	3.89	1.41	80000	150	12000000	467272.73	
Cement (tons)	2.50	0.00	50000	500	25000000	625000.00	3.34
Reinforcement steel (tons)	2.65	0.35	25000	3950	98750000	2618371.21	
Tiles (m2)	4.05	1.06	2000	25	50000	2022.73	
Bricks/blocks (m3)	4.35	0.35	80000	640	51200000	2226424.24	

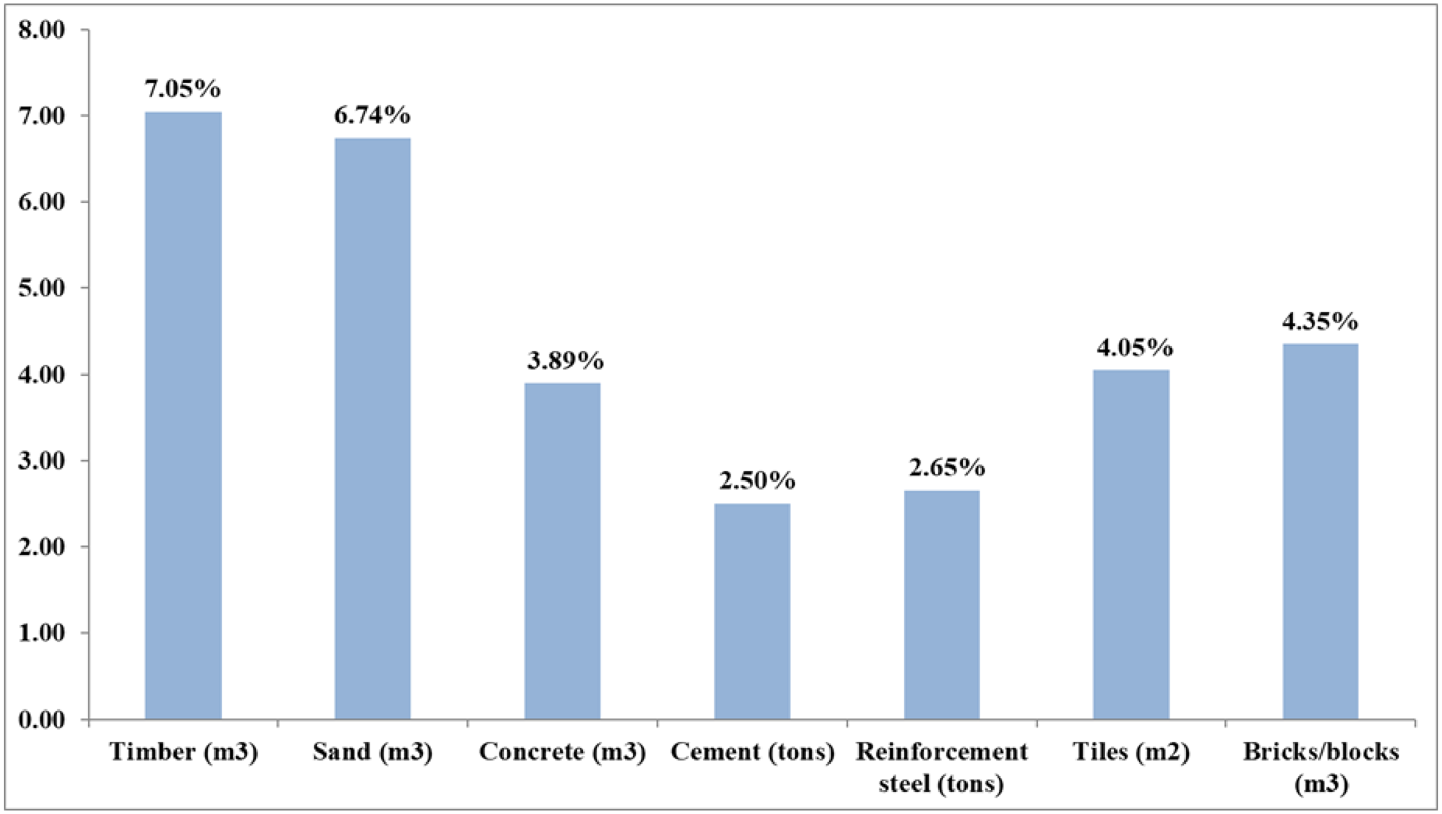

Figure 5.3 *Percentage of waste in each type of materials in the residential project*

Table 5.7 *Evaluation of different CDWR factors at the firm executed the residential project*

Factor	The composite index of the factor	Standard deviation among respondents' evaluations	Interpretation of the index	The total final score of the project's waste management (WM)	Interpretation of the score
Awareness	0.57	0.13	Good	0.53	Good
Practices	0.36	0.06	Fair		
Culture & behaviour	0.70	0.11	Very good		
Legislation	0.50	0.00	Good		

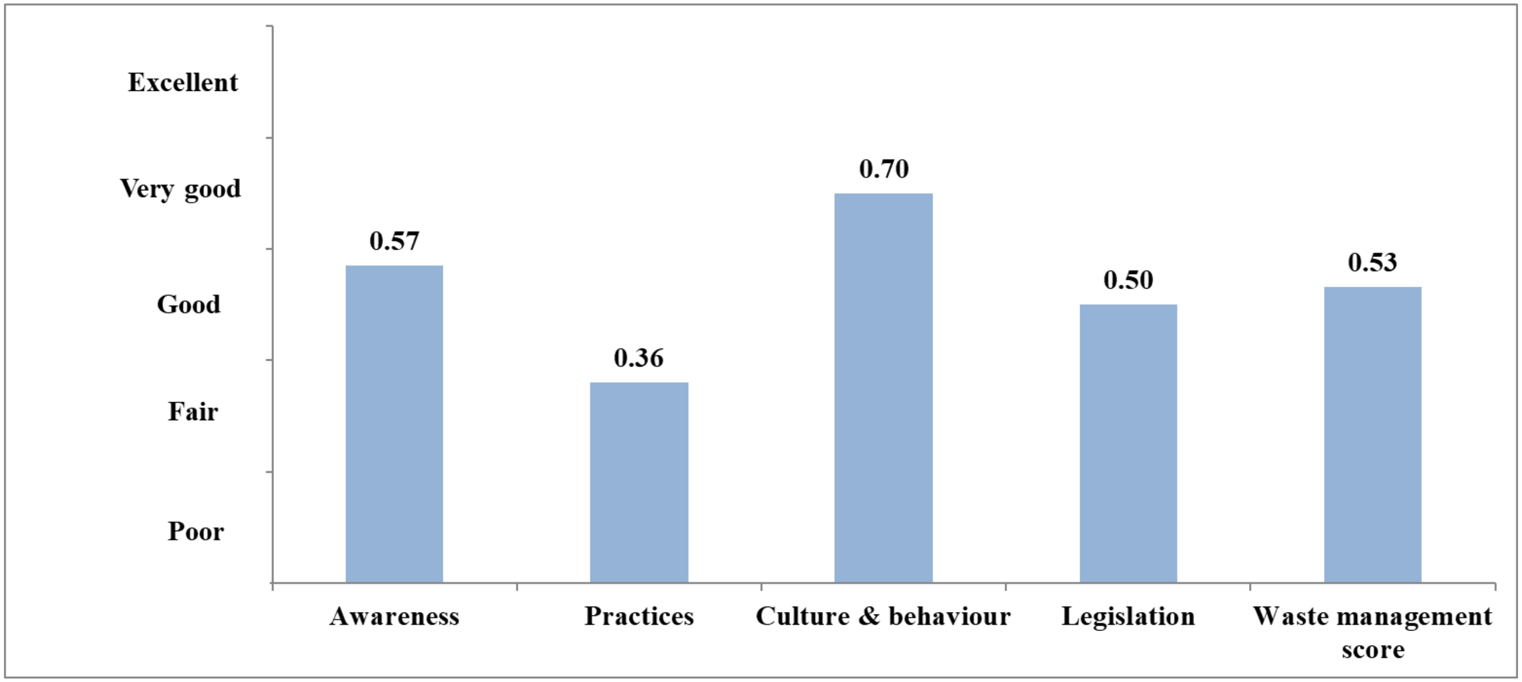

Figure 5.4 *Factors' evaluation and total WM score in the residential project*

5.3.3 Commercial Project

Table 5.8a *Qualitative analysis of the commercial project*

Theme	Subtheme	Response
Project description	Size	The project is an investment bank that consists of two basements and four floors on a BUA of 4400 m^2.
	Specifications and challenges	It consists of high specifications and advanced technology for electromechanical systems.
	Duration	The project started in 2009, and it was delivered by 2011.
	Contractual agreement	The project was delivered on a turnkey basis.
Materials procurement models	Adopted materials procurement model/s	✓ GCPM
	Reasons behind choosing the adopted model/s	Both managers stated that the owner delegated their firm for procuring all the materials of the project. This step occurred without any interference from his side or a specialty contractor.
	Relationship between the adopted model/s and CDWR	They claimed that it was the best option because the firm is more involved in the project execution and more aware of its requirements. Moreover, they added that this model enabled maximising the firm's profit and reducing CDWG.

Table 5.8b *Qualitative analysis of the commercial project*

Theme	**Subtheme**	**Response**
Materials procurement measures	Adopted materials procurement measures	✓ Suppliers' flexibility in supplying small quantities or modification to products in conformity. ✓ Supply of quality and durable products. ✓ Usage of minimal packaging (without affecting materials safety). ✓ Purchase of quality and suitable materials. ✓ Correct materials purchase. ✓ Effective protection of materials (during transportation, loading & unloading). ✓ Effective onsite access (for ease of delivery). ✓ Accurate materials take-off. ✓ Prevention of over/under ordering. ✓ Reduced waste allowance.
	Sufficiency of adopted materials procurement measures towards CDWR	Both managers confirmed that the adopted measures were sufficient in terms of CDWR.

Table 5.8c *Qualitative analysis of the commercial project*

Theme	**Subtheme**	**Response**
Green building practices	Application of green materials procurement approach	Both managers stated that these criteria were not adopted in the project. They claimed that these criteria are not widely applicable or known in Egypt. Moreover, it was not a requirement by the project owner to apply them. Finally, they said that they are not familiar with green building rating systems.
CDW problem in the Egyptian construction industry	Different reasons for CDWG	Both managers stated several reasons for such a problem. They said that the main reason behind CDWG is the carelessness of people in the Egyptian construction industry on different levels, especially labours. They claimed that reusing of materials is not applied at all. They added that the inefficient storage of materials and inadequate materials management onsite play a crucial role in CDWG. Additionally, they stated that there is an inaccuracy in taking off materials onsite. Also, they believed that inadequate supervision of superintendents onsite plays an essential role in CDWG. Moreover, they blamed legislation in Egypt for being inadequate and ineffective in solving the CDW problem.

Table 5.8d *Qualitative analysis of the commercial project*

Theme	**Subtheme**	**Response**
CDW problem in the Egyptian construction industry	Negative impacts of CDW problem	Both managers said that the CDW problem has adverse effects on society, the environment, and Egypt's economy. It may change the project profit into a loss, especially in mega construction projects. Moreover, it deteriorates the quality of life and the natural environment.

Table 5.9 Quantification of CDW in the commercial project

Material Type (unit)	Weighted mean value (%)	Standard deviation (%)	The quantity used in the project (unit)	Cost per unit (EGP/unit)	Total cost (EGP)	Cost of wasted materials (EGP)	Percentage of total wasted materials cost (%)
Timber (m3)	9.8	3.54	700	800	560000	54880	3.43
Sand (m3)	6.69	1.06	28000	12	336000	22478.4	
Concrete (m3)	3.46	0.71	12800	150	1920000	66432	
Cement (tons)	2.77	0.35	233	500	116500	3227.05	
Reinforcement steel (tons)	2.50	0.00	1200	3950	4740000	118500	
Tiles (m2)	2.04	0.71	3450	50	172500	3519	
Bricks/blocks (m3)	3.42	1.41	800	640	512000	17510.4	

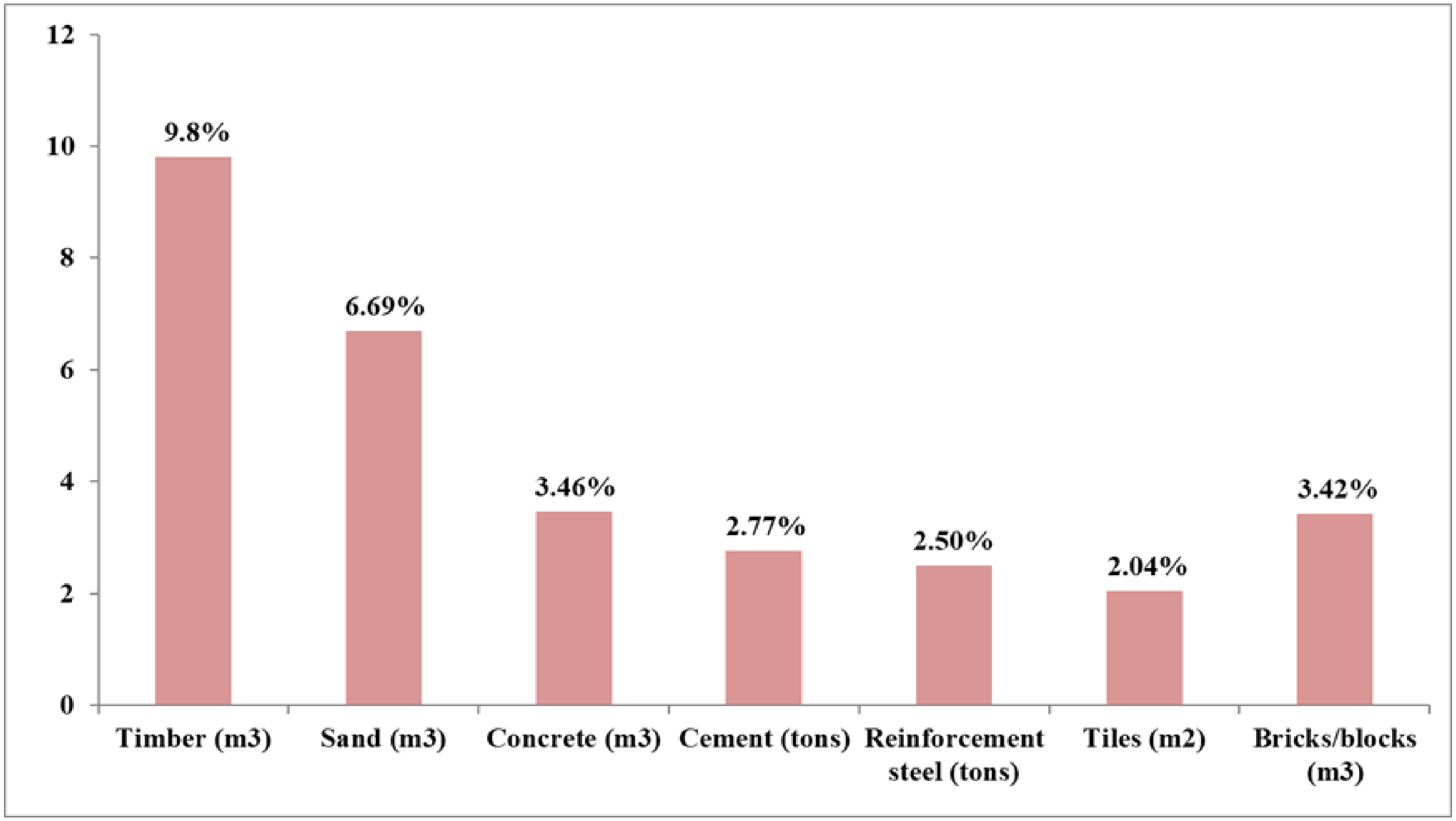

Figure 5.5 *Percentage of waste in each type of materials in the commercial project*

__Table 5.10__ Evaluation of different CDWR factors at the firm executed the commercial project

Factor	**The composite index of the factor**	**Standard deviation among respondents' evaluations**	**Interpretation of the Index**	**The total final score of the project's waste management (WM)**	**Interpretation of the Score**
Awareness	0.54	0.13	Good	0.47	Good
Practices	0.30	0.06	Fair		
Culture & behaviour	0.65	0.00	Very good		
Legislation	0.38	0.00	Fair		

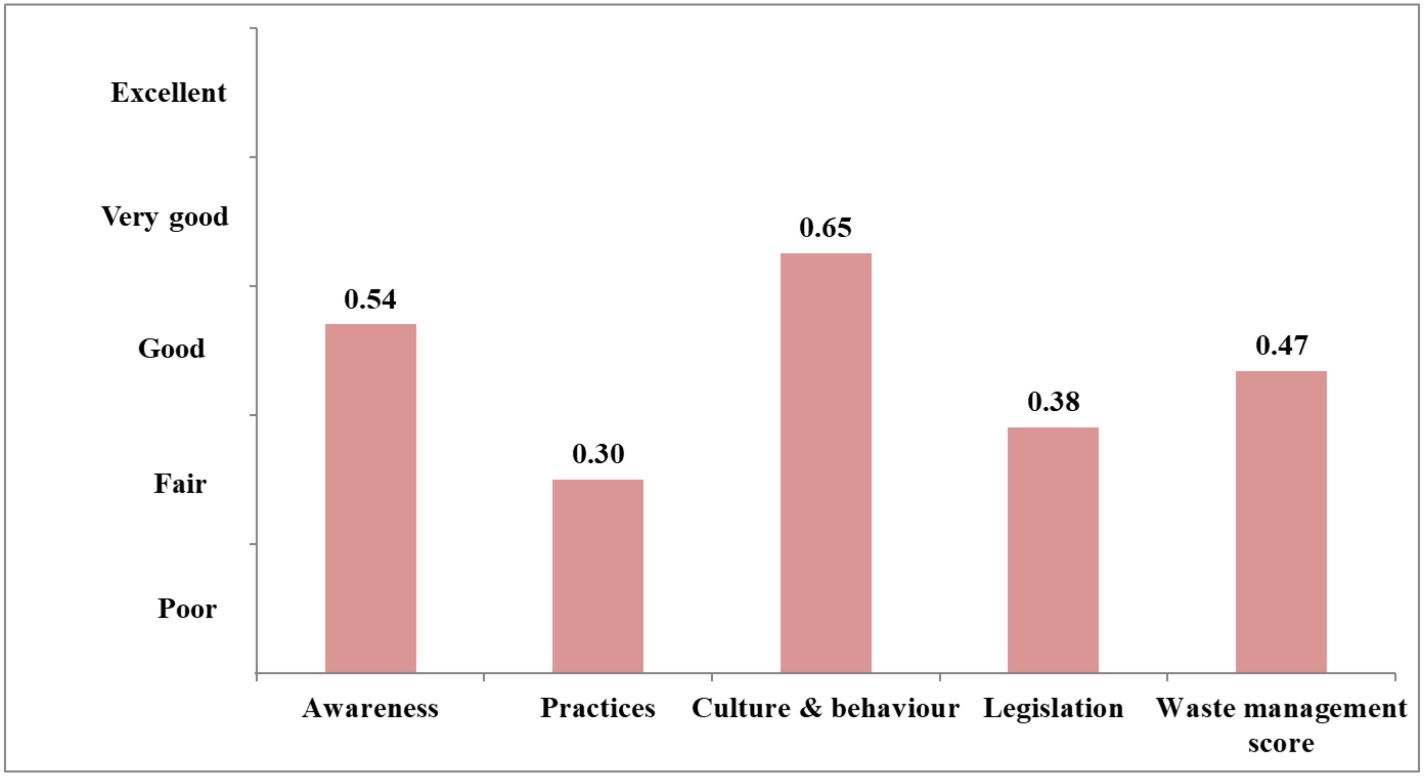

Figure 5.6 *Factors' evaluation and total WM score in the commercial project*

5.3.4 Infrastructure Project

Table 5.11a *Qualitative analysis of the infrastructure project*

Theme	Subtheme	Response
Project description	Size	The project is a thermal power plant in Egypt with an electric power production capacity of 650 megawatts (MWs).
	Specifications and challenges	The project had very high specifications and technical requirements. It is one of the most leading and complex megaprojects in Egypt. However, the firm was awarded a certificate for an excellent performance of 10 million hours with zero accidents.
	Duration	The project started in 2012, and it was delivered in 2017.
	Contractual agreement	The firm executed the project among other 18 different firms. Each firm has its scope of work. The firm was responsible for many civil works and buildings constructed in the project to be delivered fully finished.
Materials procurement models	Adopted materials procurement model/s	✓ GCPM
	Reasons behind choosing the adopted model/s	Both managers said that it was a contractual agreement, and it was a requirement stated by the project owner. The project was based on a lump sum contract in which the general contractor was responsible for procuring construction materials.

Table 5.11b *Qualitative analysis of the infrastructure project*

Theme	**Subtheme**	**Response**
Materials procurement models	Relationship between the adopted model/s and CDWR	Both managers recommended that it would have been better to use another model than the adopted one. They explained that saying millions and billions of pounds are spent on materials in construction megaprojects like this infrastructure project. The project was massive, and many construction firms, with different performances, culture & behaviour, and adopted practices, shared its execution. They concluded that this might have resulted in less control over materials wastage. From the managers' point of view, they recommend choosing between SCPM and OPM or integrating these two models as the specialty contractor is hired and controlled by the project owner. They stated that nobody would care about financial resources as the project owner. They claimed that if these two models were adopted, strict measures would have been taken differently among the construction firms, financial resources would have been saved, and environmental pollution resulting from CDW would have been reduced.

__Table 5.11c__ Qualitative analysis of the infrastructure project

Theme	**Subtheme**	**Response**
Materials procurement measures	Adopted materials procurement measures	✓ Supply of quality and durable products ✓ Purchase of quality and suitable materials ✓ Correct materials purchase ✓ Effective protection of materials (during transportation, loading & unloading) ✓ Accurate materials take-off
	Sufficiency of adopted materials procurement measures towards CDWR	Both managers complained that the adopted measures were not sufficient compared to the project size and complexity. They believed that many materials had been wasted in this project that could have been saved if the firm implemented serious materials procurement measures. They felt that their firm haphazardly executed this project. The reasons for that may be the unstable political conditions during this period and interruptions, the owner willingness to deliver the project as fast as possible, and the lack of interest and culture regarding CDWR among stakeholders.
Green building practices	Application of green materials procurement approach	Both managers stated that these criteria were not adopted in the project. Moreover, they said that they have no idea about green building rating systems.

Table 5.11d *Qualitative analysis of the infrastructure project*

Theme	**Subtheme**	**Response**
CDW problem in the Egyptian construction industry	Different reasons for CDWG	Both managers stated several reasons, from their point of view, towards such a problem in Egypt. Examples of these reasons are as follows: weak and ineffective legislation, lack of waste-efficient practices due to inadequate knowledge, lousy behaviour of construction labours, absence of CDWR culture, and lack of awareness towards the severity of the problem and its adverse effects. Moreover, they added that legal dumpsites are scarce, making it difficult and expensive for the contractors to dispose the CDW at the assigned legal dumpsites properly. Therefore, it is easier for them to dispose the CDW near their construction sites on residential roads and agricultural lands.
	Negative impacts of CDW problem	Both managers stated that CDW is a severe problem in Egypt. It leads to deterioration of infrastructure like roads, and it leads to road closures and congestions. Moreover, it negatively affects the citizens' health and well-being and leads to air, water, and soil pollution.

Table 5.12 *Quantification of CDW in the infrastructure project*

Material type (unit)	**Weighted mean value (%)**	**Standard deviation (%)**	**The quantity used in the project (unit)**	**Cost per unit (EGP/unit)**	**Total cost (EGP)**	**Cost of wasted materials (EGP)**	**Percentage of total wasted materials cost (%)**
Timber (m3)	7.23	0.71	10000	1200	12000000	867567.57	7.50
Sand (m3)	6.68	1.77	160000	45	7200000	480648.65	
Concrete (m3)	5.96	1.41	65000	1200	78000000	4648378.38	
Cement (tons)	6.41	1.06	22750	800	18200000	1165783.78	
Reinforcement steel (tons)	11.69	2.12	6400	6000	38400000	4488648.65	
Tiles (m2)	6.69	2.12	25000	120	3000000	200675.68	
Bricks/blocks (m3)	7.09	1.06	136000	180	24480000	1736756.76	

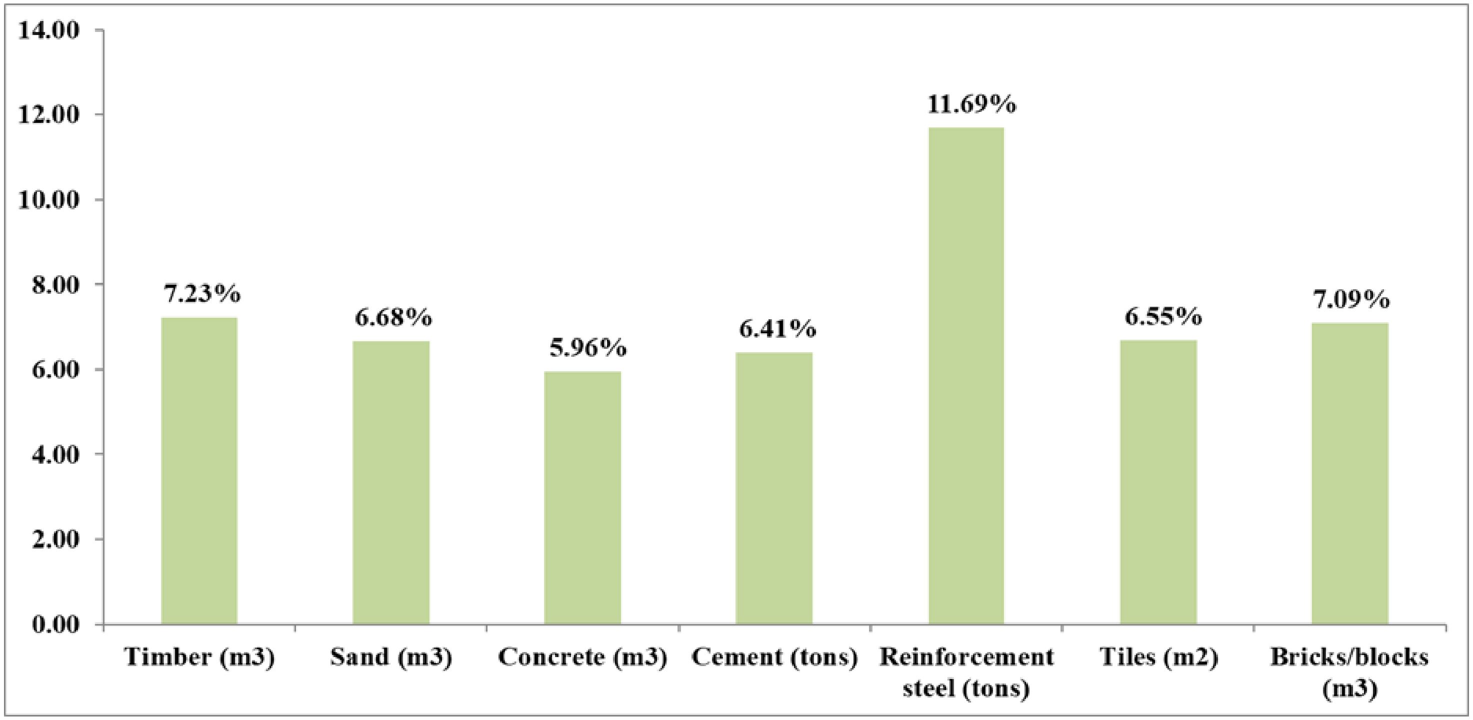

Figure 5.7 *Percentage of waste in each type of materials in the infrastructure project*

Table 5.13 *Evaluation of different CDWR factors at the firm executed the infrastructure project*

Factor	**The composite index of the factor**	**Standard deviation among respondents' evaluations**	**Interpretation of the index**	**The total final score of the project's waste management (WM)**	**Interpretation of the score**
Awareness	0.42	0.04	Good	0.28	Fair
Practices	0.25	0.00	Fair		
Culture & behaviour	0.33	0.07	Fair		
Legislation	0.13	0.00	Poor		

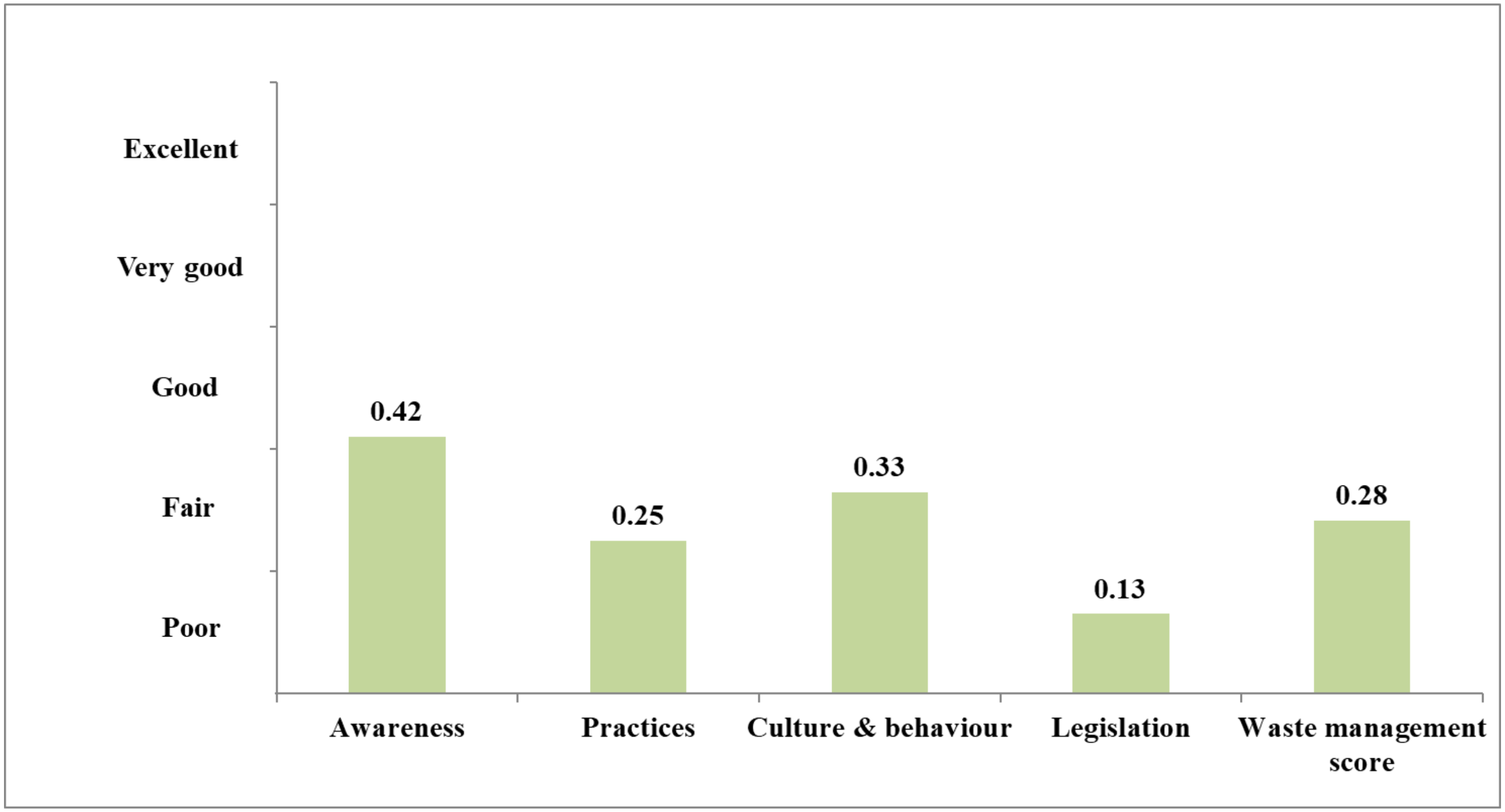

Figure 5.8 *Factors' evaluation and total WM score in the infrastructure project*

5.4 Comparison of the Four Construction Projects

After analysing the four projects investigated in the comparative case study, it is obvious that the infrastructure project was the most wasteful in terms of the percentage of total wasted materials cost in relation to total purchased materials cost and CDWG rates, as shown in Figure 5.9 and Figure 5.10 respectively. The analysis revealed variations in CDWG rates of the most common construction materials among the different construction projects, as shown in Figure 5.10. The variability in CDWG rates is obvious as follows: timber (7.05% - 11.77%), sand (2.68% - 6.69%), concrete (1.95% - 5.96%), cement (2.50% - 6.41%), reinforcement steel (0% - 11.69%), tiles (2.04% - 6.69%), and bricks/blocks (2.95% - 7.09%). These variations seem to depend on the differences in projects' nature, size, and complexity on the one hand, and the adopted practices, culture & behaviour, awareness, and legislation from a construction firm to another on the other hand.

On average, among the four projects, it was found that "timber" is the most wasteful material with an average CDWG rate of 8.96%. This is followed by "sand" with an average CDWG rate of 5.70% and "bricks/blocks" with an average CDWG rate of 4.45%. These results coincide with the previous studies for CDWM research in Egypt, in which "timber" was stated as the most wasteful material in the studies carried out by Garas *et al.* (2001) and Hany and Dulaimi (2014). On the other hand, Ragab *et al.* (2001), as reported in El-Desouky *et al.* (2018), claimed that "sand" is the most wasteful material in the Egyptian construction sector. Besides, El-Desouky *et al.* (2018) stated in their study that "bricks" is the most wasteful material in the Egyptian construction sector. The results of this study, along with the results of previous studies about CDWM in Egypt, prove that "timber", "sand", and "bricks/blocks" are the most wasteful materials in the Egyptian construction sector.

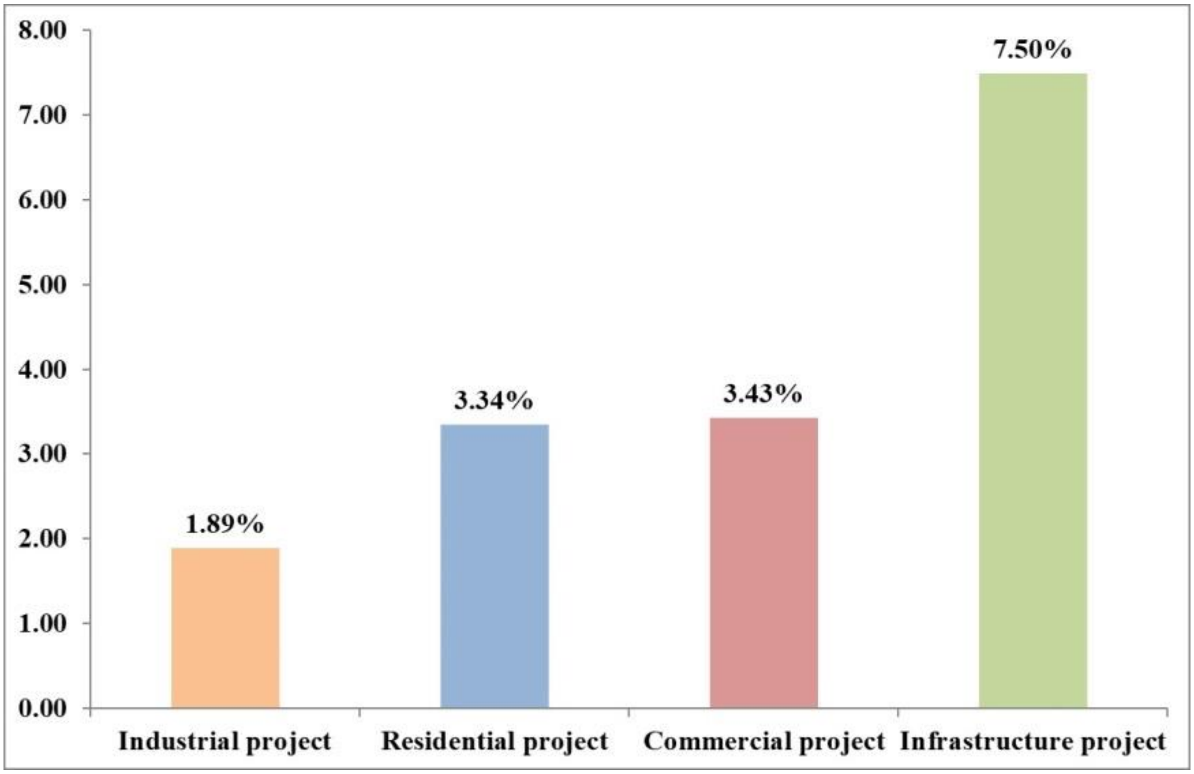

Figure 5.9 *Percentage of total wasted materials cost in relation to total purchased materials cost in different construction projects - a comparison*

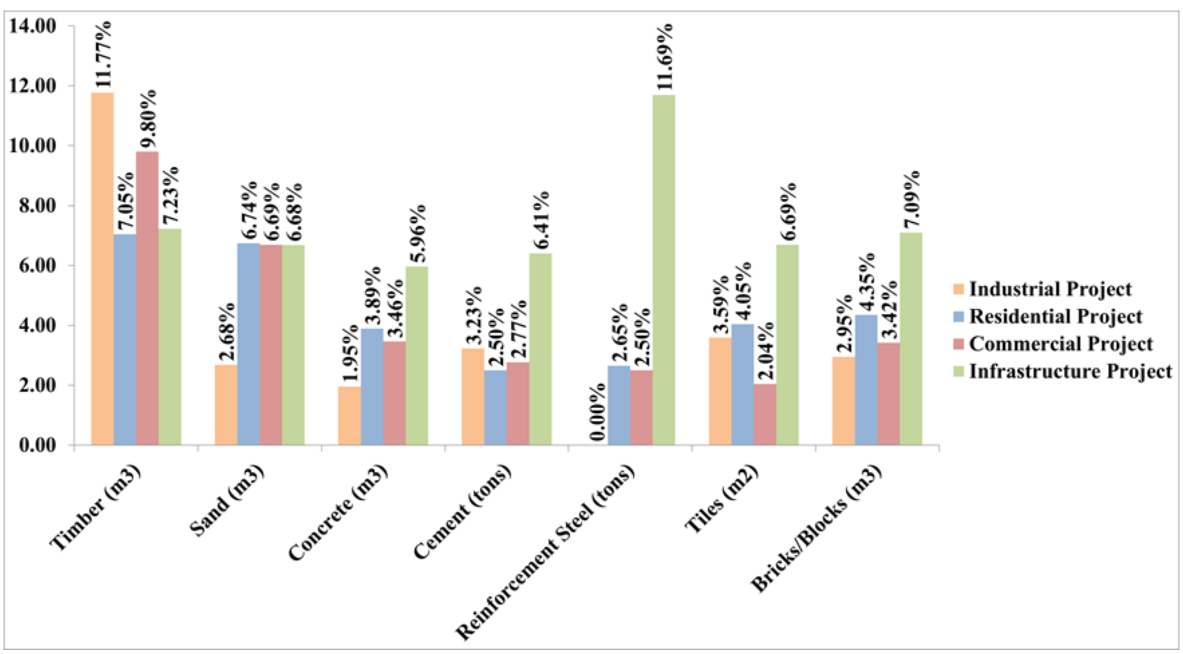

Figure 5.10 *Percentage of waste in each type of most common construction materials in different construction projects - a comparison*

The CI devised in this research reflects the actual evaluation of WM in each project. The percentage of total wasted materials cost in relation to total purchased materials cost in the four projects are as follows: industrial (1.89%), residential (3.34%), commercial (3.43%), and infrastructure (7.50%). According to Kholousy (1991) and Shamseldin (2003), it is unacceptable that the waste in total materials cost exceeds 4% under any circumstances. This coincides with the devised CI representing WM evaluation in different projects as follows: industrial (very good), residential (good), commercial (good), and infrastructure (fair), as shown in Figure 5.11. It is worth mentioning that these percentages of total wasted materials cost are for projects executed by 1st-grade firms, the most capable ones in the Egyptian construction sector, in which they are approaching the maximum recommended limit of total wasted materials cost. It is expected that the situation would be worse for lower performing firms, especially sixth and 7th-grade firms, in which the percentages of total wasted materials cost could approach 40% as stated by Shamseldin (2003).

Based on the analysis of the managers’ responses in the different projects, it can be concluded that the CDWG is affected by several factors such as adopted practices, level of managers’ awareness, quality of culture & behaviour in the firm, and applicability of legislation. On average, among the four projects, it was found that “practices” (i.e., waste-efficient materials procurement practices) and “legislation” are the least applied factors towards CDWR with average evaluation scores of 0.36 (i.e., fair) and 0.38 (i.e., fair) respectively. This is followed by “awareness” with an average evaluation score of 0.54 (i.e., good) and “culture & behaviour” with an average evaluation score of 0.63 (i.e., very good). The WM score, which depends on the four abovementioned factors, varies from one project to another in which the highest score is awarded to the industrial project with a value of 0.63 (i.e., very good), and the lowest score is awarded to the infrastructure project with a value of 0.28 (i.e., fair) as shown in Figures 5.11 and 5.12. By comparing Figures 5.9 and 5.11, it can be found that the percentage of total wasted materials cost decreases when the WM score increase. This highlights the inverse relationship between CDWG and WM score. Moreover, this indicates the importance of careful and considerate implementation of the four factors towards efficient WM and CDWR during project execution.

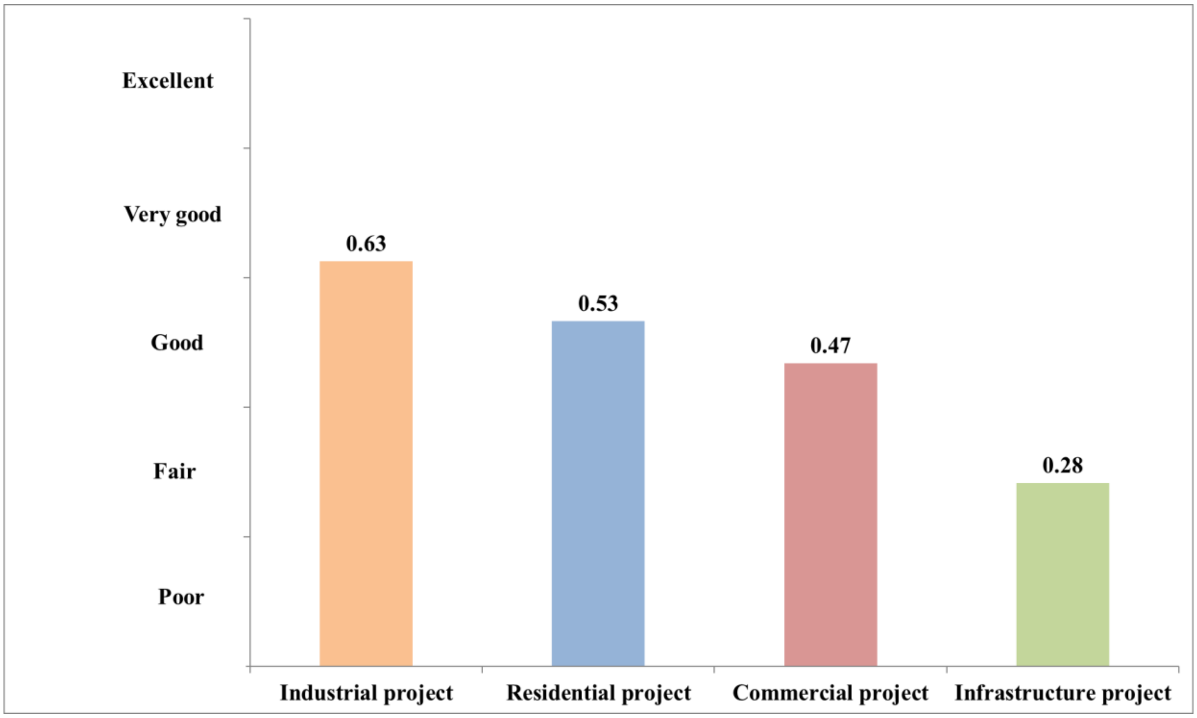

Figure 5.11 *WM score in different construction projects - a comparison*

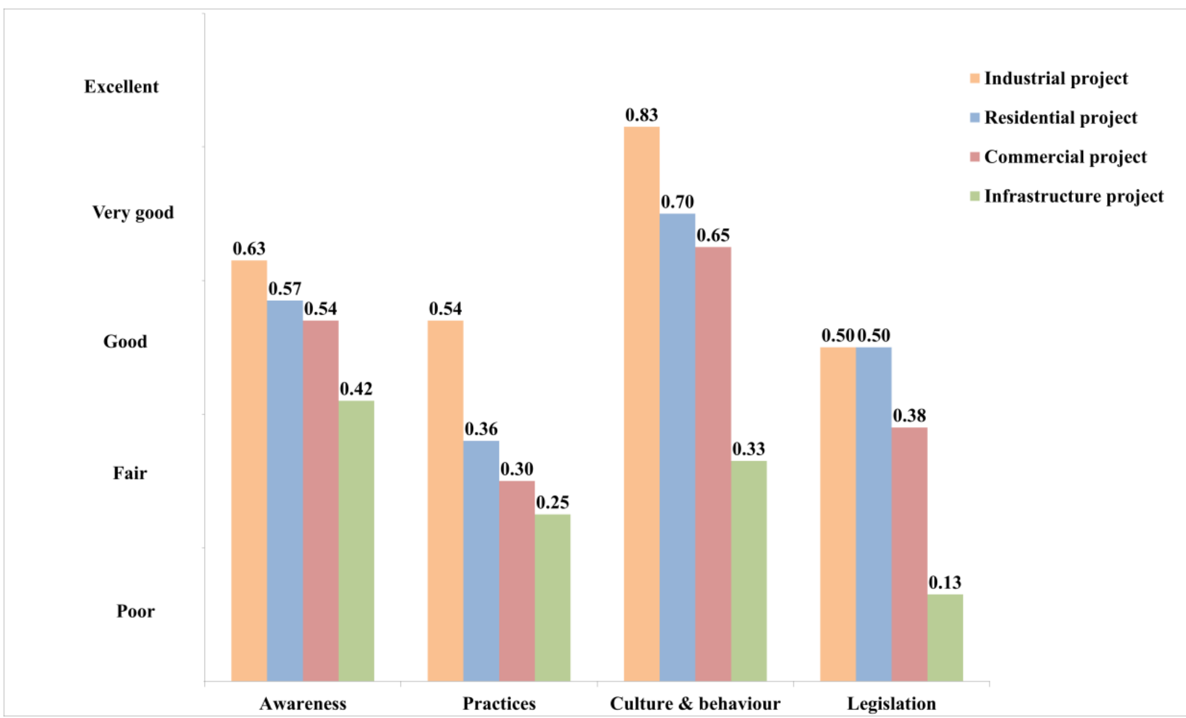

Figure 5.12 *Different CDWR factors affecting waste management WM score in different construction projects - a comparison*

More specifically, CDWG increased in the projects which adopted a low number of waste-efficient materials procurement measures and did not apply any of the green materials procurement criteria during the project execution. For instance, it was found that the industrial project, which was the best performing project regarding WM, applied 13 out of the 16 defined waste-efficient materials procurement measures plus additional measure out of the listed 16 measures, and it applied one out of the five defined green materials procurement criteria listed in the GPRS. On the other hand, it was found that the infrastructure project, which was the worst-performing project regarding WM, applied 5 out of the 16 defined waste-efficient materials procurement measures, and it did not apply any of the defined green materials procurement approaches in the GPRS due to lack of knowledge. The infrastructure project's managers also stated that the adopted waste-efficient materials procurement measures were insufficient for CDWR. This demonstrates the impact of waste-efficient materials procurement measures and green materials procurement criteria on CDWR.

Moreover, it was found that the GCPM is the dominant model being applied in the four construction projects. Based on previous studies carried out by Daneshgari and Harbin (2003), it is known that this model is not the best option regarding CDWR compared to SCPM and OPM. This was demonstrated by the responses of the infrastructure project's managers who recommended choosing between SCPM and OPM or maybe integration between these two models to better control materials procurement in mega construction projects and minimise CDW, leading to better financial savings and reduced negative environmental impact. However, the managers of the industrial, residential, and commercial projects stated that the GCPM allowed them to minimise CDWG and maximise their firms' profits. Based on different managers' responses in the data analysis section, it can be concluded that the suitability of the materials procurement model is affected by project size and nature, contractual agreement, adopted practices, level of awareness, and culture & behaviour towards CDWR implemented among different stakeholders.

Based on the insights given by the managers' responses, the CDW problem in Egypt is severe, and it is escalating over time. They stated that it results in financial losses, especially in megaprojects. Also, it negatively impacts well-being and the environment. They stated several reasons behind the problem as follows: (1) lack of good practices and especially careful dealing with materials whether during procurement or onsite; (2) poor culture & behaviour towards CDWR; (3) lack of knowledge and awareness among project participants on different levels; (4) lack of coordination among different project parties; (5) absence of efficient and effective WM legislation; (6) absence of recycling and reusing of CDW in Egypt; and (7) scarcity of legal dumpsites which forces contractors to dump CDW illegally on residential roads and agricultural lands.

5.5 Summary

This chapter provided a new contribution to knowledge through mixed research methods by (1) quantifying CDW among various Egyptian construction projects in terms of costs and generation rates; and (2) exploring the relationship between CDWR factors and CDWG. On average, among the four construction projects, it was noted that “timber” is the most wasteful material in terms of CDWG rates, followed by “sand” and “bricks/blocks” consecutively. These results coincide with previous studies carried out in CDWM research in Egypt from 2001 till 2018. It was also indicated that there is an inverse relationship between the different CDWR factors, which represent the WM evaluation in any project, and CDWG. It was proven that if these factors are improved, the CDWG will decrease represented in a decrease in the total cost of wasted materials. On average, among the four construction projects, it was found that “practices” and “legislation” are the least applied factors towards CDWR.

In the next chapter, the first part of the survey questionnaire’s analysis results is presented. It investigates respondents' demographic information and their general perceptions and attitudes towards the CDW problem in the Egyptian construction sector. Also, it demonstrates the level of applicability and effectiveness of different CDWR factors in the Egyptian construction sector and the relationship between applicability and effectiveness. Furthermore, it presents the correlation between these factors and CDWR.

CHAPTER 6: ANALYSIS OF FACTORS AFFECTING CDWR IN THE EGYPTIAN CONSTRUCTION INDUSTRY

6.1 Introduction

This chapter presents the descriptive and inferential statistical analysis of the survey questionnaire as investigated in the research methodology chapter, specifically in section 3.4.2.4. The analysis was done using statistical package for social sciences software, namely **SPSS V26**©. First, data coding and editing of the collected data is investigated. Second, a preliminary data examination is carried out, including screening for missing data, finding outliers, investigating common method bias, and testing data normality. Finally, descriptive (e.g., mean, frequency, standard deviation, cross-tabulation, RII) and inferential (e.g., chi-square test of independence, correlation analysis) statistical analysis is carried out for different questionnaire's sections.

6.2 Data Coding and Editing

The first step in data analysis is data coding and editing. This is an essential step to guarantee that the analysed data is correct, and therefore, the produced outcome makes sense and provide the perfect basis for the study's recommendations and guidelines. After collecting the data, the first step was to export the data to the SPSS file via **SPSS V26**© software. After that, the data were thoroughly examined to ensure that no mistakes occurred during the exportation. Codes were given to different IDVs and DV items to facilitate the statistical analysis via the different used software, as shown in Table 6.1 below.

All the items (i.e., indicators) of IDVs were evaluated in the survey questionnaire based on their applicability level in the Egyptian construction industry and their level of effectiveness in solving the CDW problem in the Egyptian construction sector. Accordingly, these items were accorded two evaluation codes as seen in Table 6.1, in which a code is used to represent the evaluation of the item based on its applicability level (e.g., MPMO.AP.1), and the other code is used to represent the evaluation of the item based on its effectiveness level (e.g., MPMO.EF.1). In other words, the term "AP" in the codes refers to the applicability levels' evaluation, and the term "EF" refers to the effectiveness levels' evaluation.

On the other hand, all the DV items were evaluated in the survey questionnaire based on the level of agreement on the expected improvement of different project dimensions (i.e., cost, time, and quality) via CDWR. Accordingly, these items were accorded a single evaluation code, as seen in Table 6.1, in which this code is used to represent the evaluation of the item based on the level of agreement on the expected outcomes being represented by it (e.g., CDWR.AG.1). In other words, the term "AG" in the code refers to the evaluation of the respondents' agreement levels on the expected outcomes of CDWR.

Table 6.1 *Example of evaluation codes assigned to different items of IDVs and DV*

Construct	**Type**	**Item**	**Evaluation code/s**
MPMO	IDV	MPMO.1	MPMO.AP.1 / MPMO.EF.1
		MPMO.2	MPMO.AP.2 / MPMO.EF.2
GBPR	IDV	GBPR.1	GBPR.AP.1 / GBPR.EF.1
		GBPR.2	GBPR.AP.2 / GBPR.EF.2
		GBPR.3	GBPR.AP.3 / GBPR.EF.3
		GBPR.4	GBPR.AP.4 / GBPR.EF.4
		GBPR.5	GBPR.AP.5 / GBPR.EF.5
LG	IDV	LG.1	LG.AP.1 / LG.EF.1
		LG.2	LG.AP.2 / LG.EF.2
CDWR	DV	CDWR.1	CDWR.AG.1
		CDWR.2	CDWR.AG.2
		CDWR.3	CDWR.AG.3

6.3 Preliminary Data Examination

The data examination is essential in quantitative research and specifically when using the SEM for data analysis, as presented in chapter seven (Hair *et al.*, 2017a). Sue and Ritter (2012) stated that the collected data should be screened and cleaned from errors and incomplete answers. Even though the corrective actions are not always necessary, the examination is essential to ensure that the multivariate analysis outputs are correct (Hair *et al.*, 2014a). Hair *et al.* (2017b) emphasize different aspects of collected data, such as strange response patterns, unengaged respondents, missing data, outliers, and data distribution, should be inspected and examined. Therefore, these different aspects of the primary collected data are investigated in the subsequent steps using **SPSS V26**© software. It is worth mentioning that the examined data are those measuring the effectiveness level for IDVs and those measuring the agreement level for the DV. This is because these scales are used as data for the PLS-SEM, as investigated in chapter seven.

6.3.1 Missing Data

Missing data is a common problem in behavioural (Schlomer *et al.*, 2010), marketing (Sarstedt and Mooi, 2014), and social science studies (Hair *et al.*, 2017a). It is rare when researchers do not face missing data problems (Hair *et al.*, 2014a). Missing data arise when participants leave one or more questions unanswered in the questionnaire (Sekaran and Bougie, 2016). Missing data is a problem that reduces the available data for analysis and might produce erroneous findings that lead to bias in the results (Hair *et al.*, 2014a). The effect of missing data is critical when using the SEM technique for data analysis (Hair *et al.*, 2017a) as it is not designed to analyse incomplete data (Jamil, 2012; Kline, 2012). For instance, the Bootstrapping function, used for examining the relationships between constructs (i.e., variables) in **SmartPLS**© software, cannot be calculated when the sample includes missing data. In the current study, 244 complete responses were submitted by the respondents. This is because all the online survey questionnaire questions were designed to be mandatory, and the survey could not be submitted without answering all the questions. Thus, the submitted responses did not include any missing data.

6.3.2 Outliers

A typical example of unreasonable answers is outliers, which occurs when one response is excessively different from other responses (Sekaran and Bougie, 2016). Hair *et al.* (2014) defined outliers as cases with unusual values (i.e., either too low or too high values) that distinguish them from other cases. Outliers can affect data validity (Hair *et al.*, 2016), impact the data distribution (Hair *et al.*, 2014a), and statistical bias tests (Field, 2013). In summary, outliers affect the normality of data distribution, and it is imperative to examine the data set for the existence of such outliers before being subjected to parametric analysis of SEM. Therefore, it is crucial to detect and handle outliers.

Kline (2016) has defined two types of outliers: (1) univariate outliers; and (2) multivariate outliers. Univariate outliers can be encountered when a case has an extreme value on an individual variable (Kline, 2016). Univariate detection of outliers entails identifying the cases with variable values' that are extremely low or extremely high (Sarstedt and Mooi, 2014). This type of outliers can be identified using minimum and maximum values of different variables (Sekaran and Bougie, 2016). Accordingly, there are no outliers detected, as seen in Appendix C. This was expected because five-point Likert scales were used in answering the different items included in the survey questionnaire. The respondent does not manually enter the ratings, but s/he chooses a single response from a ratings' list. Accordingly, all answers were between 1 and 5. Outliers usually do not exist in Likert scales as answering at the extreme (i.e., 1 or 5) is not considered an outlier behaviour, while entering a strange value (e.g., 170) outside the provided ratings is considered an outlier.

The second type of outliers is known as multivariate outliers, which occurs when a case (i.e., respondent) has very different values on two or more variables than the rest of the cases (Kline, 2016). In other words, it means that the correlations between the variables for these responses are significantly different or abnormal when compared to the rest of the responses in the dataset. To detect multivariate outliers, the Mahalanobis distance $(\boldsymbol{D^2})$ was used as suggested by Hair *et al.* (2014) and Kline (2016). The Mahalanobis distance indicates the case's distance from the means of IDVs (Field, 2013). As a rule of thumb for large samples (i.e., N>80) in multivariate analysis, cases with $(\boldsymbol{D^2/df}) > 3$ or 4 and $\boldsymbol{P}$**-value** < 0.001 are considered influential outliers (Hair *et al.*, 2014a). $\boldsymbol{df}$ is called "degree of freedom" which refers to the number of IDVs, so $\boldsymbol{df}$ is 6 in this this study as identified in the "theoretical framework" in chapter two. Table 6.2 demonstrates that four cases are candidates for being multivariate outliers. Two cases (i.e., ID: 35 and ID: 44) are above 4, while the other two cases (i.e., ID: 34 and ID: 161) are above 3. However, scholars stated that outliers should not be eliminated unless there is a strong evidence that they do not belong to the target population (Kline, 2016; Hair *et al.*, 2014). Furthermore, it is expected to have some outliers with a large sample, which is the case in this study, that do not affect the results substantially

(Parke, 2013). Therefore, multivariate outlier cases addressed in Table 6.2 were retained as they are very few and do not harm the data analysis.

Table 6.2 *Multivariate outliers*

Case ID	**Mahalanobis distance (D^2)**	D^2/df	***P*-value**
35	39.1951	6.532517	0.00000
44	25.07632	4.179387	0.00033
34	23.37781	3.896302	0.00068
161	22.58782	3.764637	0.00095

6.3.3 Common Method Bias Test

Common method bias occurs when the collected responses result from the instrument design rather than a reflection of the participants' perspectives. It is a measurement error that affects the validity of the study's findings (MacKenzie and Podsakoff, 2012). Common method bias can be detected by running Harman's single-factor test, commonly used by researchers in social sciences. This test is conducted by loading all the variables into an exploratory factor analysis (EFA) using the principal axis factoring method and examining the unrotated factor analysis results while placing a constraint to extract one factor only.

The percentage of the factor's explained variance determines whether the bias is of big concern in the study or not. If the factor's total variance is less than 50%, then the common method bias does not affect the data. This strategy was followed to test the data for the common bias method. Table 6.3 presents the test results indicating that the common method bias does not affect the data since the factor's total variance is about 33.5% less than the 50% threshold.

Table 6.3 *Results of Harman's single-factor test*

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.074	33.540	33.540	12.074	**33.540**	33.540
2	4.501	12.503	46.042			
3	2.610	7.249	53.292			

6.3.4 Normality

Normality refers to the data distribution of a single variable (Field, 2013). In the best-case scenario, data will take a bell-shaped curve to indicate a normal distribution (Hair *et al.*, 2016). The normality test is one of the first measures required to verify that the data collected are appropriate for statistical data analysis. In other words, data that are not normally distributed might affect the reliability and validity of multivariate data analysis (Hair *et al.*, 2014a). Even though the PLS-SEM is a non-parametric approach that does not require normal data (Hair *et al.*, 2017a; Garson, 2016), it is important to ensure that data collected are not extremely non-normal (Hair *et al.*, 2017a).

In terms of measuring the data distribution, researchers of the SEM (Hair *et al.*, 2017a; Kline, 2016; Hair *et al.*, 2014) recommended using two values to measure the shape of data distribution: skewness and kurtosis. Skewness refers to measuring the data distribution's symmetry, while kurtosis refers to the distribution height (Field, 2013). The positive skewness value indicates that the distribution is skewed to the left, and the negative skewness value indicates that the distribution is skewed to the right (Kline, 2016). Positive kurtosis indicates that the distribution is too peaked, and negative kurtosis indicates it is too flat (Kline, 2016).

While the optimum values of skewness and kurtosis are zero (Cohen *et al.*, 2013), the threshold of skewness and kurtosis is controversial. The skewness and kurtosis values between -2 and +2 are considered acceptable to prove normal distribution (Trochim and

Donnelly, 2006; Field, 2009; George and Mallery, 2010; Gravetter and Wallnau, 2014). The normality test results in Table 6.4 show that the values of skewness and kurtosis for the model's constructs were within the range of ±2, except for GBPR, LG, and AW. However, Griffin and Steinbrecher (2013) stated that it is acceptable to have skewness within the range of ±3 and kurtosis within the range of ±10 for the normality test of data when using the SEM technique. Moreover, PLS-SEM's statistical properties have a robust model estimate of both normal and highly non-normal distributional properties (Reinartz *et al.*, 2009; Ringle *et al.*, 2009). Accordingly, it can be concluded that the data are meeting the acceptance criteria of normality for the SEM technique.

Table 6.4 *Normality results through Skewness and kurtosis*

	Skewness		**Kurtosis**	
	Statistic	Std. Error	Statistic	Std. Error
MPMO	-0.757	0.156	0.838	0.310
MPMR	-1.051	0.156	0.584	0.310
GBPR	-2.025	0.156	3.697	0.310
LG	-1.227	0.156	3.101	0.310
AW	-2.009	0.156	3.400	0.310
CB	-0.272	0.156	-0.309	0.310
CDWR	-.548	0.156	0.636	0.310

6.4 Data Analysis

6.4.1 Demographic Information

This sub-section presents the respondents' demographics, representing the first half of the survey questionnaire's first section. The first question investigates the number of years' experience the respondent has in the construction sector. Table 6.5 and Figure 6.1 illustrate that respondents have different years of work experiences ranging between "0 to 5 years" and "more than 20 years". Most of the respondents, about 77%, have experiences of "0 to 5 years" and "5 to 10 years". This may indicate that younger generations are more ambitious and curious about solving the CDW problem in the Egyptian construction industry.

Table 6.5 *Frequencies and percentages for industrial work experience*

Industrial Work Experience		Count	Percentage (%)
Q1	0 to 5 years	108	44.3%
	5 to10 years	80	32.8%
	10 to 15 years	20	8.2%
	15 to 20 years	14	5.7%
	More than 20 years	22	9.0%

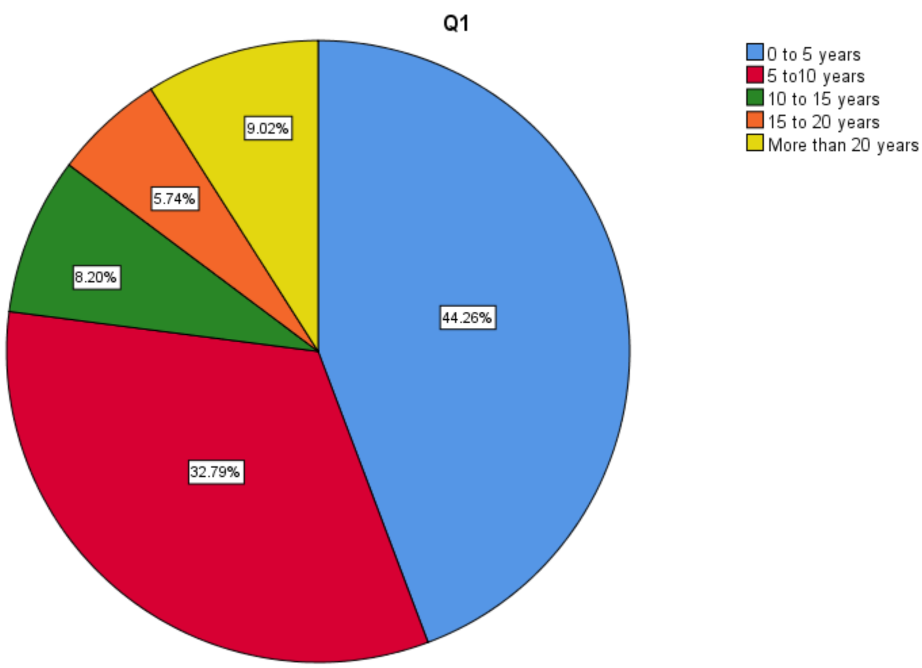

Figure 6.1 *Pie chart for industrial work experience*

The second question investigates the department at which the respondent is working. Table 6.6 and Figure 6.2 show that about 53% were in the project management department, about 16% were in the procurement management department, and 31% were in other departments such as the technical office, contracts department, QA/QC department, and operations department.

Table 6.6 *Frequencies and percentages for work department*

Work Department		Count	Percentage (%)
Q2	Project management	130	53.3%
	Procurement management	38	15.6%
	Other	76	31.1%

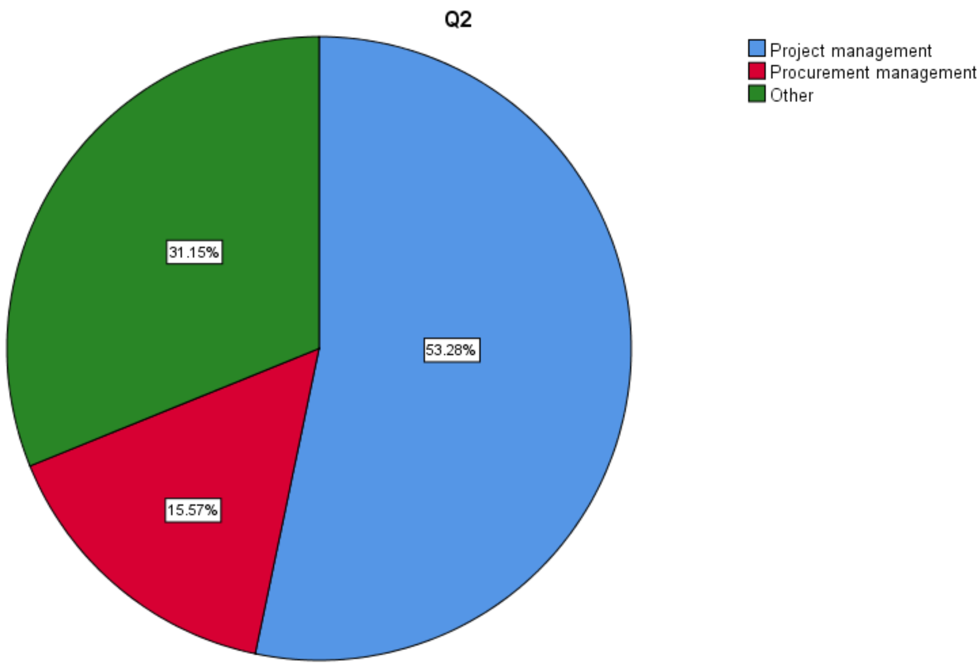

Figure 6.2 *Pie chart for work department*

The third question investigates the highest degree or level of education the respondent had completed. Table 6.7 and Figure 6.3 indicate that about 57% had a bachelor's degree, 8% had a postgraduate diploma, 24% had a master's degree, and about 11% had a doctorate. This indicates that a high percentage of the respondents, about 43%, are highly educated and holders of postgraduate diploma, master’s degree, and a doctorate in civil and architectural engineering.

Table 6.7 Frequencies and percentages for the level of education

Level of Education		Count	Percentage (%)
Q3	Bachelor's degree	138	56.6%
	Postgraduate diploma	20	8.2%
	Master's degree	58	23.8%
	Doctorate degree	28	11.5%

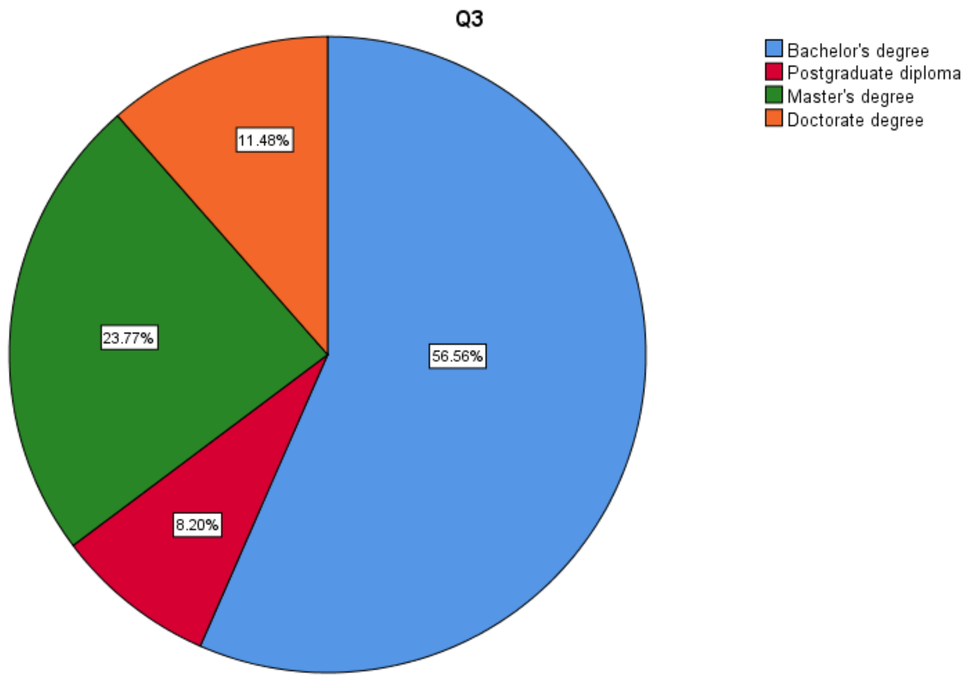

***Figure 6.3** Pie chart for level of education*

The fourth question investigates the classification grade of the respondent's firm within the EFCBC. As seen in Table 6.8 and Figure 6.4, the 1st-grade firms have the highest percentage (i.e., 45.9%), while the 2nd-grade firms have the lowest percentage (i.e., 5.7%). It is indicated that all the different firm grades per EFCBC classification are covered in this survey with different percentages. The percentage of respondents who are working at large (i.e., 1st, 2nd, and 3rd-grades) firms is about 65%, which may indicate the willingness of large firms to reduce CDW more than medium (i.e., 4th and 5th-grades) and small (i.e., 6th and 7th-grades) firms.

Table 6.8 *Frequencies and percentages for classification grades of respondents' firms within the EFCBC*

Classification Grade		**Count**	**Percentage (%)**
Q4	1st-grade	112	45.9%
	2nd-grade	14	5.7%
	3rd-grade	32	13.1%
	4th-grade	18	7.4%
	5th-grade	20	8.2%
	6th-grade	16	6.6%
	7th-grade	32	13.1%

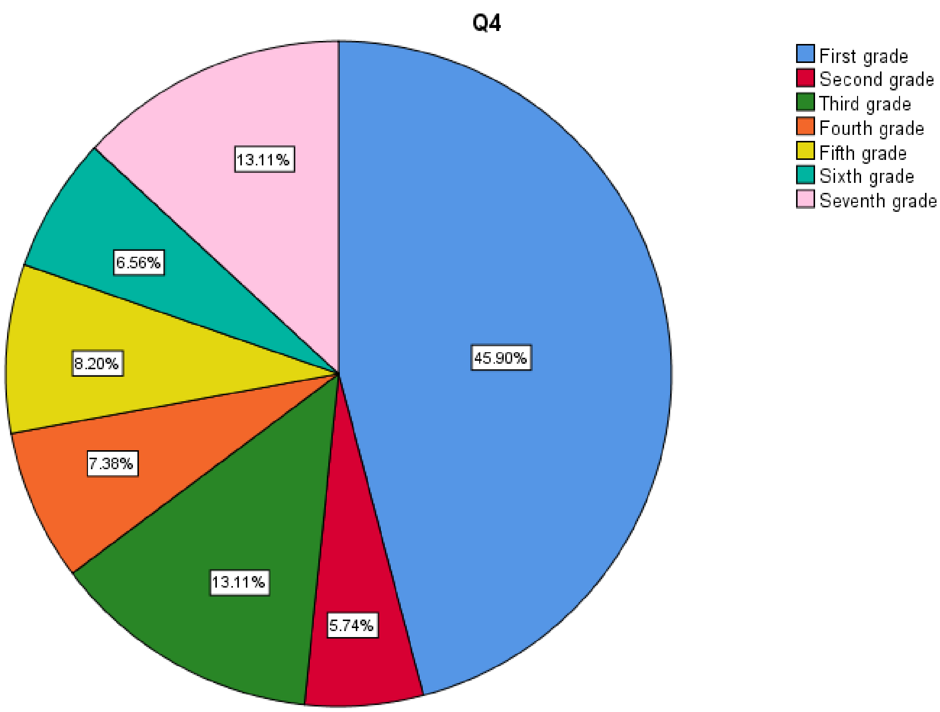

Figure 6.4 *Pie chart for level of classification grade of respondents' firms within the EFCBC*

The fifth question investigates all the types of projects carried out by the respondent's firm. Table 6.9 summarises the results of multiple response analysis in which per cent of responses and per cent of cases are displayed. Per cent of responses is the percentage of assigned responses to a specific category out of total assigned responses from the given dataset (i.e., different categories), which is 566. Thus, the total per cent of responses is 100. Similarly, per cent of cases is the percentage of cases or respondents, relative to the original data with the sample size of 244, who chose a specific category among the other different categories.

Table 6.9 *Multiple response analysis for types of project*

	Frequencies				
			Responses		**Per cent of Cases**
			N	**Per cent**	
Q5	**Types of projects**	Industrial projects	118	20.9%	48.4%
		Commercial projects	136	24.0%	55.7%
		Residential projects	198	35.0%	81.1%
		Infrastructure projects	114	20.1%	46.7%
	Total		566	100.0%	231.9%

The number of respondents who chose industrial projects was 118, representing 48.4% of total respondents, which indicates that the industrial projects constitute about 21% of total chosen projects. Similarly, 136 respondents chose commercial projects, representing 55.7% of total respondents, which indicates that the commercial projects constitute about 24% of the total chosen projects. The respondents' highest number was 198 respondents who chose residential projects, representing 81.1% of the total respondents, which indicates that these projects constitute about 35% of the total chosen projects. On the other hand, the lowest number of respondents was 114 respondents who chose infrastructure projects, representing 46.7% of total respondents, which indicates that these projects constitute about 20% of the total chosen projects. It seems that most Egyptian construction firms tend to execute residential projects following the agenda of the Egyptian government towards decentralization by planning and constructing new communities, as mentioned in Egypt's vision 2030 (Invest-gate, 2016).

To investigate the associations between the projects' different types, cross-tabulation was carried out via **SPSS V26**© software using the responses towards these projects. Table 6.10 shows that 86 respondents, out of 118 respondents, representing about 73% of the respondents, chose commercial projects with industrial projects. Similarly, 94 respondents, out of 118 respondents, representing about 80% of the respondents, chose residential projects with industrial projects. Besides, 66 respondents, out of 118 respondents, representing about 56% of the respondents, chose infrastructure projects with industrial projects.

Table 6.10 *Cross-tabulation for industrial projects with the other projects*

			Types of projects				Total
			Industrial projects	Commercial projects	Residential projects	Infrastructure projects	
Industrial projects	.00[a]	Count	0	50	104	48	126
		% within row	0.0%	39.7%	82.5%	38.1%	
	1.00[b]	Count	118	86	94	66	118
		% within row	100.0%	72.9%	79.7%	55.9%	
Total		Count	118	136	198	114	244

[a] Not in the project [b] In the project

Table 6.11 shows that 86 respondents, out of 136 respondents, representing about 63% of the respondents, chose industrial projects with commercial projects. Similarly, 130 respondents, out of 136 respondents, representing about 96% of the respondents, chose residential projects with commercial projects. Besides, 74 respondents, out of 136 respondents, representing about 54% of the respondents, chose infrastructure projects with commercial projects.

Table 6.11 *Cross-tabulation for commercial projects with the other projects*

			Types of projects				Total
			Industrial projects	Commercial projects	Residential projects	Infrastructure projects	
Commercial projects	.00[a]	Count	32	0	68	40	108
		% within row	29.6%	0.0%	63.0%	37.0%	
	1.00[b]	Count	86	136	130	74	136
		% within row	63.2%	100.0%	95.6%	54.4%	
Total		Count	118	136	198	114	244

[a] Not in the project [b] In the project

Table 6.12 shows that 94 respondents, out of 198 respondents, representing about 63% of the respondents, chose industrial projects with residential projects. Similarly, 130 respondents, out of 198 respondents, representing about 66% of the respondents, chose commercial projects with residential projects. Besides, 88 respondents, out of 198 respondents, representing about 44% of the respondents, chose infrastructure projects with residential projects.

Table 6.12 *Cross-tabulation for residential projects with the other projects*

			Types of projects				Total
			Industrial projects	Commercial projects	Residential projects	Infrastructure projects	
Residential projects	.00[a]	Count	24	6	0	26	46
		% within row	52.2%	13.0%	0.0%	56.5%	
	1.00[b]	Count	94	130	198	88	198
		% within row	47.5%	65.7%	100.0%	44.4%	
Total		Count	118	136	198	114	244

[a] Not in the project [b] In the project

Table 6.13 shows that 66 respondents out of 114 respondents, representing about 58% of the respondents, chose industrial projects with infrastructure projects. Similarly, 74 respondents out of 114 respondents, representing about 65% of the respondents, chose commercial projects with infrastructure projects. Besides, 88 respondents out of 114 respondents, representing about 77% of the respondents, chose residential projects with infrastructure projects.

Table 6.13 *Cross-tabulation for infrastructure projects with the other projects*

			Types of projects				Total
			Industrial projects	Commercial projects	Residential projects	Infrastructure projects	
Infrastructure projects	.00[a]	Count	52	62	110	0	130
		% within row	40.0%	47.7%	84.6%	0.0%	
	1.00[b]	Count	66	74	88	114	114
		% within row	57.9%	64.9%	77.2%	100.0%	
Total		Count	118	136	198	114	244

[a] Not in the project [b] In the project

Based on the analysis of cross-tabulation results investigated in Tables 6.10 – 6.13, it seems that residential projects are highly associated with all other types of projects with different percentages. Residential and commercial projects are the most associated projects in the Egyptian construction industry. In other words, the firms which carry out residential projects tend to execute commercial projects as the second priority.

6.4.2 General Perceptions and Attitudes Towards CDW Problem in Egypt

Frequencies and percentages for the sixth question are reported in Table 6.14 and Figure 6.5. The question is: “to what extent do you agree that waste-efficient practices, legislation, appropriate culture & behaviour, and high awareness positively affect CDW minimisation?”. 118 respondents, representing 48% of total respondents, chose “agree”; while 126 respondents, representing 52% of total respondents, chose “strongly agree”. This result demonstrates the initial consensus on the hypothesized theory that waste-efficient practices, CDWM legislation, appropriate culture & behaviour, and high awareness can reduce CDW in Egypt.

Table 6.14 *Frequencies and percentages for Q6*

		Count	Percentage (%)
Q6	Agree	118	48.4%
	Strongly agree	126	51.6%

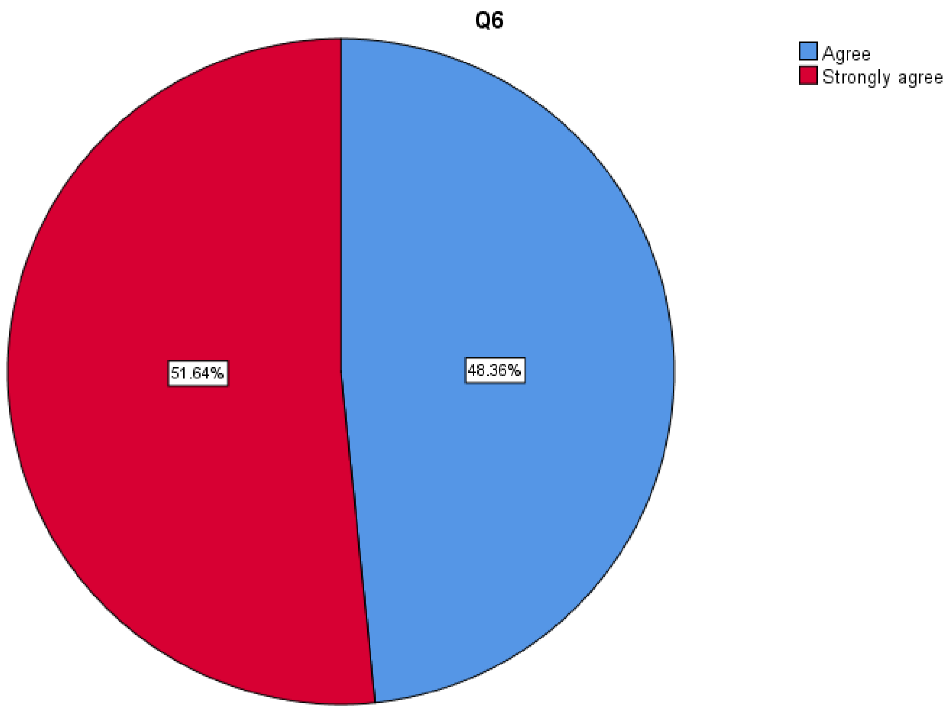

Figure 6.5 *Pie chart for Q6*

Similarly, frequencies and percentages for the seventh question are reported in Table 6.15 and Figure 6.6. The question is: "to what extent do you agree that the Egyptian construction industry needs a framework for improving current practices, legislation, culture & behaviour, and awareness in order to minimise CDW?". 140 respondents, representing 57% of total respondents, chose "agree"; In comparison, 104 respondents, representing 43% of total respondents, chose "strongly agree". This demonstrates that the research motive and objectives are on the right track given the full consensus on the necessity of developing a framework to improve the current practices, legislation, culture & behaviour, and awareness for reducing CDW in Egypt.

Table 6.15 *Frequencies and percentages for Q7*

		Count	Percentage (%)
Q7	Agree	140	57.4%
	Strongly agree	104	42.6%

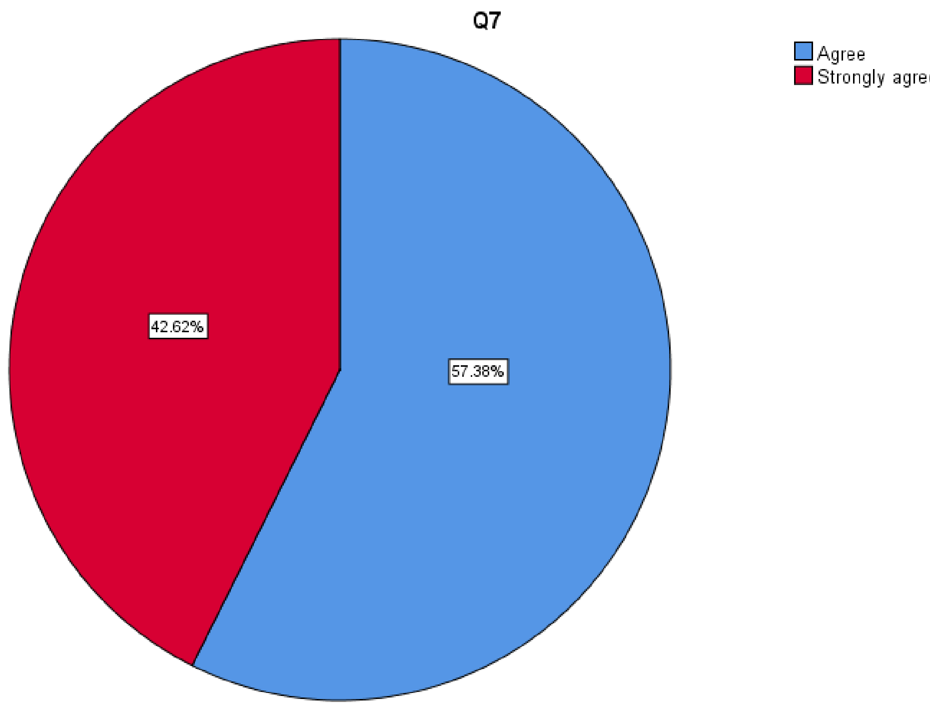

Figure 6.6 *Pie chart for Q7*

For the eighth question, the frequencies and percentages are reported in Table 6.16 and Figure 6.7. The question is: "how often do the procurement management and/or project management departments in your firm tend to reduce CDW during projects execution?". 26 respondents, representing 11% of total respondents, chose "never"; 50 respondents, representing 21% of total respondents, chose "rarely"; 92 respondents, representing 38% of total respondents, chose "sometimes"; and 76 respondents, representing 31% of total respondents, chose "often". This result demonstrates that about 70% of the respondents' firms do not pay careful attention to CDWR given the lack of waste-efficient practices, legislation, appropriate culture & behaviour, and high awareness in Egypt.

Table 6.16 *Frequencies and percentages for Q8*

		Count	Percentage (%)
Q8	Never	26	10.7%
	Rarely	50	20.5%
	Sometimes	92	37.7%
	Often	76	31.1%

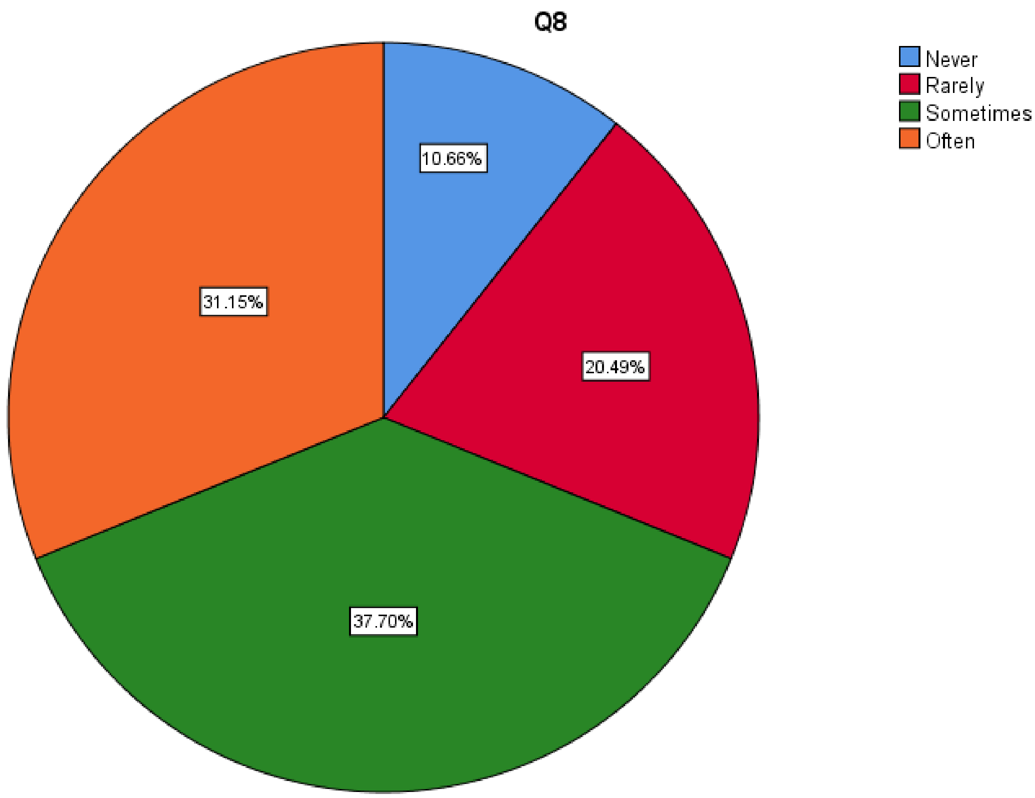

Figure 6.7 *Pie chart for Q8*

6.4.3 Applicability and Effectiveness of Different Factors Affecting CDWR

In this subsection, descriptive statistical analysis is carried out to determine the mean of responses towards evaluating the items (i.e., indicators) of different factors (i.e., IDVs) contributing to CDWR. These items were evaluated on five-point Likert scales based on their current level of applicability in the Egyptian construction sector and their level of effectiveness in solving the CDW problem in Egypt according to respondents' perspectives, representing the second, third, and fourth sections of the questionnaire. First, mean and standard deviation were calculated for the applicability and effectiveness levels of the different items. Second, the relative importance index (RII) was calculated to rank and rearrange the different items under investigation (Holt, 2014).

Items were ranked once based on their applicability levels and another time based on their effectiveness levels. For instance, Enshassi & Saleh (2019) used RII for ranking different lean construction techniques used in reducing accidents in construction projects based on their applicability levels. Also, Mendis et al. (2017) used RII for ranking different associated practices of a safe working cycle (SWC) in the Sri Lankan construction industry based on their applicability levels. On the other hand, Othman et al. (2005) used RII for ranking different factors that drive brief development in the construction industry based on their influence (i.e., effectiveness) levels. RII is calculated using the following equation as early investigated by Olomolaiye et al. (1987) and Shash (1993):

$$\text{RII} = \frac{\sum W}{\text{AN}}$$

Where "W" represents the weights accorded to each item based on its applicability or effectiveness. It ranges from 1 to 5, where 1 = not applied at all or not effective at all, and 5 = extremely applied or extremely effective. "A" represents the highest weight in the rating scales (i.e., five in this study). "N" represents the total number of engaged respondents (Kometa and Olomolaiye, 1997). RII value ranges from zero to one. In this study, high RII values indicate that some items are more applicable or more effective than those with relatively lower RIIs. According to Chen *et al.* (2010), the ranking importance levels resulting from the RII analysis are derived as investigated in Table 6.17 as follows:

Table 6.17 *Importance levels*

Source*: (Chen et al., 2010)*

Importance Levels	**Abbreviation**	**Range**
High	H	0.8 < RII < 1.0
High-Medium	H-M	0.6 < RII < 0.8
Medium	M	0.4 < RII < 0.6
Medium-Low	M-L	0.2 < RII < 0.4
Low	L	0.0 < RII < 0.2

The results of RII are reported in Table 6.18, along with the corresponding ranking and their importance level based on the items' applicability levels. It is evident from the ranking table that most of the items (i.e., 25 items) were identified with "Medium" and "Medium-Low" importance levels, while the rest of the items (i.e., eight items) were identified with "High" and "High-Medium" importance levels. This indicates that most of the items are not efficiently applied in the Egyptian construction sector and that the Egyptian construction firms are reluctant towards CDWR. These items of "Medium" and "Medium-Low" importance levels have RIIs in the range of 0.597–0.293. The items of "High" and "High-Medium" importance levels have RIIs in the range of 0.911–0.602. Overall, the most applied item among different factors is "**MPMR.LWPM.AP.5**" (i.e., correct materials purchase), and the least applied item among different factors is "**LG.AP.2**" (i.e., Article 39 of the Egyptian Environment Law 4/1994 and Article 41 of the executive regulations for the Egyptian Environment Law 4/1994).

On the other hand, the results of RII are reported in Table 6.19, along with the corresponding ranking and their importance level based on the items' effectiveness levels. It is evident from the ranking table that all the items were identified with "High" importance levels, except only one item (i.e., MPMO.EF.1), which was identified with a "High-Medium" importance level. This indicates that almost all items are considered of prime effectiveness for reducing CDWG even though not efficiently applied in Egypt. These items of "High" importance levels have RIIs in the range of 0.961–0.811. The item of "High-Medium" importance level has an RII of 0.798. Overall, the most effective item among different factors is "**GBPR.EF.3**" (i.e., reducing overall material use by using prefabricated elements and highly durable materials), and the least effective item among different factors is "**MPMO.EF.1**" (i.e., SCPM).

__Table 6.18a__ Descriptive statistics and ranking of different items based on applicability levels

Construct		Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
MPMO		MPMO.AP.1	3.098	0.659	0.620	1	5	H-M
		MPMO.AP.2	2.557	0.498	0.511	2	17	M
MPMR	**SLWC**	MPMR.SLWC.AP.1	2.984	0.726	0.597	2	8	M
		MPMR.SLWC.AP.2	2.107	0.809	0.421	3	22	M
		MPMR.SLWC.AP.3	4.074	0.761	0.815	1	3	H
		MPMR.SLWC.AP.4	1.541	0.499	0.308	4	28	M-L
	LWPM	MPMR.LWPM.AP.1	2.057	0.784	0.411	4	24	M
		MPMR.LWPM.AP.2	1.648	0.479	0.330	5	27	M-L
		MPMR.LWPM.AP.3	4.041	0.763	0.808	2	4	H
		MPMR.LWPM.AP.4	2.730	0.445	0.546	3	10	M
		MPMR.LWPM.AP.5	4.557	0.498	0.911	1	1	H
	EMDM	MPMR.EMDM.AP.1	2.041	0.785	0.408	3	25	M
		MPMR.EMDM.AP.2	3.008	0.775	0.602	1	7	H-M
		MPMR.EMDM.AP.3	2.713	0.453	0.543	2	12	M
		MPMR.EMDM.AP.4	1.721	0.449	0.344	4	26	M-L
	WEBOQ	MPMR.WEBOQ.AP.1	4.525	0.500	0.905	1	2	H
		MPMR.WEBOQ.AP.2	3.016	0.770	0.603	2	6	H-M
		MPMR.WEBOQ.AP.3	2.730	0.445	0.546	3	10	M

Table 6.18b *Descriptive statistics and ranking of different items based on applicability levels*

Construct	Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
GBPR	GBPR.AP.1	2.582	0.701	0.516	5	16	M
	GBPR.AP.2	2.779	0.416	0.556	2	9	M
	GBPR.AP.3	2.615	0.672	0.523	3	14	M
	GBPR.AP.4	2.598	0.662	0.520	4	15	M
	GBPR.AP.5	3.008	0.622	0.602	1	7	H-M
LG	LG.AP.1	2.234	0.424	0.447	1	21	M
	LG.AP.2	1.467	0.500	0.293	2	29	M-L
AW	AW.AP.1	2.721	0.449	0.544	2	11	M
	AW.AP.2	2.697	0.461	0.539	3	13	M
	AW.AP.3	2.730	0.445	0.546	1	10	M
CB	CB.AP.1	1.721	0.449	0.344	5	26	M-L
	CB.AP.2	2.516	0.501	0.503	2	19	M
	CB.AP.3	2.090	0.791	0.418	4	23	M
	CB.AP.4	2.541	0.499	0.508	1	18	M
	CB.AP.5	2.500	0.501	0.500	3	20	M

Table 6.19a *Descriptive statistics and ranking of different items based on effectiveness levels*

Construct		Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
MPMO		MPMO.EF.1	3.988	0.872	0.798	2	29	H-M
		MPMO.EF.2	4.061	0.842	0.812	1	26	H
MPMR	**SLWC**	MPMR.SLWC.EF.1	4.299	0.804	0.860	4	19	H
		MPMR.SLWC.EF.2	4.398	0.710	0.880	1	15	H
		MPMR.SLWC.EF.3	4.357	0.770	0.871	3	17	H
		MPMR.SLWC.EF.4	4.391	0.766	0.878	2	16	H
	LWPM	MPMR.LWPM.EF.1	4.549	0.698	0.910	1	8	H
		MPMR.LWPM.EF.2	4.516	0.728	0.903	4	11	H
		MPMR.LWPM.EF.3	4.520	0.740	0.904	3	10	H
		MPMR.LWPM.EF.4	4.533	0.699	0.907	2	9	H
		MPMR.LWPM.EF.5	4.504	0.729	0.901	5	12	H
	EMDM	MPMR.EMDM.EF.1	4.160	0.997	0.832	3	23	H
		MPMR.EMDM.EF.2	4.152	0.959	0.830	4	24	H
		MPMR.EMDM.EF.3	4.193	0.916	0.839	1	20	H
		MPMR.EMDM.EF.4	4.164	0.942	0.833	2	22	H

Table 6.19b *Descriptive statistics and ranking of different items based on effectiveness levels*

Construct		Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
MPMR	**WEBOQ**	MPMR.WEBOQ.EF.1	4.418	0.665	0.884	2	14	H
		MPMR.WEBOQ.EF.2	4.467	0.693	0.893	1	13	H
		MPMR.WEBOQ.EF.3	4.332	0.754	0.866	3	18	H
GBPR		GBPR.EF.1	4.654	0.752	0.931	4	6	H
		GBPR.EF.2	4.687	0.711	0.937	3	5	H
		GBPR.EF.3	4.807	0.537	0.961	1	1	H
		GBPR.EF.4	4.725	0.687	0.945	2	3	H
		GBPR.EF.5	4.520	0.927	0.904	5	10	H
LG		LG.EF.1	4.180	0.754	0.836	1	21	H
		LG.EF.2	4.061	0.791	0.812	2	26	H
AW		AW.EF.1	4.730	0.552	0.946	1	2	H
		AW.EF.2	4.635	0.722	0.927	3	7	H
		AW.EF.3	4.697	0.684	0.939	2	4	H

Table 6.19c *Descriptive statistics and ranking of different items based on effectiveness levels*

Construct	Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
CB	CB.EF.1	4.086	0.613	0.817	1	25	H
	CB.EF.2	4.057	0.706	0.811	3	27	H
	CB.EF.3	4.053	0.738	0.811	4	28	H
	CB.EF.4	4.061	0.817	0.812	2	26	H
	CB.EF.5	4.086	0.829	0.817	1	25	H

6.4.4 Applicability vs Effectiveness – Chi-square test of Independence

The chi-square test of independence was conducted to investigate the association between the current applicability level and the effectiveness level of different practices, legislation, culture & behaviour measures, and awareness measures in the Egyptian construction sector. Each variable can have two or more categories for evaluation. The frequency of one categorical variable is compared with different values of the second categorical variable. Chi-square analysis compares the observed and expected frequencies in each category to test that all categories contain the same proportion of values or that each category contains a user-specified proportion of values (Bland, 2000). A Pearson Chi-square (χ^2) test of independence is used to explore the relationship and dependency between two categorical variables (i.e., applicability and effectiveness levels). The significance of the relationship was reviewed using the null hypothesis $\mathbf{H_0}$ that the two categorical variables are independent of one another, which will be rejected at a significance level (***P*-value**) of 5% (i.e., 0.05). The proposed alternative hypothesis $\mathbf{H_1}$ is that the two categorical variables are dependent on one another.

David and Sutton (2004) and Urdan (2005) stated two assumptions for using the Pearson Chi-square test and reporting its results. The first assumption is that the collected records should have no influence on one another, in which data in this study meet this assumption. The second assumption is that the maximum percentage of cells in tables with expected counts less than five should be restricted to 20% maximum, in which data in this study do not meet this condition in all cases. Accordingly, Fisher's exact test was more suitable to be used in this situation in which reporting its significance values would be more accurate than reporting those of Pearson Chi-square test (Urdan, 2005). Results of Chi-square and Fisher's exact tests for all items and the cross-tabulation tables are reported in Appendix D. Each page in this appendix shows a test for the association between the applicability and the effectiveness levels of different items. The first table shows a cross-tabulation between applicability and effectiveness of different items, where the applicability item is in the rows, and the effectiveness item is in the columns. The second table demonstrates the asymptotic significance (***P*-value**) of both the Pearson Chi-square test and Fisher's exact test.

The results show no association for all items, except one, between the current applicability level and the effectiveness of different practices, legislation, culture & behaviour measures, and awareness measures in the Egyptian construction sector. This is because the ***P*-value** is greater than 0.05, in which the null hypothesis could not be rejected. This confirms that despite the high effectiveness of these different factors contributing to CDWR as being recognised by the respondents; however, the applicability of these factors is still not high enough due to Egyptian construction firms' reluctance. This means that these different factors' effectiveness is independent and has no influence on their applicability in the Egyptian construction sector, given Egyptian construction firms' reluctance to apply them. The only significant association found is between the current applicability level and the effectiveness level of **MPMR.WEBOQ.3** (i.e., reduced waste allowance); since the ***P*-value** is less than 0.05. A clustered bar charts are also presented, which show a graphical representation of the association between the current applicability and effectiveness levels of different factors contributing to CDWR in the Egyptian construction sector.

6.4.5 Initial Examination of Relationships – Bivariate Correlation between Independent and Dependent Variables

In this subsection, the relationships between IDVs and DV are investigated through correlation analysis. Before analysing the theoretical model in PLS-SEM, an initial examination of the effect of each IDV on the DV was carried out to indicate the strongest and weakest variables' associations as a matter of checking the internal validity of the cause-effect proposed model (Mitchell, 1985). Internal validity check helps determine the degree of confidence that the investigated model's cause-effect relationships are trustworthy and not affected by any other surrounding variables. In this correlation analysis, IDVs are represented by the level of effectiveness, while DV is represented by the level of agreement on reaching targeted outcomes of CDWR. The Pearson product-moment correlation coefficient ($\boldsymbol{r}$) was calculated to determine the strength of the relationships and the effect of each IDV on the DV (Zhang *et al.*, 2019). Pearson correlation gives an indication of both directions (i.e., positive or negative) and the strength of a relationship (i.e., weak, moderate, strong) between two variables (Field, 2009). A positive correlation means that if one variable increases, then the other variable will also increase. On the other hand, a negative correlation means that if one variable increases, the other variable will decrease (Norusis, 2004; Pallant, 2010).

The values of $\boldsymbol{r}$ range from -1 (i.e., perfect negative correlation) to +1 (i.e., perfect positive correlation). Accordingly, the following values of $\boldsymbol{r}$ determine the strength of the relationship between the variables: 0.00 means no linear relationship; 0.01–0.30 means a weak relationship; 0.31–0.70 means a moderate relationship; 0.71–1.00 means a strong relationship; and 1.00 means a perfect linear relationship (Ratner, 2009). Values of $\boldsymbol{r}$ were used to examine the association of CDWR with MPMO, MPMR, GBPR, LG, AW, and CB. The values of $\boldsymbol{r}$ were reported altogether with significance level values (i.e., $\boldsymbol{P}$**-values**) to determine whether a relationship is significant or not. Suppose $\boldsymbol{P}$-value is below 5% (i.e., 0.05); in that case, this means that there is sufficient evidence to reject the null hypothesis $\mathbf{H_0}$ (i.e., there is no relationship existing between the IDV and DV) in favour of the alternative hypothesis $\mathbf{H_1}$ (i.e., there is a positive linear relationship existing between the IDV and DV).

Table 6.20 shows the correlation analysis results (i.e., $\boldsymbol{r}$ and $\boldsymbol{P}$ values) and descriptive statistics (i.e., mean and standard deviation) of the IDVs and DV. It shows a matrix of $\boldsymbol{r}$ (i.e., first row) and $\boldsymbol{P}$ (i.e., second row) values corresponding to each variable. The $\boldsymbol{r}$ and $\boldsymbol{P}$ values demonstrate significant positive relationships among the DV and IDVs except "LG". There is a statistically significant moderate positive relationship between MPMO and CDWR, in which $\boldsymbol{r}(244) = 0.533$ and $\boldsymbol{P} < 0.001$. Also, there is a statistically significant moderate positive relationship between MPMR and CDWR, in which $\boldsymbol{r}(244) = 0.452$ and $\boldsymbol{P} < 0.001$. Moreover, there is a statistically significant moderate positive relationship between GBPR and CDWR, in which $\boldsymbol{r}(244) = 0.509$ and $\boldsymbol{P} < 0.001$. Additionally, there is a statistically significant moderate positive relationship between AW and CDWR, in which $\boldsymbol{r}(244) = 0.566$ and $\boldsymbol{P} < 0.001$. Furthermore, there is a statistically significant moderate positive relationship between CB and CDWR, in which $\boldsymbol{r}(244) = 0.563$ and $\boldsymbol{P} < 0.001$. In contrast, there is a statistically non-significant weak positive relationship between LG and CDWR, in which $\boldsymbol{r}(244) = 0.086$ and $\boldsymbol{P} = 0.183$. The $\boldsymbol{P}$**-value** exceeds 0.05; accordingly, there is no evidence to reject the null hypothesis $\mathbf{H_0}$ in favour of the alternative proposed hypothesis $\mathbf{H_1}$ in this case.

Table 6.20 *Descriptive Statistics and Bivariate Correlations among Variables*

	MPMO	MPMR	GBPR	LG	AW	CB	CDWR
MPMO	1	0.313***	0.335***	0.020	0.467***	0.649***	0.533***
		0.000	0.000	0.751	0.000	0.000	0.000
MPMR		1	0.361***	0.021	0.515***	0.367***	0.452***
			0.000	0.749	0.000	0.000	0.000
GBPR			1	-0.099	0.528***	0.380***	0.509***
				0.124	0.000	0.000	0.000
LG				1	-0.008	0.072	0.086
					0.904	0.263	0.183
AW					1	0.467***	0.566***
						0.000	0.000
CB						1	0.563***
							0.000
CDWR							1
Mean	4.0246	4.3648	4.6787	4.1209	4.6872	4.0689	4.0594
SD	0.78529	0.55914	0.53223	0.71199	0.57619	0.592	0.647

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

The non-significant relationship between “LG” and “CDWR” can be demonstrated by the responses of Q13, which is “to what extent do you agree with the following statement “the Egyptian legislation lack effective waste minimisation strategies and they only focus on waste transfer, charge, and dumping?”. All the respondents either agreed or strongly agreed with this statement, as shown in Table 6.21 and Figure 6.8, which shows that the Egyptian legislation are not fully effective in reducing CDWG efficiently.

Table 6.21 *Frequencies and percentages for Q13*

		Count	%
Q13	Agree	124	50.8%
	Strongly agree	120	49.2%

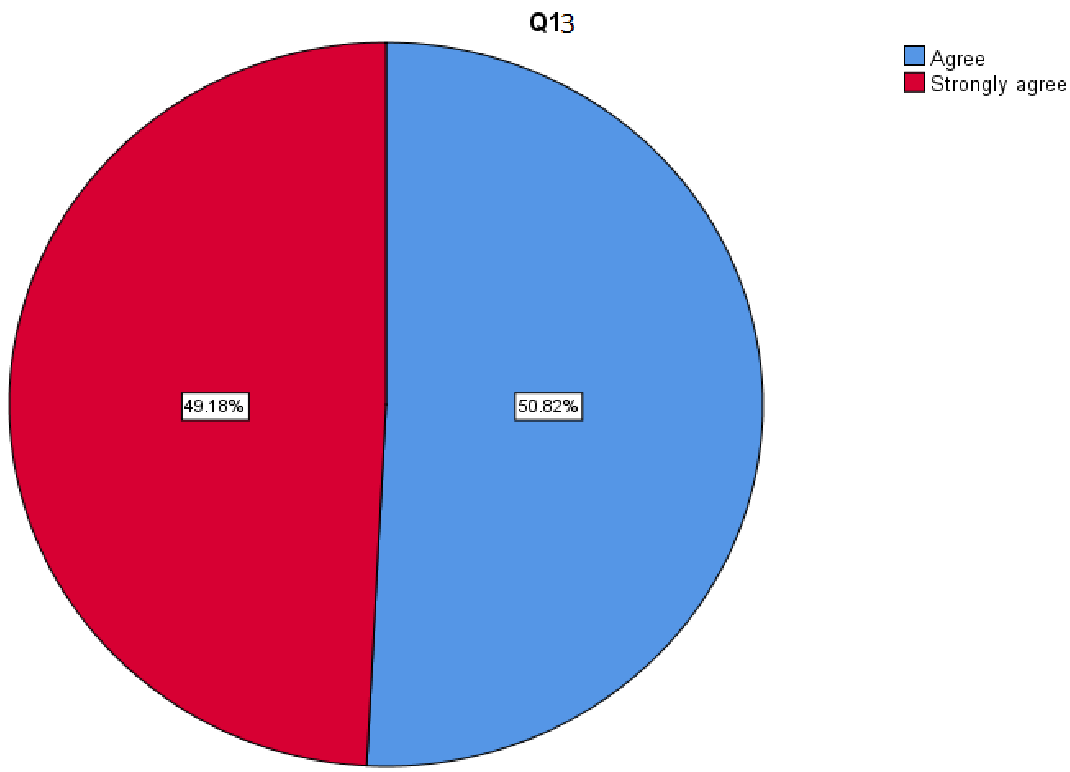

Figure 6.8 *Pie chart for Q13*

6.5 Summary

This chapter presented the first part of the statistical analysis of the survey questionnaire's responses. First, the collected data were screened and examined before statistical analysis to ensure their appropriateness and validity for different analysis operations carried out in this chapter and chapter seven. Moreover, through the descriptive statistics, demographic information of respondents and their firms were investigated. Given the participants' responses, there was a consensus among the respondents that efficient practices, legislation, culture & behaviour, and awareness can help reduce CDW in Egypt. The respondents also pointed out the need to develop a framework to integrate all of these factors to reduce CDW in Egypt. Besides, the respondents agreed that Egyptian CDWM legislation are ineffective in reducing CDWG efficiently because they do not foster CDWR. Unfortunately, the responses showed that most respondents' firms do not care for reducing CDW as they do not efficiently apply the abovementioned factors, which can significantly help CDWR.

Based on the RII formula, the different CDWR factors were ranked based on their current applicability level in the Egyptian construction sector and their level of effectiveness towards CDWR. It was found that "**MPMR.LWPM.AP.5**" (i.e., correct materials purchase) is the most applied item among the different factors, while the most effective item among different factors is "**GBPR.EF.3**" (i.e., reducing overall material use by using prefabricated elements and highly durable materials). Also, the relationship between the applicability and effectiveness of different factors was investigated. It was found that there is no interdependency between both of them. This means that these different factors' effectiveness has no impact on their applicability in the Egyptian construction sector, given Egyptian construction firms' unwillingness to apply them. Finally, correlation analysis was carried out to investigate the cause-effect relationship between each IDV and the DV. It was found that there are significant positive relationships between the DV and all IDVs except "LG" (i.e., legislation). This demonstrates that Egyptian legislation are not significantly effective solely in reducing CDWG. In the next chapter, a multivariate statistical analysis of the survey questionnaire's responses is carried out using the PLS-SEM technique. This is helpful to test and validate the theoretical framework of different hypotheses and different factors in a multiple system in favour of developing a conceptual framework for minimising CDW in the Egyptian construction sector.

CHAPTER 7: TOWARDS A CONCEPTUAL FRAMEWORK FOR MINIMISING CDW IN THE EGYPTIAN CONSTRUCTION INDUSTRY: A STRUCTURAL EQUATION MODELING APPROACH

7.1 Introduction

This chapter presents the multivariate statistical analysis of the survey questionnaire, as investigated in the research methodology chapter, specifically in section 3.4.2.4. This step is important to test and validate the hypotheses of the cause-effect relationships between the IDVs and the DV in a multiple system (i.e., theoretical framework). The analysis is following the PLS-SEM technique using **SmartPLS 3.3.2**© software. In this PLS-SEM technique, IDVs are represented by the level of effectiveness, while the DV is represented by the level of agreement on reaching CDWR targeted outcomes, as shown in Figure 7.1. The following sections illustrate the running of the model via **SmartPLS 3.3.2**© software, assessing the quality of measurement and structural models, and interpreting the results and drawing conclusions.

7.2 PLS-SEM Model Estimation

After data collection and examination, as investigated in chapter six, the data is used in the path model estimation. This stage requires selecting the parameter settings based on the understanding of the PLS-SEM algorithm and its statistical properties. The structural model's weighing schemes are the centroid weighting scheme, the factor weighting scheme, and the path weighing scheme. Although the results of using these schemes do not differ vastly, it is recommended to select the path weighing scheme as it produces the highest $\boldsymbol{R^2}$ value for the endogenous construct (i.e., DV). Moreover, the path weighing scheme applies to all the different path model specifications and estimations (Hair *et al.*, 2016). In addition, when the path model includes higher-order constructs (i.e., constructs measured at different levels of indicators), which is the case in this study, as shown in Figure 7.1, researchers should never adopt the centroid weighting scheme.

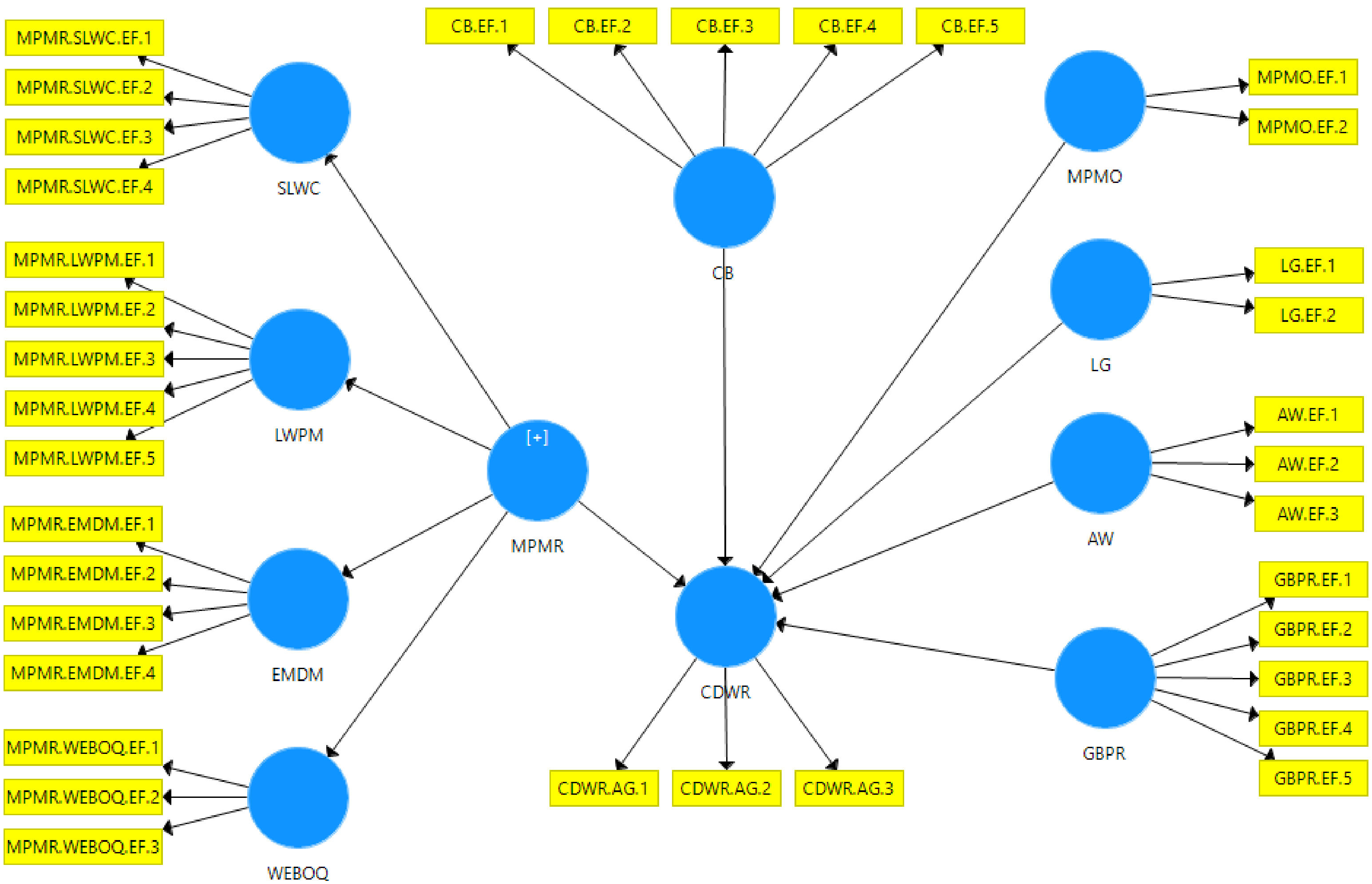

Figure 7.1 *Structural and measurement models of the study*

7.3 Assessing the Measurement Models

The assessment of the reflective measurement models in PLS-SEM requires evaluating the internal consistency reliability, convergent validity, and discriminant validity. As adapted from previous research studies, Table 7.1 summarises the rules and roadmap of evaluating the reflective measurement model. Once the reliability and validity of the measurement model are established, the structural model can be assessed. The following subsections will discuss the reliability and validity of the measurement model.

Table 7.1 *Criteria of reflective measurement model assessment*

Source*: (Nachtigall et al., 2003; Hair et al., 2011; Xiong et al., 2015; Henseler et al., 2015; Garson, 2016; Hair et al., 2017a)*

Evaluation Items	**Measurement Items**	**Fitting Criteria**
	Reflective Measurement Model	
Internal consistency reliability	Composite reliability	> 0.70
Convergent validity	Indicator loadings	> 0.70
	Average variance extracted (AVE)	> 0.50
Discriminant validity	Hetrotrait-Monotrait (HTMT) ratio	< 0.85 – 0.90

7.3.1 Internal Consistency Reliability

The internal consistency reliability examines whether all of the indicators associated with a construct are measuring it (Pallant, 2010). There are different ways to measure internal consistency. Cronbach's alpha is a statistical measure that is the most commonly used for this purpose. Cronbach's alpha provides the average correlation between all of the indicators that belong to one construct. Despite its popularity, Cronbach's alpha is criticised for assuming that all of the indicators have equal outer loadings (Hair *et al.*, 2016). Also, it is criticised for the fact that the number of indicators influences the calculation of Cronbach's alpha in which fewer items produce a lower value, especially in scales with items fewer than 10 (Pallant, 2010, Hair *et al.*, 2016).

Due to Cronbach's alpha's limitations, researchers are advised to use other internal consistency measures such as composite reliability (Hair *et al.*, 2017a). Composite reliability measures the internal consistency while considering that each indicator has a different outer loading. The composite reliability ranges between 0 and 1, with higher values indicating higher levels of reliability. It is generally explained in the same way as Cronbach's alpha. Specifically, composite reliability values of 0.60 to 0.70 are acceptable in exploratory research, while in more advanced stages of research (i.e., explanatory research), values between 0.70 and 0.90 can be regarded as satisfactory (Hair *et al.*, 2017a). Accordingly, in the case of this study, it is recommended to have a composite reliability value exceeding 0.70.

Cronbach's alpha is a conservative measure of reliability (i.e., it results in relatively low-reliability values). On the other hand, composite reliability overestimates the internal consistency reliability resulting in comparatively higher reliability estimates. Therefore, it is adequate to report and consider both criteria in reliability assessment. When analysing and assessing the measures of internal consistency reliability, the accurate reliability measure usually located between Cronbach's alpha measure (i.e., representing the lower bound) and the composite reliability measure (i.e., representing the upper bound) (Hair *et al.*, 2017a). Following the previous rules, each construct's reliability was assessed using the calculations provided by **SmartPLS 3.3.2**© software. The results in Table 7.2 show that all constructs had a reliability score, based on Cronbach's alpha and composite reliability calculation, of more than 0.70. These findings provide evidence of high reliability and sufficient internal consistency of the constructs.

Table 7.2 *Reliability of measurement model analysis*

Construct	Cronbach's Alpha	Composite Reliability
GBPR	0.782	0.85
AW	0.875	0.923
LG	0.824	0.913
MPMO	0.818	0.916
CB	0.863	0.901
SLWC	0.937	0.955
LWPM	0.958	0.967
EMDM	0.942	0.958
WEBOQ	0.773	0.867
CDWR	0.828	0.897

7.3.2 Convergent Validity

The convergent validity evaluates the correlation between the variables that measure one construct. The convergent validity of reflective measurement models is usually evaluated using the items' outer loadings and the average variance extracted (**AVE**). The minimum significant outer loadings required is 0.70 (Hair *et al.*, 2014; Hair *et al.*, 2016). The reason behind specifying that the outer loading should be at least 0.70 is that the square of a standardized item's outer loadings, also known as communality, indicates how much variance is shared between the construct and the item. The square of 0.70 will approximately equal 0.50. This means that if an item has an outer loading of 0.70, the construct can explain about 50% of the item's variance (Hair *et al.*, 2016). However, Hair *et al.* (2017a) suggested that if the outer loading is between 0.40 – 0.70, a researcher should analyse the impact of indicator deletion on internal consistency reliability. If deletion does not increase measure(s) above the threshold, the reflective indicator should be retained.

The **AVE** is a common measure used to establish convergent validity. **AVE** represents the grand mean of the squared loadings of the indicators measuring a construct.

The **AVE** of a construct should be 0.50 or higher to be considered significant. Following this rule, the **AVE** of the constructs was evaluated. All of the constructs in Figure 7.2 had **AVE** scores higher than 0.50. Table 7.3 and Figure 7.2 presents the **AVE** values of each construct. Table 7.4 and Figure 7.2 shows outer loadings for the items of each construct. For all the reflective measurements, the values of outer loadings were above the threshold value of 0.7. This suggests sufficient levels of indicator reliability; accordingly, all items were retained.

Table 7.3 *Average variance extracted (AVE) of different constructs*

Construct	**GBPR**	**AW**	**LG**	**MPMO**	**CB**	**MPMR**
AVE	0.532	0.799	0.84	0.846	0.646	0.506
Construct	**SLWC**	**LWPM**	**EMDM**	**WEBOQ**	**CDWR**	
AVE	0.843	0.855	0.852	0.684	0.744	

Table 7.4a *Item loadings of different constructs*

	Items	GBPR	AW	LG	MPMO	CB	SLWC	LWPM	EMDM	WEBOQ	CDWR
GBPR	GBPR.1	0.733									
	GBPR.2	0.776									
	GBPR.3	0.705									
	GBPR.4	0.727									
	GBPR.5	0.705									
AW	AW.1		0.848								
	AW.2		0.922								
	AW.3		0.91								
LG	LG.1			0.962							
	LG.2			0.869							

__Table 7.4b__ Item loadings of different constructs

	Items	GBPR	AW	LG	MPMO	CB	SLWC	LWPM	EMDM	WEBOQ	CDWR
MPMO	MPMO.1				0.925						
	MPMO.2				0.914						
CB	CB.1					0.795					
	CB.2					0.827					
	CB.3					0.865					
	CB.4					0.77					
	CB.5					0.758					
SLWC	SLWC.1						0.855				
	SLWC.2						0.946				
	SLWC.3						0.942				
	SLWC.4						0.925				
LWPM	LWPM.1							0.88			
	LWPM.2							0.931			
	LWPM.3							0.928			
	LWPM.4							0.951			
	LWPM.5							0.933			

Table 7.4c *Item loadings of different constructs*

	Items	GBPR	AW	LG	MPMO	CB	SLWC	LWPM	EMDM	WEBOQ	CDWR
EMDM	EMDM.1								0.9		
	EMDM.2								0.943		
	EMDM.3								0.934		
	EMDM.4								0.915		
WEBOQ	WEBOQ.1									0.844	
	WEBOQ.2									0.86	
	WEBOQ.3									0.775	
CDWR	CDWR.1										0.834
	CDWR.2										0.881
	CDWR.3										0.872

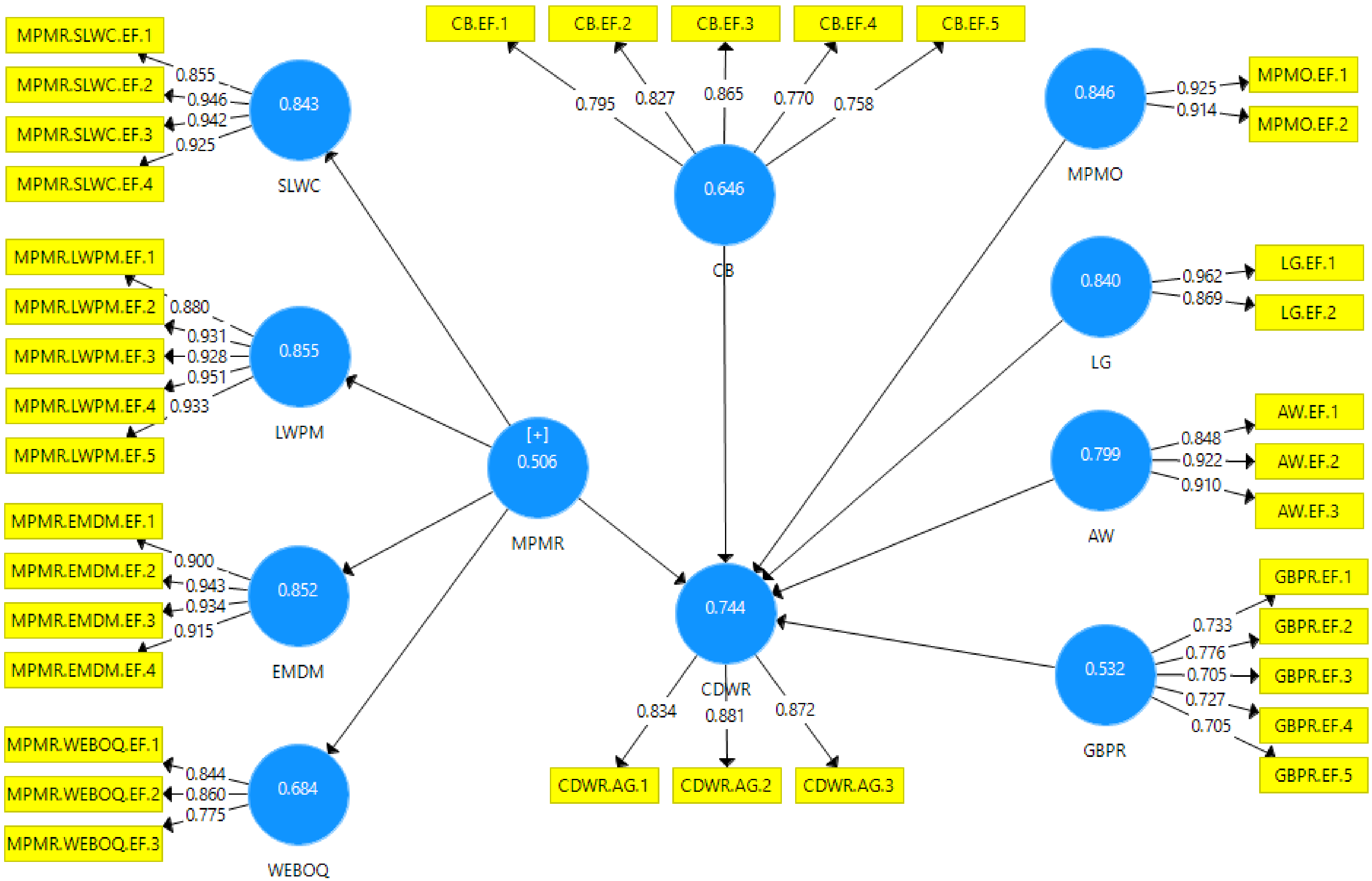

Figure 7.2 *Outer loadings and AVE for different constructs in the research model*

7.3.3 Discriminant Validity

After establishing the convergent validity, the discriminant validity should be examined. Discriminant validity examines how much a construct differs from other constructs. Discriminant validity is usually established by one of the following three methods: (1) examining cross-loadings of items; (2) adopting Fornell-Larcker criterion; or (3) checking Hetrotrait-Monotrait (**HTMT**) ratio. A recent study by Henseler *et al.* (2015) found that using the abovementioned first two options is an unreliable way to establish discriminant validity. Precisely, cross-loadings cannot specify the lack of discriminant validity when two constructs are perfectly correlated, making this criterion ineffective for empirical research. Similarly, the Fornell-Larcker criterion performs inaccurately, especially when indicator loadings of the constructs under consideration differ slightly (e.g., all indicator loadings vary between 0.60 and 0.80).

To overcome the shortcoming of the cross-loadings and Fornell-Larcker criterion, researchers should assess the Hetrotrait-Monotrait (**HTMT**) ratio. **HTMT** is “the ratio of the between-trait correlations to the within-traits correlations” (Hair *et al.*, 2016, p. 118). In other words, it is the average of the correlations of indicators across constructs measuring different phenomena relative to the average of the correlations of indicators within the same construct (Henseler *et al.*, 2015). The **HTMT** value should be lower than 0.90 if the model's constructs are conceptually very similar and lower than 0.85 if the model's constructs are conceptually different. Following these guides, the **HTMT** values were calculated. All of the constructs have **HTMT** values less than the defined threshold. Table 7.5 presents the constructs’ **HTMT** values. It was found that **HTMT** values of all constructs were lower than 0.85, which suggests that the discriminant validity is accomplished for all constructs.

Table 7.5 *HTMT values*

	AW	CB	CDWR	EMDM	GBPR	LG	LWPM	MPMO	SLWC	WEBOQ
AW										
CB	0.529									
CDWR	0.661	0.664								
EMDM	0.334	0.174	0.271							
GBPR	0.631	0.457	0.624	0.185						
LG	0.014	0.089	0.119	0.056	0.124					
LWPM	0.664	0.428	0.615	0.284	0.539	0.055				
MPMO	0.563	0.762	0.65	0.186	0.413	0.036	0.421			
SLWC	0.349	0.287	0.365	0.63	0.26	0.054	0.493	0.307		
WEBOQ	0.509	0.465	0.469	0.654	0.357	0.026	0.564	0.309	0.735	

7.4 Assessing the Structural Model

After establishing the reliability and validity of the measurement models, the structural model should be assessed. The structural model's assessment includes inspecting the predictive power of the model and relationships between the constructs. The structural model, also known as an inner model, refers to the relationships between the constructs themselves (Hair *et al.*, 2014; Benitez-Amado *et al.*, 2017), and its assessment includes evaluating the relationships between the constructs in the model (Henseler and Sarstedt, 2013; Hair *et al.*, 2011; Henseler *et al.*, 2009).

Different researchers provided guidelines for evaluating and reporting the structural model, which includes multicollinearity, path coefficients, coefficient of determination ($\boldsymbol{R^2}$), effect size ($\boldsymbol{f^2}$), predictive relevance ($\boldsymbol{Q^2}$), and goodness of fit (**GoF**). Table 7.6 summarises the criteria used for evaluating the structural model in this study. Review studies on the PLS-SEM (Ringle *et al.*, 2012; Hair *et al.*, 2012; Hair *et al.*, 2014; Hair *et al.*, 2017b; Ringle *et al.*, 2018; Ali *et al.*, 2018) stated that researchers usually report these criteria when examining the structural model. Given these criteria and guidelines mentioned in the Table 7.6 below, the results of these assessments are presented in the following subsections.

***Table 7.6** Criteria of structural model assessment*

***Source**: (Cohen, 1988; Chin, 1998; Wetzels et al., 2009; Henseler et al., 2009; Hair et al., 2011; Hair et al., 2013; Hair et al., 2014; Henseler et al., 2015; Hair et al., 2016; Hair et al., 2017a; Hair et al., 2017b)*

Criteria	**Guidelines**
Multicollinearity	**VIF** < 5
Path coefficients	At a significane level = 5%; ***P*-value** ≤ 0.05 & ***t*-value** ≥ 1.96, significant relationship.
Coefficient of determination ($\boldsymbol{R^2}$)	$\boldsymbol{R^2}$ < 0.19, unacceptable predictive accuracy; $\boldsymbol{R^2}$ = 0.19 – 0.33, small predictive accuracy; $\boldsymbol{R^2}$ = 0.33 – 0.67, moderate predictive accuracy; $\boldsymbol{R^2}$ ≥ 0.67, high predictive accuracy.
Effect size ($\boldsymbol{f^2}$)	$\boldsymbol{f^2}$ < 0.02, no effect; $\boldsymbol{f^2}$ = 0.02 – 0.15, small effect; $\boldsymbol{f^2}$ = 0.15 – 0.35, moderate effect; $\boldsymbol{f^2}$ ≥ 0.35, high effect.
Cross-validated redundancy ($\boldsymbol{Q^2}$)	predictive relevance using blindfolding; $\boldsymbol{Q^2}$ > 0
Goodness of fit (**GoF**)	**GoF** < 0.1, no fit; **GoF** = 0.1 – 0.25, small fit; **GoF** = 0.25 – 0.36, medium fit; **GoF** ≥ 0.36, large fit.

7.4.1 Multicollinearity

Collinearity occurs when there is a high correlation between two constructs, which produces interpretation and estimation problems (Hair *et al.*, 2017a). If more than two constructs are involved in collinearity, it refers to multicollinearity. Multicollinearity can be assessed using the variance inflation factor (**VIF**), which is obtained by dividing “one” by “tolerance”, referring to the variance explained by one independent construct not explained by the other independent constructs (Hair *et al.*, 2017a; Benitez-Amado *et al.*, 2017). A **VIF** value of 5 or higher (i.e., tolerance value of 0.20 or lower) indicates a high multicollinearity problem (Hair *et al.*, 2011; Hair *et al.*, 2017b). Table 7.7 shows that all **VIF** values were below the cut-off point, demonstrating that multicollinearity between independent constructs does not exist.

Table 7.7 *Variance inflation factors for IDVs*

Independent Variables	AW	CB	GBPR	LG	MPMO	MPMR
VIF	1.861	1.945	1.465	1.024	1.888	1.448

7.4.2 Path Coefficients

Path coefficients refer to the estimates of the relationships between the model's constructs (Hair *et al.*, 2014b). These coefficients range from +1 to -1, where +1 means a strong positive relationship, 0 means a weak or non-existent relationship, and -1 means a strong negative relationship (Garson, 2016). When assessing PLS paths, studies should report path coefficients besides the significance level, ***t*-value**, and ***P*-value** (Hair *et al.*, 2012). Ringle *et al.* (2012) reviewed studies that used the PLS-SEM and were published in MIS Quarterly between 1992 and 2011 and concluded that the majority of studies had reported path coefficients (**β**), significance level (**α**), ***t*-value**, and ***P*-value** when examining the structural model. As Chin (1998) stated, evaluating the model's quality should also be based on the path coefficients' directions and significance levels. Therefore, these values are reported for the path analysis test. For a significance level (**α**) of 5%, which is the adopted case in this study, the ***P*-value** should be smaller than 0.05 and the ***t*-value** should be larger than 1.96 in order to evaluate the relationship as a statistical significant one (Hair et al., 2017). If ***P*-value** is below 0.05 and ***t*-value** is greater than 1.96, this means that there is sufficient evidence to reject the null hypothesis $\mathbf{H_0}$ (i.e., there is no effect of the IDV on the DV) in favour of the alternative hypothesis $\mathbf{H_1}$ (i.e., there is a positive effect of the IDV on the DV).

Table 7.8 *Model path coefficients*

Path	β	Standard Deviation	*t*-value	*p*-value
AW -> CDWR	0.188	0.059	3.192	0.001^{***}
CB -> CDWR	0.217	0.073	2.963	0.003^{**}
GBPR -> CDWR	0.231	0.057	4.069	0.000^{***}
LG -> CDWR	0.106	0.052	2.037	0.042^{*}
MPMO -> CDWR	0.174	0.074	2.357	0.019^{*}
MPMR -> CDWR	0.152	0.055	2.754	0.006^{**}
MPMR -> EMDM	0.751	0.033	23.112	0.000^{***}
MPMR -> LWPM	0.741	0.045	16.326	0.000^{***}
MPMR -> SLWC	0.863	0.023	38.288	0.000^{***}
MPMR -> WEBOQ	0.82	0.027	30.407	0.000^{***}

$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

Table 7.8 and Figure 7.3 show the model path coefficients associated with its ***t*-values** and ***P*-values**. It can be observed that "AW" has a statistically significant positive effect on CDWR; since **β** = 0.188, ***t*** = 3.192, and ***P*** ≤ 0.001. Also, "CB" has a statistically significant positive effect on CDWR; since **β** = 0.217, ***t*** = 2.963, and ***P*** < 0.01. Moreover, "GBPR" has a statistically significant positive effect on CDWR; since **β** = 0.231, ***t*** = 4.069, and ***P*** < 0.001. Additionally, "MPMO" has a statistically significant positive effect on CDWR; since **β** = 0.174, ***t*** = 2.357, and ***P*** < 0.05. Furthermore, "MPMR" has a statistically significant positive effect on CDWR; since **β** = 0.152, ***t*** = 2.754, and ***P*** < 0.01. Finally, "LG" has a statistically significant positive effect on CDWR; since **β** = 0.106, ***t*** = 2.037, and ***P*** < 0.05. These results indicate that there is sufficient evidence to reject the null hypotheses in favour of all the proposed hypotheses in this study stated in chapter two.

It was observed in bivariate correlation analysis, as demonstrated in chapter six, that "LG" has a non-significant weak positive relationship with CDWR. It means that Egyptian legislation solely does not have a significant effect on CDWR. However, by applying the multivariate analysis of PLS-SEM, it was found that "LG" has a statistically significant positive effect on CDWR. This can be explained by the fact that path coefficients are calculated by relating the correlation coefficients between variables in a multiple system to the functional relations among them (Wright, 1934). In other words, the effect of "LG" on CDWR becomes effective in the presence of other external surrounding factors such as "GBPR", "MPMR", "MPMO", "CB", "AW". This makes sense as legislation alone is ineffective in the absence of other factors such as waste-efficient practices, high awareness, and appropriate culture and behaviour.

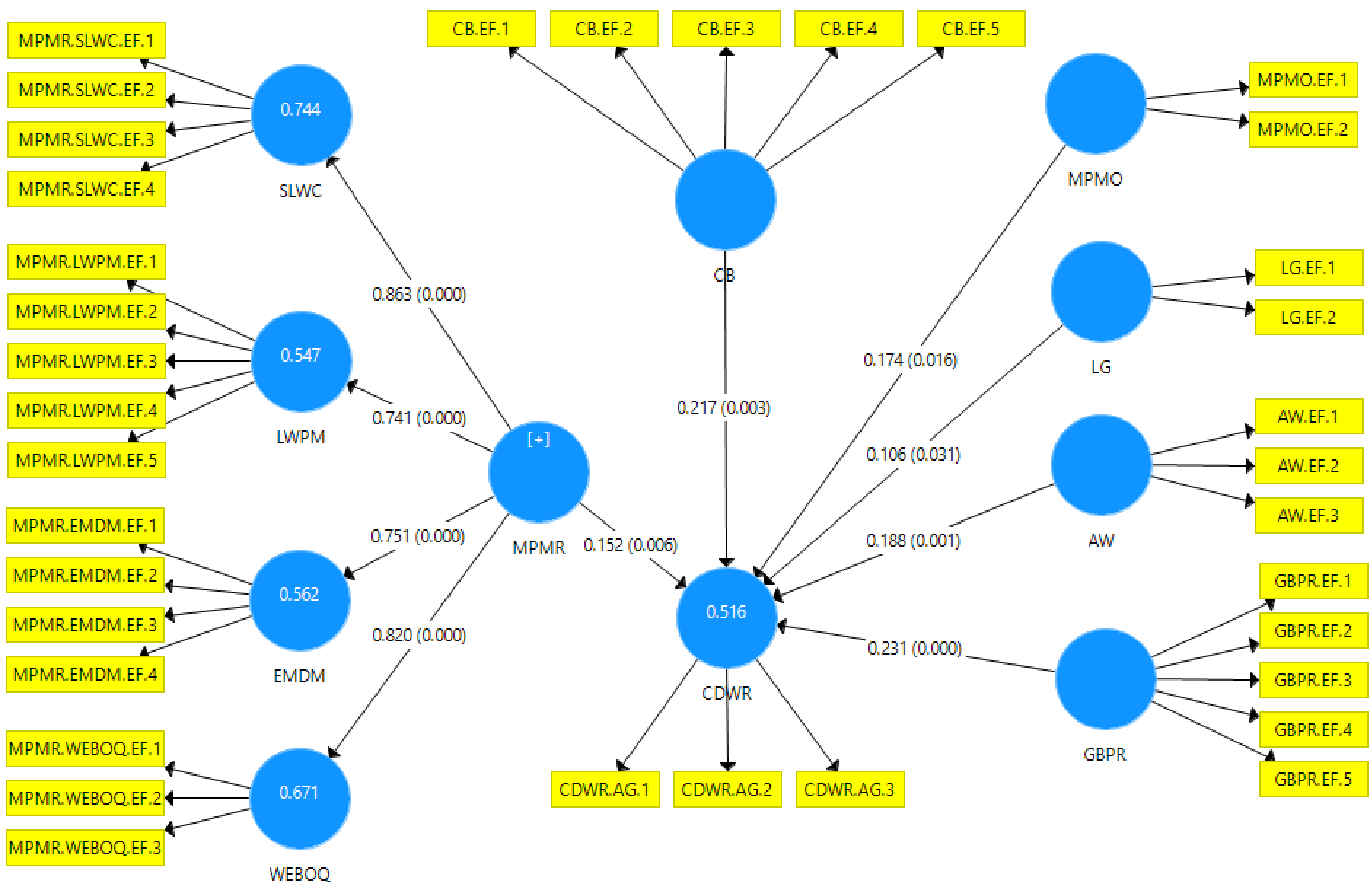

Figure 7.3 *Path coefficients with corresponding p-values and* R^2_{adj} *value of DV*

7.4.3 Coefficient of Determination (R^2)

Coefficient of determination (R^2) refers to the effect of IDVs on the DV (Hair *et al.*, 2012), which is one of the quality measures of the structural model (Hair *et al.*, 2014b). Hair *et al.* (2012) reviewed 204 paper using the PLS-SEM and found that R^2 is the main criterion for the structural model assessment. Similarly, Ringle *et al.* (2012) reviewed studies that used the PLS-SEM in information systems and revealed that R^2 had been reported in 105 models out of 109. R^2 values vary from 0 to 1, in which 0 means low explained variance and 1 means high explained variance. Researchers have used a different cut-off of R^2 value. For example, Hair *et al.* (2011), in marketing research, described that R^2 values of 0.25, 0.50, or 0.75 are low, moderate, and high, respectively. In business research, Chin (1998) suggested that R^2 with 0.19, 0.33, or 0.67 are low, moderate, and high, respectively.

Researchers should report the adjusted R^2 (i.e., R^2_{adj}) values that consider the number of IDVs and sample size (Henseler *et al.*, 2016; Hair *et al.*, 2017a). Adding more IDVs leads to an increase in R^2 values; however, the R^2_{adj} recompenses this issue by taking into account the complexity of the model (Hair *et al.*, 2017a). Furthermore, the R^2_{adj} values are useful in assessing the quality of various models or comparing the model across different contexts (Henseler *et al.*, 2016). The results of R^2_{adj} are reported in Table 7.9 and demonstrated in Figure 7.3. The R^2 value of the model equals 0.528 and its R^2_{adj} value is 0.516, which means that about 52% of the variations in CDWR are explained by the variations in the IDVs.

Table 7.9 *Values of R^2 and associated R^2_{adj} for the DV*

	R^2	R^2_{adj}	**Predictive accuracy**
CDWR	0.528	0.516	Moderate

7.4.4 Effect Size (f^2)

The f^2 effect size is the measure of how much the endogenous construct will be affected or impacted if an exogenous construct (i.e., IDV) is removed from the model leading to a change in the R^2 value of the model. The f^2 values are computed in **SmartPLS**© software by running the PLS-SEM algorithm. A construct is considered to have a small effect if its f^2 value is between 0.02 and 0.15, while it is considered to have a medium effect if its f^2 value is between 0.15 and 0.35, and a large effect if its f^2 value ≥ 0.35. A construct with an f^2 value < 0.02 means it has no effect on the endogenous construct (Hair *et al.*, 2016). Table 7.10 presents the f^2 effect size of the constructs.

Table 7.10 *Effect size of IDVs*

	AW	**CB**	**GBPR**	**LG**	**MPMO**	**MPMR**
Effect Size	0.04	0.051	0.077	0.023	0.034	0.034
Evaluation	Small	Small	Small	Small	Small	Small

The results show that all IDVs have small effects on the DV. Despite that, the removal of any IDV will affect the DV leading to a change in R^2 value of the model. The "GBPR" has the highest effect size among the IDVs, and "LG" has the lowest effect size among the IDVs. The IDVs can be ranked from highest to lowest according to their effect size as follows: (1) GBPR; (2) CB; (3) AW; (4) MPMR & MPMO; and (5) LG. The fact that "GBPR" has the highest effect size on CDWR demonstrates the importance of the initiative taken by this study of proposing improvements to the GPRS, as demonstrated in detail in chapter four, to overcome the shortcomings existing in the M&R category and better tackle the challenges of CDWG.

7.4.5 Predictive Relevance (Q^2)

Q^2 value indicates the model's out-of-sample predictive power. When a model is said to have a predictive power or predictive relevance, it can accurately predict data not used in the model estimation. The Q^2 value is calculated through running a blindfolding procedure. Before running this procedure, an omission distance (***D***) must be specified. Hair *et al.* (2017a) suggest specifying a ***D*** between 5 and 12 while being careful that the sample size divided by the selected ***D*** will not produce an integer. The omission distance indicates that while running the blindfolding procedure, every d^{th} data point of the endogenous construct's items will be omitted and then predicted. A ***D*** of 5 means that about 20% of the data points have been omitted per blindfolding round. Similarly, a ***D*** of 10 indicates that about 10% of the data points were omitted per blindfolding round. The number of blindfolding rounds always equals omission distance $\boldsymbol{D}$.

The omitted data points are considered missing values and treated accordingly using the pairwise deletion or mean value replacement when running the PLS-SEM algorithm. The resulting estimates are then used to predict the omitted data points. The difference between the true (i.e., omitted) data points and the predicted ones is then used as input for calculating the value of $\boldsymbol{Q^2}$. An endogenous construct's $\boldsymbol{Q^2}$ value that is larger than 0 indicates the model's predictive relevance for this construct (Hair *et al.*, 2016). Based on the recommendation of Hair *et al.* (2017b), an omission distance $\boldsymbol{D}$ of 10 was selected to examine the predictive power of the model, in which that the sample size (i.e., 244) divided by the selected $\boldsymbol{D}$ (i.e., 10) did not produce an integer. Table 7.11 presents the $\boldsymbol{Q^2}$ values obtained from the analysis. The value of $\boldsymbol{Q^2}$ for CDWR in Table 7.11 is higher than 0, so it can be safely concluded that the model has a good predictive relevance.

Table 7.11 *Predictive relevance*

	SSO	**SSE**	**Q^2 (=1-SSE/SSO)**
CDWR	720	469.633	**0.348**

7.4.6 Goodness of Fit of the Model

Tenenhaus *et al.* (2005) proposed the Goodness of Fit (**GoF**) as a global fit indicator. **GoF** is the geometric mean of both the average of **AVE** values and $\boldsymbol{R^2}$ values of the endogenous variables. The **AVE** values are previously listed in Table 7.3. On the other hand, the values of $\boldsymbol{R^2}$ are listed in Table 7.12.

Table 7.12 *Values of R^2 for different constructs in the model*

Construct	**SLWC**	**LWPM**	**EMDM**	**WEBOQ**	**CDWR**
$\boldsymbol{R^2}$	0.745	0.549	0.564	0.673	0.528

GoF aims to consider the research model at both levels (i.e., the measurement model and the structural model), emphasising the overall model performance (Henseler and Sarstedt, 2013). The **GoF** index can be calculated as follow:

$$\boldsymbol{GOF} = \sqrt{\overline{R^2} \times \overline{AVE}} = \sqrt{0.612 \times 0.741} = 0.673.$$

The criteria of **GoF** for deciding whether **GoF** values are not acceptable, small, moderate, or high to be regarded as a globally appropriate PLS model have been stated in Table 7.6. According to these criteria and given the GoF index calculated value, it can be safely concluded that the **GoF** of this model is large enough to be considered a sufficient valid global PLS model.

7.5 Importance-Performance Map Analysis (IPMA) for the total effects of IDVs on DV

The importance-performance map analysis (**IPMA**) is used for identifying predecessors (i.e., IDVs) which have relatively high importance (i.e., strong total effect) for the targeted construct (i.e., DV) but also relatively low performance (i.e., low average latent variable scores) (Hair et al., 2017). These constructs having such characteristics represent potential areas of improvement that may receive great attention to better improve the DV. These scores' mean values indicate the construct’s performance, with 0 representing the lowest and 100 representing the highest performance, as shown in Table 7.13. It can be concluded that the “CB” construct is the second most important factor contributing to CDWR; however, it has the lowest performance among the six contributing factors. Accordingly, there is substantial room for improvement of “CB” in Egyptian society to achieve better results towards CDWR. Strict actions need to be taken to improve the culture and behaviour towards CDWR.

Table 7.13 *Importance-performance matrix of IDVs*

IDV	Importance	Performance
AW	0.212	89.033
CB	0.238	72.080
GBPR	0.293	92.169
LG	0.096	78.400
MPMO	0.143	75.718
MPMR	0.181	83.236

7.6 Roadmap for Implementing the Conceptual Framework in the Egyptian Construction Industry

Based on the results of effect size analysis and importance-performance matrix of the IDVs introduced in this chapter and the results of RII analysis for the effectiveness of different IDVs' components (i.e., items) introduced in chapter 6, an implementation roadmap of the conceptual framework is introduced to set the priority of applying the different factors along with their different components and measures in a sequential manner. This roadmap needs to be followed in order to achieve the goal, which is CDWR. This roadmap descendingly arranges the application of the different factors based on their weights (i.e., effect size and importance) and the application of their measures and components based on their importance levels resulting from RII analysis of their effectiveness. According to the results in this chapter, the different IDVs can be arranged in descending order according to their weights as follows: (1) GBPR; (2) CB; (3) AW; (4) MPMR; (5) MPMO; and (6) LG. Each factor's components are listed in a descending order based on their importance levels, as discussed in chapter 6. The roadmap for the implementation of the conceptual framework is summarised in Figure 7.4.

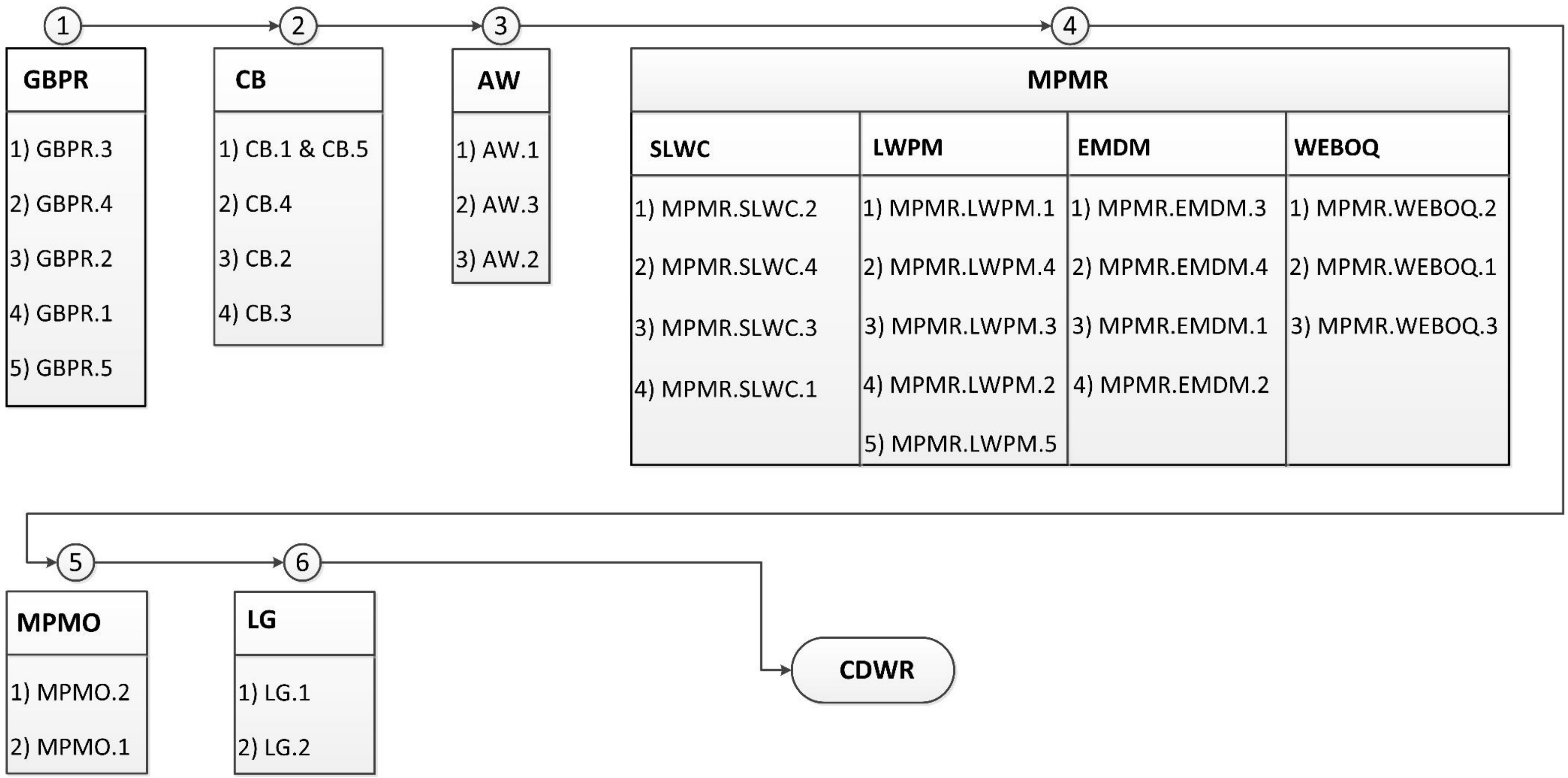

Figure 7.4 *Roadmap for implementing the conceptual framework*

7.7 Summary

This chapter presented the second part of the statistical analysis of the survey questionnaire's responses. First, the measurement models were assessed for their quality. The measurement models demonstrate the relationships between each construct and its indicators. As demonstrated in this chapter, the measurement models passed all the thresholds stated by the defined evaluation criteria regarding internal consistency reliability, convergent validity, and discriminant validity. Second, the structural model was assessed for its quality. The structural model demonstrates the relationships between each construct and the other. As demonstrated in this chapter, the structural model passed all the thresholds stated by the defined evaluation criteria regarding multicollinearity, the significance of path coefficients, coefficient of determination, the effect size of IDVs, predictive relevance of the model, and model's goodness of fit.

In a multiple system of the model, it was found that all the IDVs have a statistically significant positive effect on the DV. This demonstrates that "LG" has an effect on CDWR in the presence of other external surrounding factors, but it does not solely have a statistically significant relationship with CDWR, as demonstrated in the correlation analysis in chapter six. Based on the effect sizes of the IDVs, it was found that "GBPR" has the highest effect size while "LG", "MPMO", and "MPMR" have the least effect sizes. These results demonstrate the importance of the GPRS improvement proposal presented by this study in chapter four, given the high effect of the "GBPR" on CDWR. Additionally, IPMA was carried out to investigate IDVs with relatively high importance for the DV and relatively low performance. It was found that "CB" is the second most important factor contributing to CDWR; however, it has the lowest performance among the six contributing factors. Accordingly, "CB" needs to be better improved in order to achieve better results towards CDWR.

Finally, a roadmap was introduced to implement the conceptual framework, which resulted from rigorous statistical tests. This roadmap descendingly arranged the application of both the factors and their components, based on their weights and importance, to achieve the targeted results of CDWR. It showed how to apply the factors (i.e., DVs) and their components (i.e., indicators or items) sequentially to reach the targeted outcomes of CDWR. In the next chapter, the validation of research outputs is carried out through a panel of experts through a validation survey questionnaire. This is critically important to ensure that the research outputs are reliable and valuable for application.

CHAPTER 8: VALIDATION OF RESEARCH OUTPUTS

8.1 Introduction

In this chapter, as investigated in the research methodology chapter, specifically in section 3.4.5, the research outputs are validated through experts to ensure that this study's findings are: (1) robust and comprehensive; (2) logical; (3) valuable and applicable; and (4) strong and complete. Ten experts were invited to evaluate both the MPCF and GPRS improvement proposal (i.e., research outputs). The experts' evaluation demonstrated that the research outputs are satisfying the abovementioned four aspects, and no additional areas of improvement were needed.

8.2 Arrangement of Outputs Validation by Experts

The validation process is an essential step in any study to ensure that the research findings or outputs are detailed, thorough, and unbiased. Validity means truthfulness, which refers to bridging theory and practicability (Lawrence 2003, cited in Bapir 2012). Bryman (2012) stated that validity means the integrity of research findings. The validation process's importance is to ensure that the research findings accurately represent the social concerns to which the research study was set to address in the first place (Hammersley, 1997). Additionally, Flick (2009) and Gagliardi *et al.* (2011) claimed that the validation of research findings is achieved once it is demonstrated that the findings have relevance and they have more strengths and fewer weaknesses than any other existing findings.

Accordingly, a validation survey questionnaire was designed in this study to validate the MPCF and the GPRS improvement proposal based on the aforementioned investigated aspects of validation. The survey questionnaire was sent along with the MPCF and the GPRS improvement proposal to the ten experts who expressed their willingness to participate in the validation process. The validation survey questionnaire consists of four simple close-ended questions and one open-ended question, as shown in Appendix E. The open-ended question allows the respondents to express their ideas or thoughts for improving the MPCF and/or the GPRS improvement proposal by adding or removing any suggested components. On the other hand, the close-ended questions use a five-point Likert scale, in which "1" means “strongly disagree with very poor results” and “5” means “strongly agree with excellent results”, in order to assess the research findings based on the following aspects: (1) robustness and comprehensiveness; (2) logicalness and acceptability; (3) applicability and practicality; and (4) strength and completeness.

8.3 Demographic Information of the Experts

As aforementioned in chapter 3, specifically in section 3.5, ten experts from those 30 experts who participated in the pilot study were interested in being updated with the final study’s outputs. Accordingly, these ten experts were contacted to participate in the validation process. All respondents are well-experienced either in the construction sector or higher education. They all have more than ten years’ experience of industrial work or teaching & research. Their evaluation of the research findings is considered reliable, and any received feedback could improve the study findings’ effectiveness and quality. All respondents were given one week to review the research findings and answer the validation survey questionnaire. The profile of respondents is summarised in Table 8.1.

Table 8.1 *Profiles of the respondents for results validation*

Respondent	Position	Years of Experience
1	Assistant professor	11
2	Assistant professor	13
3	Associate professor	16
4	Professor	20
5	Professor	22
6	Project manager	25
7	Project manager	23
8	Procurement manager	18
9	Civil engineer	14
10	Architect	10

8.4 Validation Results

Table 8.2 summarises the results of the four validation questions. It is worth mentioning that the open-ended question (i.e., Q5) was left blank by all experts as they agree that the research findings are complete and does not lack essential elements. Accordingly, there is no need for areas of improvements. Mean scores for the different aspects (i.e., questions) were calculated based on weighted arithmetic mean, via **Microsoft Excel 2016©** software, to consider the weight of each expert's opinion based on the number of years' experience. The mean score of Q1 is 4.60, which indicates that both the MPCF and GPRS improvement proposal components are suitable and significant. Also, the mean score of Q2 is 4.51, which indicates that the MPCF and GPRS improvement proposal are logical and can be followed, and the underlying relationships are acceptable. Furthermore, the mean score of Q3 is 4.28, which indicates that the MPCF and GPRS improvement proposal are applicable and useful, and they are practical in solving the current challenges in Egypt investigated in this study. Finally, the mean score of Q4 is 4.37, which indicates that the MPCF and GPRS improvement proposal are complete and include all the essential elements needed for addressing the current challenges in Egypt investigated in this study.

Table 8.2 *Respondents' validation results*

Validity Aspect	Question Number	Mean Score
Comprehensiveness and robustness	1	4.60
Logicalness and acceptability	2	4.51
Applicability and practicality	3	4.28
Strength and completeness	4	4.37

8.5 Summary

This chapter presented the validation of the study findings. Ten experienced experts were invited to answer five main questions, as shown in Appendix E, regarding four main aspects of the study findings' validity, namely: (1) robustness and comprehensiveness; (2) logicalness and acceptability; (3) applicability and practicality; and (4) strength and completeness. The validation results indicate nearly a full agreement on the four aspects of validity. This indicates that the study findings are reliable, valuable, and usable.

CHAPTER 9: CONCLUSIONS AND FUTURE RESEARCH

9.1 Introduction

In this chapter, a review of the work conducted in this study is presented, including its aim, objectives, and adopted research methods. This chapter also highlights the main research findings, including recommendations for improving the Egyptian construction sector's current situation. Moreover, it summarises the main contributions of this research. Furthermore, research limitations and recommendations for development and future research are presented.

9.2 Research Summary

The construction industry plays a significant role in the development of societies. It leads to significant developments in the economic and social sectors of nations. However, the negative environmental impacts of CD activities globally are non-negligible. Countries worldwide are suffering from the environmental hazards caused by CDW, which consequently affects citizens' lives. Focusing on the SW problem in the MENA region, the current situation is very critical, and it may worsen year after year, given that most of the MENA countries are developing countries. It is claimed that the MENA region is expected to generate 200 million tonnes of SW annually by 2020, in which CDW constitutes the majority of its components.

The main reasons behind the SW problem in the MENA region were investigated based on the explored literature. Examples of these reasons are: (1) lack of strict legislation, policies, strategies, and enforced laws; (2) shortage in public awareness towards environmental issues, WM practices and WR, and sustainable living; (3) dominance of unsustainable practices by dumping SW; (4) lack of sustainable WM policies (i.e., reduce, reuse, and recycle); and (5) lack of sufficient allocated funds, lack of coordination among stakeholders, shortage of trained and qualified personnel, and shortage in technical and operational decision making.

Based on the explored literature, different proposed solutions were investigated to solve the MENA region's SW problem. Examples of these solutions are: (1) developing effective legislation, policies, strategies, and enforced laws; (2) increasing the public awareness of citizens about WM and sustainability; (3) encouraging the industrial sector to apply sustainable production practices; (4) encouraging different business sectors to apply WM hierarchy by offering incentives; (5) allocating sufficient funds for SWM; and (6) developing institutional capacity on SWM at the municipal level by investing in people, institutions, and practices.

Considering the CDW problem in the Egyptian construction industry, the situation is critical given the continuous unprofessional way of dealing with CDW by dumping on streets, residential areas, and at illegal dumping sites. This illegal dumping of CDW has severe adverse effects on the TBL of sustainability. Moreover, the Egyptian laws that manage CDW are considered poor, weak, and ineffective towards reducing CDW. The literature review revealed different methodologies and strategies that could significantly minimise CDW in the Egyptian construction industry. Examples of these methods are industrialisation, computer integrated construction, constructability, partnership, robotized and automated construction, BIM, and GB practices. These strategies mainly focus on minimising CDW during the design and construction stages. However, limited research focused on minimising waste during the materials procurement stage, a critical interface between the design and construction stages. It has been proven that proper materials procurement process could reduce both CDW and total project cost. The literature review revealed four different clusters of waste-efficient materials procurement measures that could help in minimising CDW as follows: (1) suppliers' low waste commitment; (2) low waste purchase management; (3) effective materials delivery management; and (4) waste-efficient bill of quantity.

Moreover, based on the literature review, it has been indicated that OPM and SCPM are better materials procurement models than GCPM to reduce CDWG. Additionally, GB practices are one of the main approaches to optimising and rationalising materials procurement in Egypt via applying the Egyptian GPRS. The criteria listed in the M&R category of the GPRS is responsible for guiding the sustainable and green procurement of construction materials leading to a reduction in CDWG in the Egyptian construction sites. These criteria focus on: (1) using renewable materials and materials manufactured using renewable energy; (2) using regionally procured materials and products; (3) reducing overall materials use; (4) using alternative building prefabricated elements; and (5) using environment-friendly, sound and thermal insulation materials.

After investigating solutions to the SW problem and presented waste-efficient materials procurement practices for CDWR, it is worth mentioning that the Egyptian construction industry lacks a framework for minimising CDW. This framework shall mainly consist of the aforementioned waste-efficient materials procurement practices compounded with effective legislation, high awareness, and appropriate culture and behaviour. Accordingly, the thesis's main aim is to introduce a materials procurement conceptual framework (MPCF), which consists of six main factors, as investigated in chapter two, to reduce CDW in Egypt. This framework provides recommendations for improvement of practices, legislation, culture and behaviour, and awareness. Besides, this research aims to propose improvements to the GPRS to enhance its ability to minimising the environmental hazards in general and CDW problem in specific by addressing its current limitations and shortcomings.

The main and secondary aims of the thesis were achieved through three research phases. Each phase was adopted to fulfil defined research objectives, in which they were adopted consecutively. The three phases are as follows:

- **Phase one**: this phase adopts exploratory research using "grounded theory" in order to: (1) explore different knowledge areas in the literature related to SW in general and CDW in specific on the global, regional, and local contexts; and (2) propose improvements to the GPRS generally and its M&R category specifically through comparison with the well-established BREEAM and LEED.

- **Phase two**: this phase adopts a mix of exploratory and descriptive research using a "structured interview questionnaire" to (1) quantify CDW in terms of generation rates and costs among different project types in the Egyptian construction sector; and (2) investigate the relationship between CDWG and different adopted CDWR factors among different project types in the Egyptian construction sector.

- **Phase three**: this phase adopts a mix of descriptive and explanatory research using "survey questionnaire" to (1) investigate the current applicability and effectiveness levels of different practices, legislation, measures of culture and behaviour, and awareness measures in the Egyptian construction sector; (2) evaluate the effect of different practices, legislation, culture & behaviour measures, and awareness measures on CDWR in the Egyptian construction sector; and (3) develop the MPCF in order to reduce CDW in the Egyptian construction sector in support of Egypt's vision 2030.

A final step in the research process is to validate the research outputs: (1) GPRS improvement proposal; and (2) the developed MPCF. Both outputs were validated through a panel of academics and industry professionals using a "survey questionnaire". The validation results indicated that both the GPRS improvement proposal and the developed MPCF are: (1) suitable and significant; (2) logical and can be followed; (3) applicable and useful; and (4) complete and include all the essential elements needed.

9.3 Research Findings

The three aforementioned research phases resulted in different findings which address different aspects. Accordingly, the findings are classified into three main subsections to demonstrate the findings of each phase.

9.3.1 Findings of Phase One

This phase explored the literature to investigate different SW and CDW problems on the global, regional, and local levels. Based on the knowledge gaps found in the CDWM research in Egypt, as aforementioned, a theoretical framework was built to be tested and validated throughout this research. This theoretical framework consists of six IDVs (i.e., factors affecting CDWR) and one DV (i.e., CDWR), along with six hypotheses to be tested and validated through a survey questionnaire. These six IDVs are as follows: (1) MPMR; (2) MPMO; (3) GBPR; (4) LG; (5) AW; and (6) CB. The factors and their indicators were involved in the theoretical framework based on extensive literature review and investigation to various previous studies in the research domain of SW generally and CDW specifically. The result of the statistical testing and validation is a final developed conceptual framework to reduce the CDW problem, as discussed later on in the findings of phase three.

Also, this phase thoroughly investigated the GPRS and compared it with the well-established BREEAM and LEED in general, on the categorical level, and the criteria level of M&R category. It was found that most of the categorical weights of the GPRS are imitating those of BREEAM and LEED without being tailored to the local Egyptian context to address the current challenges in Egypt. For instance, the weight of the M&R category is imitating its peers in BREEAM and LEED without considering the escalating problem of CDW in Egypt. Accordingly, this study proposed newly modified categorical weights that may be considered for tackling Egypt's current challenges regarding CDW, energy conservation, and water scarcity. These three categories (i.e., M&R, EE, and WE) were assigned the highest weights in the newly proposed categorical weights to demonstrate their criticality and importance.

Based on an in-depth comparison of M&R category in three GBRSs, shortcomings and limitations in this category of the GPRS were discussed. It was found that three essential criteria are missing in the M&R category of the GPRS, compared to BREEAM and LEED, which are: Construction waste management, building and material reuse, and material efficiency. It is recommended to integrate these criteria in the next version of the GPRS as they may significantly reduce and adequately manage CDW in Egypt. Besides, it was found that existing criteria lacks critical elements. For instance, Renewable Materials and Materials Manufactured Using Renewable Energy criterion lacks critical elements such as a database for green materials in Egypt and their suppliers, green materials certifications, and standards needed to ensure that renewable materials are obtained from a rapidly renewable source. It is recommended to address the absence of the critical elements needed for the rigour and effective application of the criteria. Furthermore, it was found that some of the existing criteria are suffering from ineffective application due to low awareness of contractors, the absence of qualified contractors, and high initial costs of its application. The Egyptian government is recommended to increase the awareness and capabilities towards applying these high-tech methods and provide incentives for their application.

A case study of using PFs as a green material for concrete reinforcement was investigated. Through the application of this case study, it was proved that the efficient adoption of one criterion (i.e., using renewable materials) of M&R category could positively impact the TBL of sustainability. The main aim of the case study was to demonstrate the impact of M&R category on sustainability and to reinforce the argument of according it a higher weight than its current weight in the recent version of the GPRS. In summary, the next version of the GPRS has to revise the weights of the different categories based on the current challenges in the Egyptian context. Also, it has to ensure that the M&R category is rigorous enough by addressing the current shortcomings and limitations in its criteria to help in solving the CDW problem in Egypt.

To foster the application of GPRS in the Egyptian construction industry, several recommendations are suggested by Daoud *et al.* (2018a) as follows: (1) implementing GB principles extensively in construction education at universities across Egypt to boost their application and increase the awareness of the negative impact of CDW on the TBL of sustainability; (2) setting a minimum score of GPRS certification as an obligation for issuing building's permits like what has been done by several countries such as the UK, Japan, and United Arab Emirates; (3) introducing incentives for construction companies which apply GB principles; and (4) implementing green construction technologies and green procurement methodologies by construction companies within its projects and encourage their clients and employees to follow and implement them.

9.3.2 Findings of Phase Two

This phase provided a new contribution to knowledge through mixed research methods by (1) quantifying CDW among various Egyptian construction projects in terms of costs and generation rates; and (2) exploring the relationship between CDWR factors and CDWG. Based on the analysis results among the four projects, it was noted that "timber" is the most wasteful material regarding CDWG rates, followed by "sand" and "bricks/blocks" consecutively. Moreover, it was noted that the infrastructure project was the most wasteful in terms of CDWG rates and total wasted materials cost.

It was also indicated that there is an inverse relationship between the different CDWR factors, which represent the WM evaluation in any project, and CDWG. It was proven that if these factors are improved, the CDWG decreases represented in a decrease in the total cost of wasted materials. On average, among the four projects, it was found that "practices" (i.e., waste-efficient materials procurement practices) and "legislation" are the least applied factors towards CDWR. More specifically, it was noted that the project which adopts more waste-efficient materials procurement measures and green materials procurement criteria is characterised by less CDWG than its peers, such as the case in the industrial project, which is the least wasteful project. It was also noted that all projects adopted the GCPM during project execution, which is not the best option regarding CDWR. Some experts in this study recommended adopting either SCPM or OPM or integration between them to minimise CDW, especially in mega construction projects.

Based on the findings of this case study and the experts' responses, it is recommended to adopt different strategies to solve the CDW problem in Egypt as follows: (1) adopt waste-efficient practices, especially waste-efficient materials procurement measures and green materials procurement criteria based on their high impact on the reduction of both CDWG and total project cost; (2) increase the awareness of citizens and professionals towards CDWR; (3) promote the culture and improve the behaviour towards CDWR at workplaces, schools, governmental bodies, and universities; (4) develop strict legislation which offers incentives for CDWR and penalise the construction firms which dump CDW illegally; (5) enhance the communication channels between different project parties; (6) suffice an adequate number of legal dumpsites all over the different Egyptian governorates; and (7) promote the adoption of reuse and recycle of CDW.

9.3.3 Findings of Phase Three

This phase screened a representative sample of construction firms in the Egyptian construction sector through a survey questionnaire. This survey aimed to (1) investigate the current applicability and effectiveness levels of different practices, legislation, measures of culture and behaviour, and awareness measures in the Egyptian construction sector; (2) evaluate the effect of different practices, legislation, culture & behaviour measures, and awareness measures on CDWR in the Egyptian construction sector; and (3) develop and introduce an MPCF for minimising CDW in the Egyptian construction sector. Through the analysis of respondents' answer, different conclusions were highlighted as follows:

- Waste-efficient materials procurement practices, legislation, culture & behaviour, and awareness can reduce CDW in Egypt.
- There is a necessity for developing a conceptual framework that can integrate all CDWR factors for reducing CDWG in Egypt.
- Egyptian CDWM legislation are not fully effective in solving the CDW problem as they focus only on CDW collection, transfer, and disposal without encouraging the adoption of reduction technique or any other technique of the 4Rs techniques. Egyptian CDWM legislation can be better improved by including guidance for

adopting waste-efficient materials procurement practices to foster CDWR and apply incentives to adopt them.

- Most of the respondents' firms do not pay attention to CDWR as they do not efficiently apply the abovementioned factors, which can significantly reduce CDWG.
- Given the ranking of different factors according to their applicability and effectiveness levels, it was found that "**correct materials purchase**" is the most applied item among the different factors and "**reducing overall material use by using prefabricated elements and highly durable materials**" is the most effective item among the different factors.
- It was found that there is a lack of interdependency between the level of applicability and the level of effectiveness of different CDWR factors, which means that the effectiveness of these different factors has no influence on their applicability in the Egyptian construction sector given the reluctance of Egyptian construction firms towards applying them.
- Based on correlation analysis of each IDV with the DV, it was found that there are significant positive relationships between DV and all IDVs except "LG". This indicates that Egyptian legislation are ineffective alone in reducing CDWG.
- Based on a rigorous statistical analysis using SEM, where the relationships between all IDVs and the DV were tested in a multiple system of the model, it was found that all the IDVs have a statistically significant positive effect on the DV. This indicates that "LG" has a statistically significant positive effect on CDWR in the presence of other external surrounding factors, but it does not have a statistically significant positive relationship with CDWR alone, as demonstrated in the correlation analysis results.
- Based on effect size analysis of the CDWR factors (i.e., IDVs), it was found that "GBPR", as one out of three dimensions of waste-efficient materials procurement practices (i.e., GBPR, MPMR, MPMO), has the highest effect size. On the other hand, "LG", "MPMR", and "MPMO" have the least effect sizes. The effect size measures how much the DV will be affected if an IDV is removed from the model. The high effect size of "GBPR" highlights the importance of this study's GPRS improvement proposal presented in chapter four.

- Based on the IPMA, it was found that "CB" is the second most important factor contributing to CDWR and the least performing factor at the same time. This means that this factor needs careful attention for better results towards CDWR.
- Based on the abovementioned statistical tests results, a final developed and validated conceptual framework, which consists of all the CDWR factors, was introduced. This developed conceptual framework acts as a roadmap to assist the industry practitioners and the Egyptian government in achieving the target of CDWR.

9.4 Research Contributions

This research is intended to produce a wide range of contributions that will positively impact the industry, Egyptian governmental agencies, and academia. Some of these contributions are more relevant to researchers (i.e., academia) and are thus classified as academic contributions, while other contributions are more relevant to the construction industry or the government and are classified as industrial or governmental contributions, respectively.

9.4.1 Industrial Contributions

The industrial contributions of this research are as follows:

- Main CDWR factors and their measures needed for overcoming the CDW problem in Egypt were introduced.
- The importance of waste-efficient materials procurement practices, according to the TBL of sustainability, was highlighted.
- A developed and validated conceptual framework consisting of waste-efficient materials procurement practices, legislation, culture & behaviour measures, and awareness measures needed for CDWR was introduced. This acts as a guide for industry practitioners to adopt CDWR factors within their organisations and implement them among their project and employees. It is worth mentioning that this framework may be of benefits to other African construction organisations given the structural similarity of African construction industry

9.4.2 Governmental Contributions

The governmental contributions of this research are as follows:

- Shortcomings in CDWM legislation and the GPRS were highlighted and investigated, and recommendations for improvement were introduced.
- A developed and validated conceptual framework consisting of waste-efficient materials procurement practices, legislation, culture & behaviour measures, and awareness measures needed for CDWR was introduced. This acts as a roadmap to assist the governmental bodies in Egypt in improving the current situation of adopting and applying the different abovementioned factors. It is worth mentioning that this framework may be of benefits to other African governments given the similarity of African countries' nature as developing countries existing in the same continent.

9.4.3 Academic Contributions

The academic contributions of this research are as follows:

- Better investigation of the relationship between waste-efficient materials procurement practices and CDWR was introduced.
- Encouragement of more research on CDWM through waste-efficient materials procurement practices was done instead of the main focus on CDWM through design and construction strategies.
- Promotion of the SEM technique application in the construction research domain was done to encourage applying a rigorous statistical modelling technique in (1) testing and validating theoretical frameworks; and (2) developing and introducing conceptual frameworks.

9.5 Research Limitations and Recommendations for Future Research and Development

The current research, like other research, includes several strengths and limitations. This research's strengths have been highlighted in the previous section, section 9.4, indicating the research contributions to industry, government, and academia. This section discusses the encountered research limitations and recommendations for future research and development based on the work presented in this thesis. The main limitations of this research are as follows:

- Based on the experience gained through the research process, it became clear and evident that Egypt's construction sector does not pay attention to construction research and development (R&D). Participation in investigations and surveys is something hard to find in this domain. The majority of industry professionals think that participation in research surveys or studies is something useless and time-wasting. The researcher faced many challenges during data collection, whether through the interview questionnaires or the survey questionnaire. It was hard to collect the data promptly in which much time was wasted.
- The sample size that participated in the survey questionnaire was sufficient. However, the number of participants for each stratum was unbalanced. For instance, based on stratified random sampling, it was expected to collect 87 responses from construction firms of 7th-grade. However, due to the unwillingness of contacted firms to participate in the survey questionnaire, only 32 responses representing 7th-grade firms were collected through the random distribution of the survey among industry professionals via different communication channels.
- No weights were assigned to the indicators (i.e., items) used to evaluate and represent the different constructs; instead, each construct's indicators were assumed to be equally weighted. However, industry professionals may assign different weights to the indicators according to the importance of some indicators over others in representing a specific construct.
- No computerized application was developed to facilitate the adoption and application of the conceptual framework by different users in a real-life context. This application may help apply the framework and evaluate the construction firm in terms of their performance towards CDWM.

Accordingly, based on the abovementioned research limitations, the recommendations for future research and development are as follows:

- To update industry professionals with the Egyptian construction sector's current challenges, especially environmental hazards, and available solutions to overcome these challenges. This can be done through different communication channels such as email newsletter, workshops, and seminars. This is to demonstrate the importance of R&D and to encourage industry professionals to exert effort and participate in the research process when needed.

- To examine a balanced and representative stratified sample of Egyptian construction firms while using a survey questionnaire. It means that, based on stratified sample size calculations, the survey should cover the defined number of participants per each stratum. This is to ensure that no bias has occurred during data collection and to allow the findings' generalisation from the sample to the whole population. Also, it is needed to ensure the inclusion of sufficient points per strata to permit the separate analysis of any strata.
- To collect experts' opinions on the weights of the different indicators representing the constructs. This can be achieved through data collection and analysis to develop the indicators' weights contributing to different constructs. Consequently, some indicators would have higher weights than other indicators in evaluating and representing the construct they belong to.
- To develop computer application software to help industry professional and governmental bodies adopt and apply the conceptual framework in real-life projects. Moreover, add-on features can be added to this software to be used as an evaluation tool to evaluate different construction firms based on their performance towards CDWM. This shall evaluate the construction firm based on the applied practices, followed legislation, level of awareness, and adopted culture & behaviour. Based on the final score, the company shall be evaluated on different levels as follows: (1) green waste reducer; (2) golden waste reducer; (3) silver waste reducer; and (4) bronze waste reducer.

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APPENDICES

APPENDIX A: STRUCTURED INTERVIEW QUESTIONNAIRE

MATERIALS PROCUREMENT CONCEPTUAL FRAMEWORK FOR MINIMISING WASTE IN THE EGYPTIAN CONSTRUCTION INDUSTRY

Construction Industry Professionals – Structured Interview Questionnaire for Construction Projects' Case Study

Thank you for agreeing to participate in this interview questionnaire. We estimate that it will take ***45-60 minutes*** to complete the questions.

YOUR RESPONSES IN THIS QUESTIONNAIRE WILL BE KEPT STRICTLY CONFIDENTIAL.

This questionnaire will be used by a PhD Researcher at London South Bank University for exploring the materials waste problem in the Egyptian construction industry. This PhD research aims to develop a framework that will incorporate elements to address the deficiencies in practices, legislation, behaviour, culture, and lack of awareness through a different approach focusing on materials procurement.

Your responses are important to the success of the study, and any additional comments are welcomed. Please do not hesitate to ask the researcher for assistance should you have any questions.

INSTRUCTIONS

1. Answers should reflect your current status and knowledge. Do not refer to procedures or capabilities that are anticipated or proposed.

2. The questionnaire aims to: (1) determine the waste percentages in main common building materials in the project you participated in; (2) explore the current adopted materials procurement models and measures in the project you participated in; and (3) investigate the current status of awareness, practices, culture & behaviour, and legislation at your firm from your perspective. Each section is composed of a series of defined questions that represent the section to be evaluated. Please respond to all questions to the best of your knowledge.

Date completed (DD/MM/YYYY): ______________________________

SECTION 1: RESPONDENT INFORMATION

Firm Name: _______________ Firm Department: __________________

Name: ______________________________ Job title: ______________________________

Work address: ____________________________ City: ___________________

Work phone: _________________ Work fax: ___________________

Work email: __________________

Current position within the firm: __________________________________

You have been working in the industry for: ________years _________ months

Your status in the firm is: ☐ Full-time ☐ Part-time

Education: Highest degree or level of schooling you have completed.

☐ Bachelor's degree

☐ Master's degree

☐ Doctorate

☐ Other (please specify): _______________________________

Please specify any professional designation you currently hold: _____________________

Please select the type of projects carried out by your firm: (please choose ALL that apply to your firm)

☐ Industrial projects ☐ Commercial Projects

☐ Residential Projects ☐ Infrastructure projects

Please specify the grade of your firm in the Egyptian Federation for Construction and Building Contractors (EFCBC):

☐ 1st-grade ☐ 2nd-grade ☐ 3rd-grade ☐ 4th-grade ☐ 5th-grade ☐ 6th-grade

☐ 7th-grade

SECTION 2: DETERMINING MATERIALS WASTE PERCENTAGES

Q1. Please state a brief description (e.g., type and size, inception year, purpose, complexity) of this construction project, the core of this case study in which you have participated.

Q2. Please state the different types of main common building materials used in this construction project from the following options:

☐ Timber ☐ Sand ☐ Concrete ☐ Cement ☐ Reinforcement Steel

☐ Tiles ☐ Bricks/blocks

Q3. Please state the quantities, cost per unit, and waste percentages of the abovementioned materials used in this construction project.

Material Type	**Quantity**	**Cost per unit**	**Waste percentage**
Timber			
Sand			
Concrete			
Cement			
Reinforcement Steel			
Tiles			
Bricks/blocks			

SECTION 3: EXPLORING CURRENT ADOPTED MATERIALS PROCUREMENT MODELS AND MEASURES

Q4. Please specify the materials procurement model/s adopted in this construction project from the following options:

☐ General contractor procurement model ☐ Specialty contractor procurement model

☐ Owner procurement model

Q5. Why have the abovementioned model/s been adopted in this construction project?

Q6. Do you think that the adopted procurement model/s is the best option for this kind of construction projects in terms of materials waste reduction? If not, which one do you think is the best option? And why?

Q7. Please specify the materials procurement measures taken to reduce materials waste in this construction project from the following options:

☐ Suppliers' flexibility in supplying small quantities or modification to products in conformity

☐ Commitment to take back scheme (packaging, unused, reusable and recyclable materials)

☐ Supply of quality and durable products

☐ Usage of minimal packaging (without affecting materials safety)

☐ Procurement of waste-efficient materials/technology (pre-assembled/cast/cut)

☐ Purchase of secondary materials (recycled and reclaimed)

☐ Purchase of quality and suitable materials

☐ Avoidance of variation orders ☐ Correct materials purchase

☐ Effective protection of materials (during transportation, loading & unloading)

☐ Effective onsite access (for ease of delivery) ☐ Efficient delivery schedule

☐ Usage of Just in Time (JIT) delivery system ☐ Accurate materials take-off

☐ Prevention of over/under ordering ☐ Reduced waste allowance

☐ Other (please specify): ____________________

Q8. Do you think that the materials procurement measures applied in this construction project were sufficient to reduce materials waste? If not, what would have you recommended during the project execution to reduce materials waste?

Q9. Did you apply any of the following green materials procurement criteria listed in the Egyptian GPRS during this construction project's execution? If not, please specify the reason.

☐ Usage of renewable materials and materials manufactured using renewable energy

☐ Usage of regionally procured materials and products

☐ Reduction of Overall Material Use

☐ Usage of alternative building prefabricated elements

☐ Usage of environment – friendly, sound and thermal insulation materials

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SECTION 4: INVESTIGATING THE CURRENT STATUS OF AWARENESS, PRACTICES, CULTURE & BEHAVIOUR, AND LEGISLATION

Q10. To what extent you are aware of the severity of the materials waste problem in Egypt and its negative impacts?

1- Not aware at all 2- Slightly aware 3- Somewhat aware
4- Very aware 5- Extremely aware

Q11. To what extent you are aware of the current Egyptian legislation towards construction and demolition waste management (CDWM)?

1- Not aware at all 2- Slightly aware 3- Somewhat aware
4- Very aware 5- Extremely aware

Q12. To what extent are you aware of the Egyptian green pyramid rating system (GPRS)?

1- Not aware at all 2- Slightly aware 3- Somewhat aware
4- Very aware 5- Extremely aware

Q13. To what extent you are aware of the aforementioned materials procurement measures which should be applied during the project execution for materials waste reduction?

1- Not aware at all 2- Slightly aware 3- Somewhat aware
4- Very aware 5- Extremely aware

Q14. What do you think of the materials waste problem in the Egyptian construction industry?

Q15. How often do you apply materials procurement measures in the projects in which you participate?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

Q16. How often do you apply a green building rating system (e.g., GPRS, BREEAM, LEED) in the projects in which you participate?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

Q17. How often do you apply SCPM and OPM for materials procurement in the projects in which you participate?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

Q18. To what extent are you interested in reducing materials waste in the construction projects in which you participate?

1- Not interested at all 2- Slightly interested 3- Somewhat interested
4- Very interested 5- Extremely interested

Q19. How often do you encourage the employees and labours in the construction projects which you participate in to reduce materials waste during project execution?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

Q20. To what extent do you think that employees and labours at your firm are interested in reducing materials waste during the execution of the construction projects?

1- Not interested at all 2- Slightly interested 3- Somewhat interested
4- Very interested 5- Extremely interested

Q21. The culture of materials waste reduction is adopted by your firm and exists among its employees and labours.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree

Q22. Your firm and its employees and labours tend to develop ideas and solutions for mitigating materials waste problems during the construction projects' execution.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree

Q23. Your firm follows the current Egyptian legislation towards CDWM.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree

Q24. Your firm encourages its managers to adopt Egyptian legislation towards CDWM during project execution through informative policies and clear frameworks.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree

APPENDIX B: MAIN SURVEY QUESTIONNAIRE

MATERIALS PROCUREMENT CONCEPTUAL FRAMEWORK FOR MINIMISING WASTE IN THE EGYPTIAN CONSTRUCTION INDUSTRY – MAIN SURVEY QUESTIONNAIRE

Thank you for agreeing to participate in this survey questionnaire. We estimate that it will take ***45-60 minutes*** to complete the questions.

This questionnaire will be used by a PhD Researcher at London South Bank University for exploring the construction and demolition waste (CDW) problem in the Egyptian construction industry. This PhD research aims to develop a framework that will incorporate elements to address the deficiencies in practices, legislation, behaviour, culture, and lack of awareness through a different approach focusing on materials procurement.

Your responses are important to the success of the study, and any additional comments are welcomed. Please do not hesitate to ask the researcher for assistance should you have any questions.

INSTRUCTIONS

1. Answers should reflect your current status and knowledge. Do not refer to procedures or capabilities that are anticipated or proposed.
2. The questionnaire aims to: (1) Investigate the CDW problem in Egypt and its current status; (2) evaluate the applicability of materials procurement models and measures and green building practices within the Egyptian construction industry and their effectiveness towards CDW reduction (CDWR); (3) evaluate the applicability of Egyptian construction and demolition waste management (CDWM) legislation and their effectiveness towards CDWR; (4) evaluate the applicability of awareness, and culture and behaviour measures in Egypt and their effectiveness towards CDWR; and (5) evaluate the effectiveness of CDWR in improving different project dimensions (i.e., cost, time, and quality). This survey consists of five main sections addressing the abovementioned five aims. Each section is composed of a series of defined questions that represent the section to be evaluated. Please respond to all questions to the best of your knowledge.

Section 1: General Information

Q1. How many years of industrial work experience do you have?

1- 0 to 5 years 2- 5 to10 years 3- 10 to 15 years 4- 15 to 20 years 5- more than 20 years

Q2. At which department do you work currently within your firm?

1- Project Management 2- Procurement Management 3- Other (please specify):________________

Q3. Kindly specify the highest degree or level of education you have completed.

1- Bachelor's degree 2- Postgraduate diploma 3- Master's degree 4- Doctorate 5- Other (please specify):________________

Q4. Kindly specify your firm's classification grade within the Egyptian Federation for Construction and Building Contractors (EFCBC) from the following options.

1- 1st-grade 2- 2nd-grade 3- 3rd-grade 4- 4th-grade 5- 5th-grade 6- 6th-grade 7- 7th-grade

Q5. Kindly specify all the types of projects carried out by your firm from the following options.

1- Industrial projects 2- Commercial projects 3- Residential projects 4- Infrastructure projects

Q6. To what extent do you agree that waste-efficient practices, legislation, appropriate culture & behaviour, and high awareness positively affects CDW minimisation?

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree 4- Agree 5- Strongly agree

Q7. To what extent do you agree that the Egyptian construction industry needs a framework for improving current practices, legislation, culture and behaviour, and awareness to minimise CDW?

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree 4- Agree 5- Strongly agree

Q8. How often do the procurement management and/or project management departments in your firm tend to reduce CDW during projects execution?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

Section 2: Applicability of Materials Procurement Models and Measures, Green Building Practices, and their Effectiveness

Q9. For the following materials procurement models, kindly specify their level of applicability and effectiveness within the Egyptian construction industry.

Materials procurement models (MPMO)	**1) Level of current applicability (1= not applicable at all --- 5= extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= extremely effective)**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
a) Specialty contractor procurement model (SCPM) (i.e., the specialty contractor is responsible for procuring materials for the project owner)										
b) Owner procurement model (OPM) (i.e., the project owner directly procures the required materials from the vendors)										

Q10. For the following waste-efficient materials procurement measures, kindly specify their applicability level within the Egyptian construction industry.

Materials procurement measures (MPMR)	**1) Level of current applicability (1= not applicable at all --- 5= extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= extremely effective)**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
1) Suppliers' low waste commitment (SLWC)										
a) Suppliers' flexibility in supplying small quantities or modification to products in conformity										
b) Commitment to take back scheme (packaging, unused, reusable and recyclable materials)										
c) Supply of quality and durable products										
d) Usage of minimal packaging (without affecting materials safety)										
2) Low waste purchase management (LWPM)										
a) Procurement of waste-efficient materials/technology (pre-assembled/cast/cut)										
b) Purchase of secondary materials (recycled and reclaimed)										
c) Purchase of quality and suitable materials										
d) Avoidance of variation orders										

Materials procurement measures (MPMR)	**1) Level of current applicability (1= not applicable at all --- 5= extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= extremely effective)**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
e) Correct materials purchase										
3) Effective materials delivery management (EMDM)										
a) Effective protection of materials (during transportation, loading & unloading)										
b) Effective onsite access (for ease of delivery)										
c) Efficient delivery schedule										
d) Usage of Just in Time (JIT) delivery system										
4) Waste-efficient bill of quantity (WEBOQ)										
a) Accurate materials take-off										
b) Prevention of over/under ordering										
c) Reduced waste allowance										

Q11. For the following Materials and Resources criteria listed in the GPRS, kindly specify their level of applicability and effectiveness within the Egyptian construction industry.

Green building practices (GBPR) for materials procurement in the GPRS – green materials procurement approach	**1) Level of current applicability (1= not applicable at all --- 5= extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= extremely effective)**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
a) Utilising renewable materials and materials manufactured using renewable energy.										
b) Using regionally procured materials and products extracted or manufactured within a distance of 500 km of the project site with no less than 50% of the total materials value based on cost.										
c) Reducing overall material use by: (1) using standard assemblies and reducing customised spaces, (2) using materials that do not need finishing, or (3) using materials that possess high durability and require low maintenance.										
d) Using alternative building prefabricated elements not less than 10% of the total element quantity.										
e) Using environment – friendly, sound and thermal insulation materials which have specific requirements as follows: (1) free from chlorofluorocarbons, (2) does not release toxic fumes when burned, (3) the percentage of volatile organic compound is less than 0.1, and (4) thermal insulation materials should have an ozone depleting materials of zero and a low global warming potential which does not exceed 5.										

Section 3: Applicability of Egyptian CDWM Legislation and their Effectiveness

Q12. For the following Egyptian CDWM legislation, kindly specify their applicability level within the Egyptian construction industry and their level of effectiveness in solving the CDW problem in Egypt.

Egyptian CDWM legislation (LG)	**1) Level of current applicability (1= not applicable at all --- 5= extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= Extremely effective)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
a) Laws 106/1976 and **101/1996**: Local governments are authorised to involve CDWM in the permits needed for construction activities. Also, these laws authorise local governments to gather fees from contractors and owners to provide or pay for CDW collection and disposal.										
b) Article 39 of the Environment Law 4/1994 and Article 41 of the executive regulations for the Environment Law 4/1994 (Prime Minister Decree Number 338/1995): When carrying out exploration, digging construction, or demolition work, or while transporting waste substances or soil, all bodies and individuals shall take necessary precautions to store or transport this waste in a safe way to prevent it from being dispersed. The authority granting permits for building or demolition shall indicate such requirements on the permit as mentioned in the following: **(1)** stacking of waste on-site shall be safely carried out so as not to form any impediment to traffic and pedestrian movement. Waste liable to dispersal into the air shall be covered to avoid air pollution;										

Egyptian CDWM legislation (LG)	1) Level of current applicability (1= not applicable at all --- 5= extremely applicable)					2) Level of effectiveness (1= not effective at all --- 5= Extremely effective)				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
(2) waste substances and soil resulting from digging, demolishing and construction work shall be transported in special containers or receptacles by using trucks provided and licensed for this purpose, and which fulfil the following conditions: a) trucks shall be fitted with special containers or with tight covers to prevent spreading of dust, soil, and waste substances into the air, or their falling off on the road, and b) trucks shall be provided with special loading and unloading equipment; and c) trucks shall be in good condition conforming to regulations for safety, efficiency, and lighting and shall be equipped with comprehensive safety systems; **(3)** locations assigned to receive this transported waste shall be at a minimum distance of 1.5 kilometres from residential areas and at a lower contour level. Also, they shall be levelled after complete filling with waste; and **(4)** local authorities shall determine the locations to which waste shall be transported. It shall not be authorized to transport or dispose of it except in locations specially prepared for such purpose and designated as such by the concerned local authorities.										

Q13. To what extent do you agree with the following statement "the Egyptian legislation lack effective waste minimisation strategies, and they only focus on waste transfer, charge, and dumping"?

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree 4- Agree 5- Strongly agree

<u>Section 4: Applicability of Awareness and Culture & Behaviour Measures and their Effectiveness towards CDW Reduction in Egypt</u>

Q14. For the following measures of efficient awareness, kindly specify their level of applicability and effectiveness.

Awareness (AW) measures	**1) Level of current applicability (1= not applicable at all --- 5= Extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= extremely effective)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
a) Promotion of public awareness campaigns about solid waste (SW) and its negative impacts.										
b) Encouraging the cooperation between the public, service providers, and government officials to participate in solid waste management (SWM) activities.										
c) Increasing the awareness about SWM at the workplace.										

Q15. For the following measures of efficient culture and behaviour, kindly specify their level of applicability and effectiveness.

Culture & behaviour (CB) measures	**1) Level of current applicability (1= not applicable at all --- 5= Extremely applicable)**					**2) Level of effectiveness (1= not effective at all --- 5= extremely effective)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
a) Fostering waste reduction via financial incentives to encourage municipalities and industry practitioners to act.										
b) Establishing educational content about SWM in schools' curriculum.										
c) Implementing training and educational programmes about SWM and governance, including officials from central and regional governments.										
d) Arranging information exchange trips for SW officials to share their experiences and knowledge, improve policies, and learn about new green techniques and practices.										
e) Implementing SWM educational and research programmes at universities.										

Section 5: CDW Reduction and its Effect on improving Project Dimensions (i.e., cost, time, and quality)

Q16. Kindly specify your level of agreement on the following project outcomes as a result of CDW reduction, as tabulated below.

Project outcomes	**1) Level of agreement (1= strongly disagree --- 5= strongly agree)**				
	1	**2**	**3**	**4**	**5**
a) Reducing unnecessary wasted project cost and eliminate project cost overruns.					
b) Delivering the project within the specified time schedule with minimal possible delays.					
c) Delivering the project according to the desired quality and specifications.					

End of Survey

Thank you for taking part in this study. The responses to this survey will be aggregated, and they will be used to develop a framework that will incorporate elements to address the deficiencies in practices, legislation, behaviour, culture, and lack of awareness. Accordingly, your responses to the three sections listed in this survey are very important.

The data collected in this study may also be published in scientific journals or presented at conferences. Information and data gathered during this research study will only be available to the research team identified in the information sheet. Should the research be presented or published in any form, all data will be anonymous (i.e., your personal information or data will not be identifiable). All information and data gathered during this research will be stored in line with the Data Protection Act. During that time, the data may be used by members of the research team only for purposes appropriate to the research question, but at no point will your personal information or data be revealed. If you wish to receive feedback about this research study's findings, please contact the researcher.

Thank you again for taking part. If there is anything you would like to discuss concerning this study, please contact the researchers. The researcher has equipped this survey with a unique ID generated online to identify a particular survey within the sample, and neither contains your name nor initials. If you would like to withdraw your data, please contact the researcher, and mention your unique ID.

APPENDIX C: DIFFERENT DESCRIPTIVE STATISTICS FOR ITEMS

	Min	Max	Skewness		Kurtosis	
			Statistic	Std. Error	Statistic	Std. Error
MPMO.AP.1	2	4	-.107	.156	-.699	.310
MPMO.AP.2	2	3	-.232	.156	-1.962	.310
MPMO.EF.1	1	5	-.801	.156	.709	.310
MPMO.EF.2	1	5	-.827	.156	.750	.310
MPMR.SLWC.EF.1	1	5	-1.074	.156	.973	.310
MPMR.SLWC.EF.2	2	5	-1.025	.156	.739	.310
MPMR.SLWC.EF.3	2	5	-.983	.156	.271	.310
MPMR.SLWC.EF.4	1	5	-1.243	.156	1.556	.311
MPMR.LWPM.EF.1	1	5	-1.677	.156	3.244	.310
MPMR.LWPM.EF.2	1	5	-1.732	.156	3.849	.310
MPMR.LWPM.EF.3	1	5	-1.733	.156	3.291	.310
MPMR.LWPM.EF.4	1	5	-1.612	.156	3.056	.310
MPMR.LWPM.EF.5	1	5	-1.559	.156	2.645	.310
MPMR.EMDM.EF.1	1	5	-1.259	.156	1.201	.311
MPMR.EMDM.EF.2	1	5	-1.014	.156	.460	.310
MPMR.EMDM.EF.3	1	5	-1.039	.156	.577	.310
MPMR.EMDM.EF.4	1	5	-1.049	.156	.641	.310
MPMR.WEBOQ.EF.1	2	5	-.967	.156	.862	.310
MPMR.WEBOQ.EF.2	1	5	-1.527	.156	3.441	.310
MPMR.WEBOQ.EF.3	2	5	-.983	.156	.586	.310
GBPR.EF.1	1	5	-2.446	.156	5.780	.311
GBPR.EF.2	1	5	-2.668	.156	7.728	.311
GBPR.EF.3	2	5	-3.032	.156	9.189	.310
GBPR.EF.4	1	5	-2.813	.156	8.012	.310
GBPR.EF.5	1	5	-2.059	.156	3.590	.310
LG.EF.1	1	5	-1.241	.156	2.858	.310
LG.EF.2	1	5	-1.065	.156	1.882	.310
AW.EF.1	3	5	-1.945	.156	2.792	.310
AW.EF.2	2	5	-2.172	.156	4.347	.310
AW.EF.3	1	5	-2.726	.156	8.487	.310
CB.EF.1	2	5	-.265	.156	.497	.310
CB.EF.2	2	5	-.223	.156	-.529	.310
CB.EF.3	2	5	-.332	.156	-.397	.310
CB.EF.4	1	5	-.571	.156	.013	.310
CB.EF.5	1	5	-.904	.156	1.029	.310

CDWR.AG.1	1	5	-1.172	.156	3.466	.310
CDWR.AG.2	1	5	-.454	.156	.182	.311
CDWR.AG.3	1	5	-.869	.156	1.252	.310

APPENDIX D: RESULTS OF CHI-SQUARE AND FISHER'S EXACT TESTS

MPMO.AP.1 * MPMO.EF.1 Crosstabulation

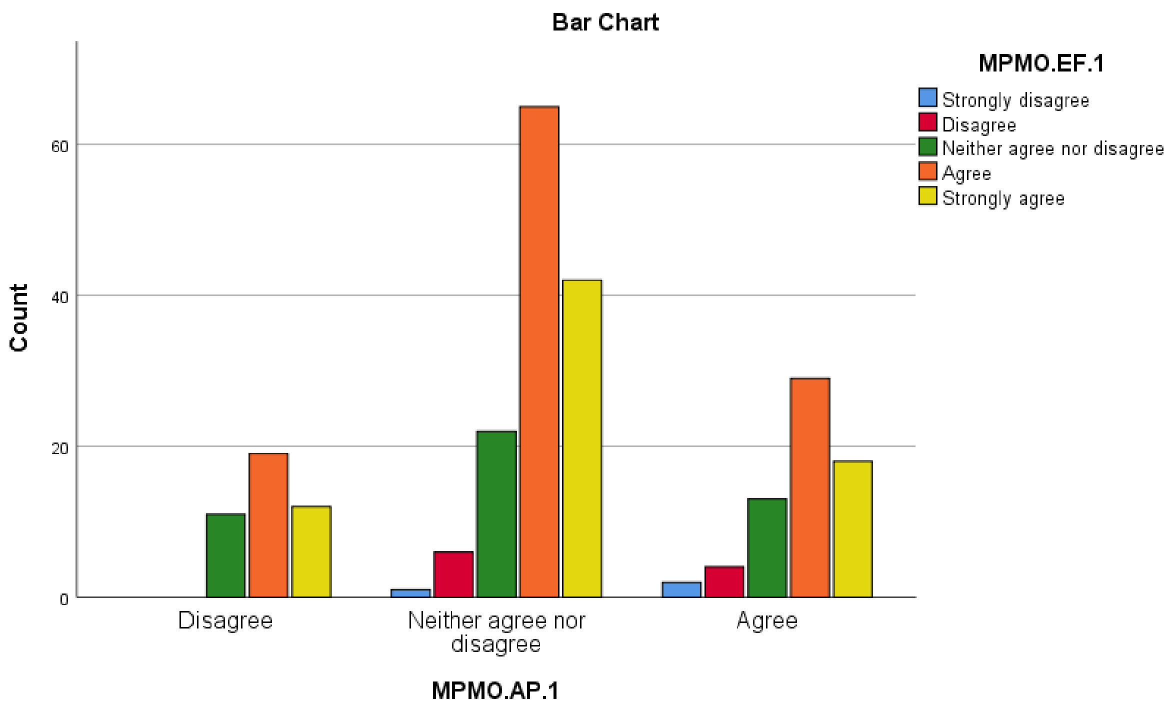
Count

		MPMO.EF.1					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMO.AP.1	Disagree	0	0	11	19	12	42
	Neither agree nor disagree	1	6	22	65	42	136
	Agree	2	4	13	29	18	66
Total		3	10	46	113	72	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.009[a]	8	.536
Likelihood Ratio	8.599	8	.377
Linear-by-Linear Association	1.171	1	.279
N of Valid Cases	244		
Fisher's Exact Test			0.589

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .52.



MPMO.AP.2 * MPMO.EF.2 Crosstabulation

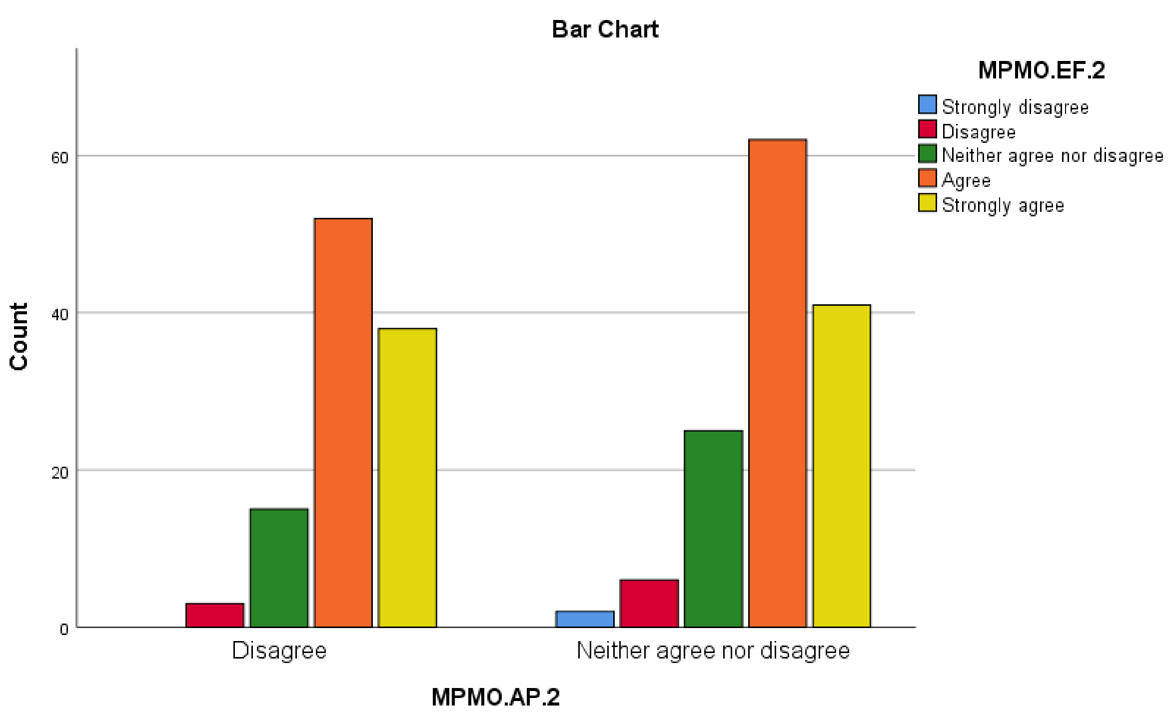
Count

		MPMO.EF.2					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMO.AP.2	Disagree	0	3	15	52	38	108
	Neither agree nor disagree	2	6	25	62	41	136
Total		2	9	40	114	79	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.322[a]	4	.505
Likelihood Ratio	4.091	4	.394
Linear-by-Linear Association	2.518	1	.113
N of Valid Cases	244		
Fisher's Exact Test			0.598

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is .89.



MPMR.SLWC.AP.1 * MPMR.SLWC.EF.1 Crosstabulation

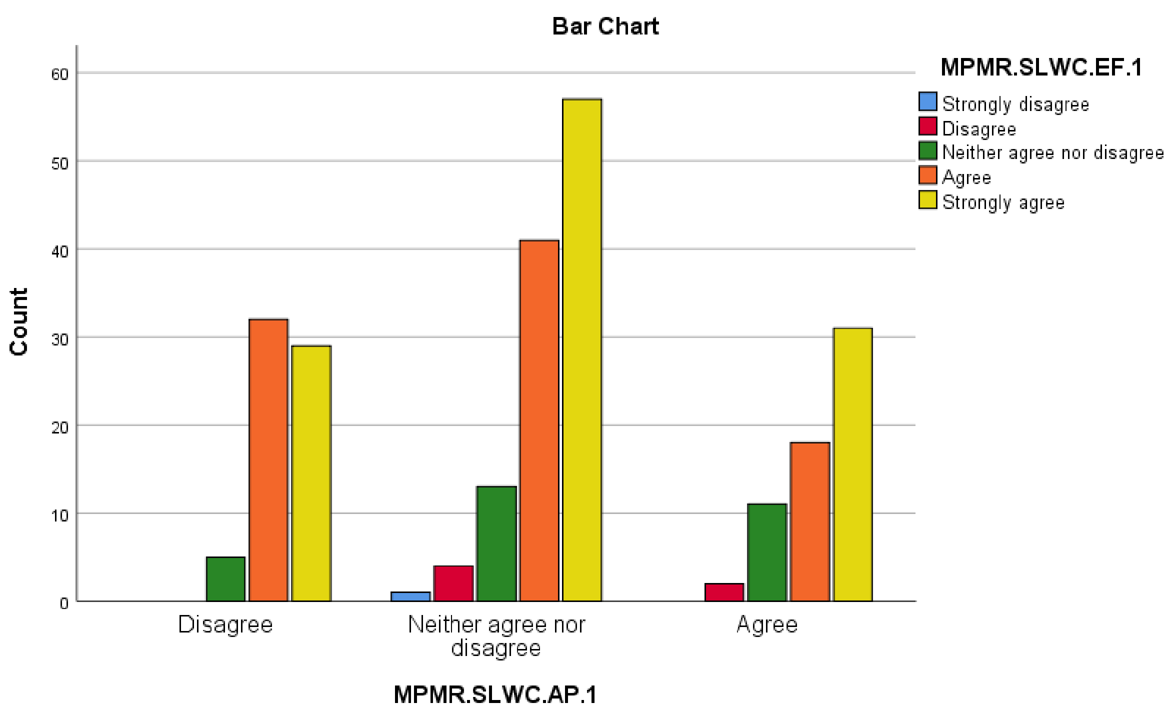
Count

		MPMR.SLWC.EF.1					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.SLWC.AP.1	Disagree	0	0	5	32	29	66
	Neither agree nor disagree	1	4	13	41	57	116
	Agree	0	2	11	18	31	62
Total		1	6	29	91	117	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.981[a]	8	.266
Likelihood Ratio	11.748	8	.163
Linear-by-Linear Association	.559	1	.455
N of Valid Cases	244		
Fisher's Exact Test			0.224

a. 6 cells (40.0%) have expected count less than 5. The minimum expected count is .25.



MPMR.SLWC.AP.2 * MPMR.SLWC.EF.2 Crosstabulation

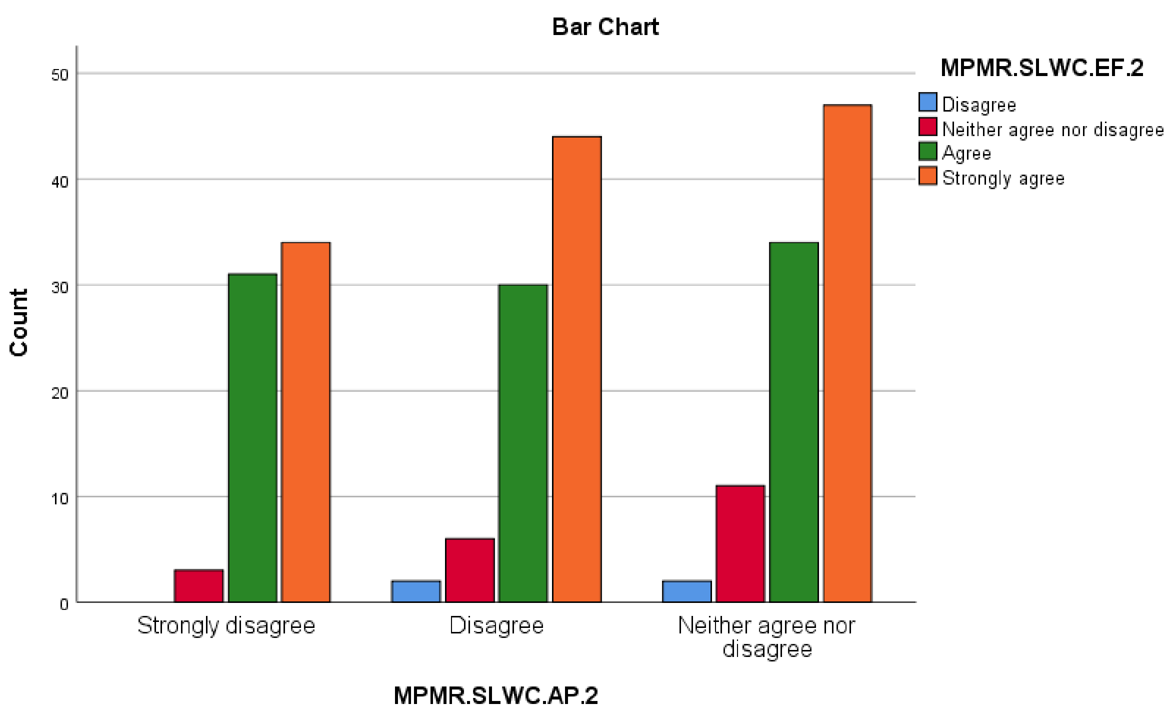
Count

		MPMR.SLWC.EF.2				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.SLWC.AP.2	Strongly disagree	0	3	31	34	68
	Disagree	2	6	30	44	82
	Neither agree nor disagree	2	11	34	47	94
Total		4	20	95	125	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.463[a]	6	.486
Likelihood Ratio	6.567	6	.363
Linear-by-Linear Association	1.086	1	.297
N of Valid Cases	244		
Fisher's Exact Test			0.517

a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 1.11.



MPMR.SLWC.AP.3 * MPMR.SLWC.EF.3 Crosstabulation

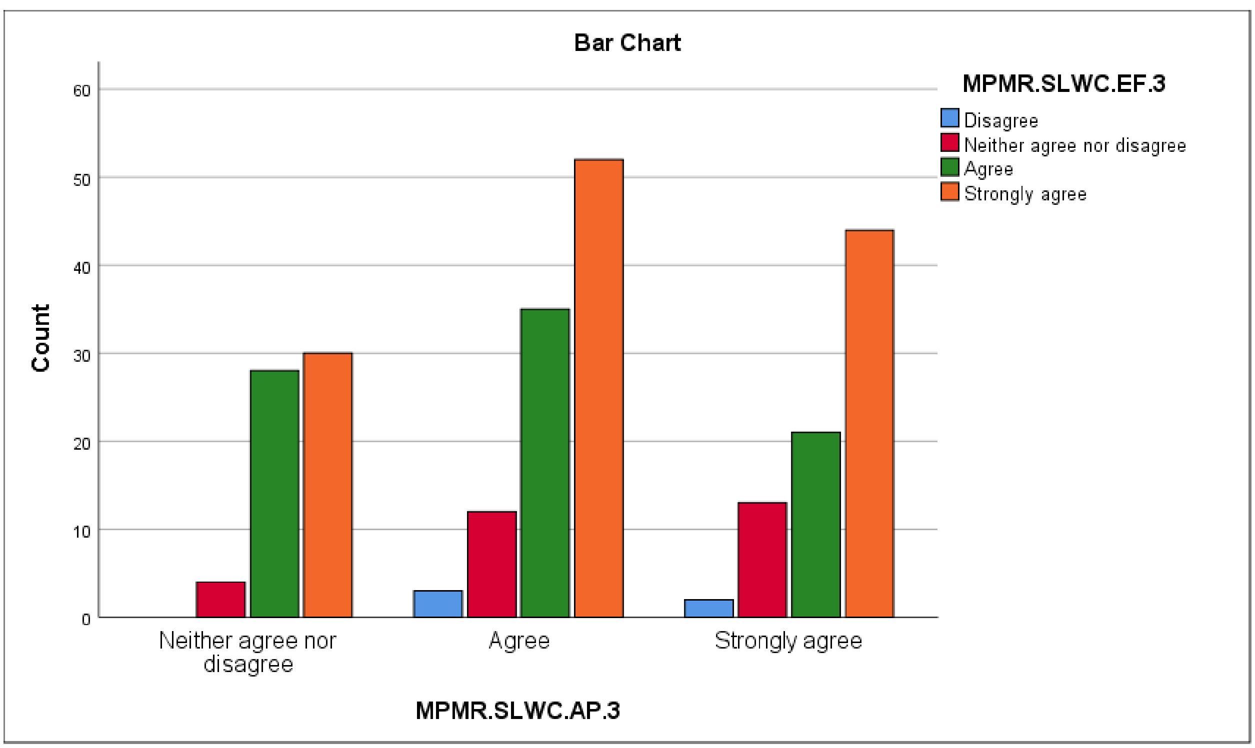
Count

		MPMR.SLWC.EF.3				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.SLWC.AP.3	Neither agree nor disagree	0	4	28	30	62
	Agree	3	12	35	52	102
	Strongly agree	2	13	21	44	80
Total		5	29	84	126	244

Chi-Square Tests

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.509[a]	6	.203
Likelihood Ratio	9.856	6	.131
Linear-by-Linear Association	.352	1	.553
N of Valid Cases	244		
Fisher's Exact Test			0.197

a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 1.27.



MPMR.SLWC.AP.4 * MPMR.SLWC.EF.4 Crosstabulation

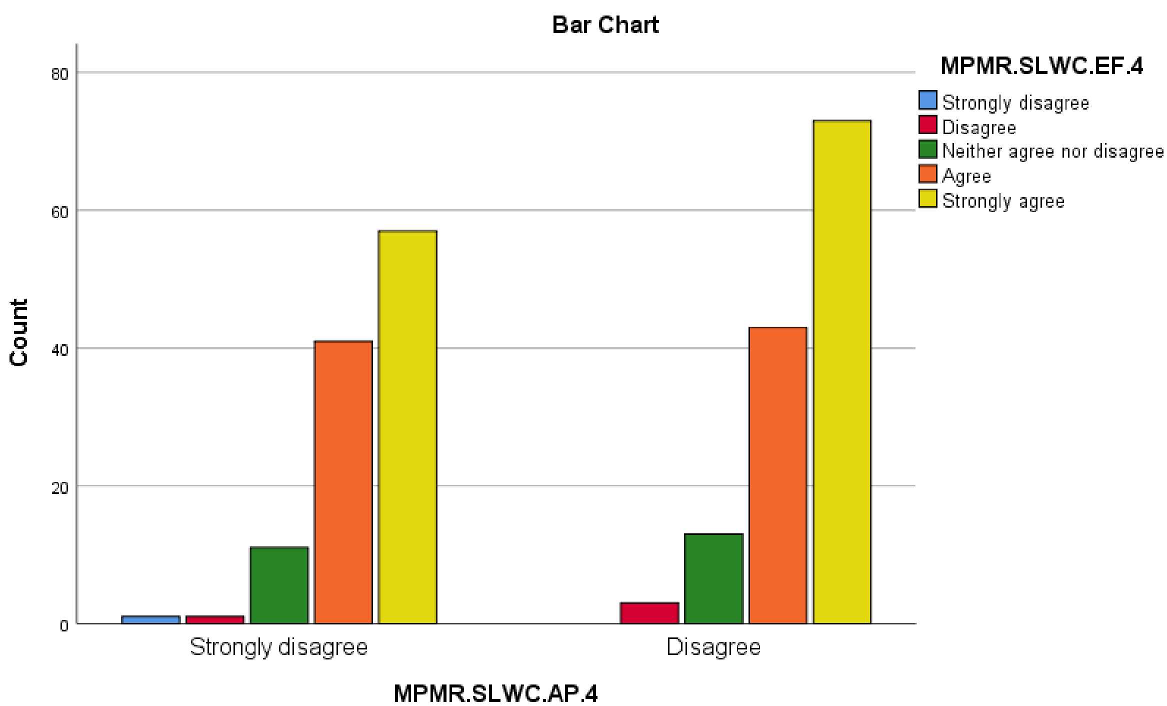
Count

		MPMR.SLWC.EF.4					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.SLWC.AP.4	Strongly disagree	1	1	11	41	57	111
	Disagree	0	3	13	43	73	132
Total		1	4	24	84	130	243

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.387[a]	4	.665
Likelihood Ratio	2.804	4	.591
Linear-by-Linear Association	.162	1	.687
N of Valid Cases	243		
Fisher's Exact Test			0.698

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .46.



MPMR.LWPM.AP.1 * MPMR.LWPM.EF.1 Crosstabulation

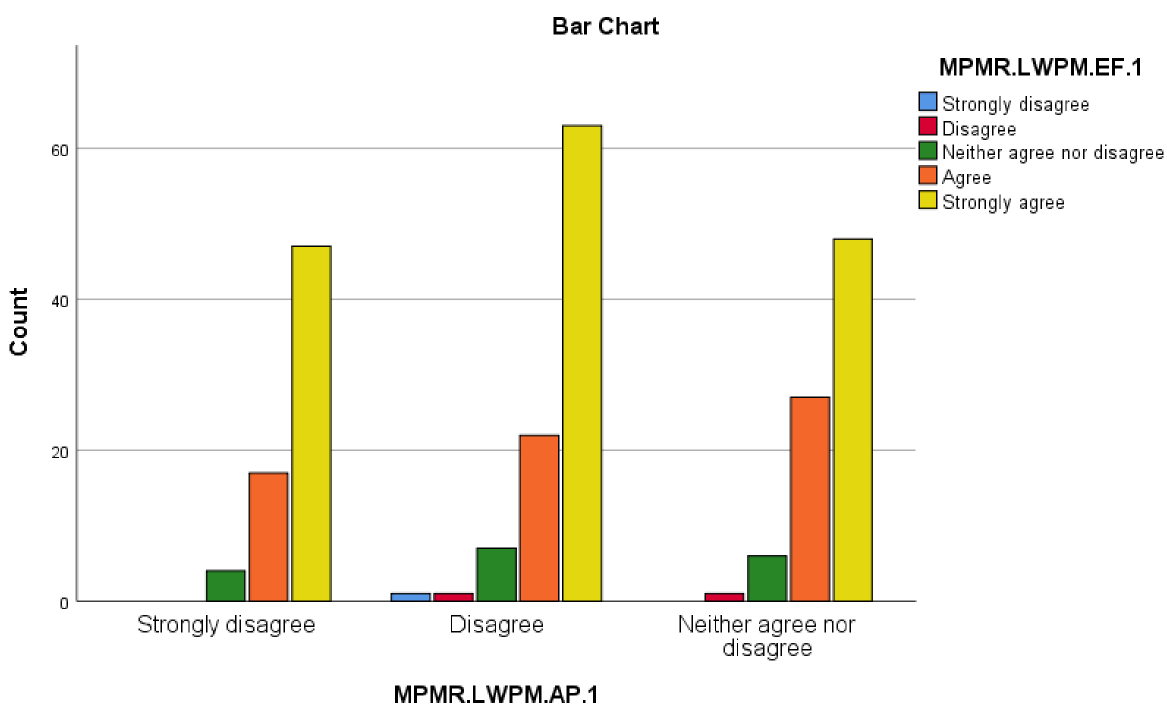
Count

		MPMR.LWPM.EF.1					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.LWPM.AP.1	Strongly disagree	0	0	4	17	47	68
	Disagree	1	1	7	22	63	94
	Neither agree nor disagree	0	1	6	27	48	82
Total		1	2	17	66	158	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.920[a]	8	.766
Likelihood Ratio	5.736	8	.677
Linear-by-Linear Association	1.571	1	.210
N of Valid Cases	244		
Fisher's Exact Test			0.819

a. 7 cells (46.7%) have expected count less than 5. The minimum expected count is .28.



MPMR.LWPM.AP.2 * MPMR.LWPM.EF.2 Crosstabulation

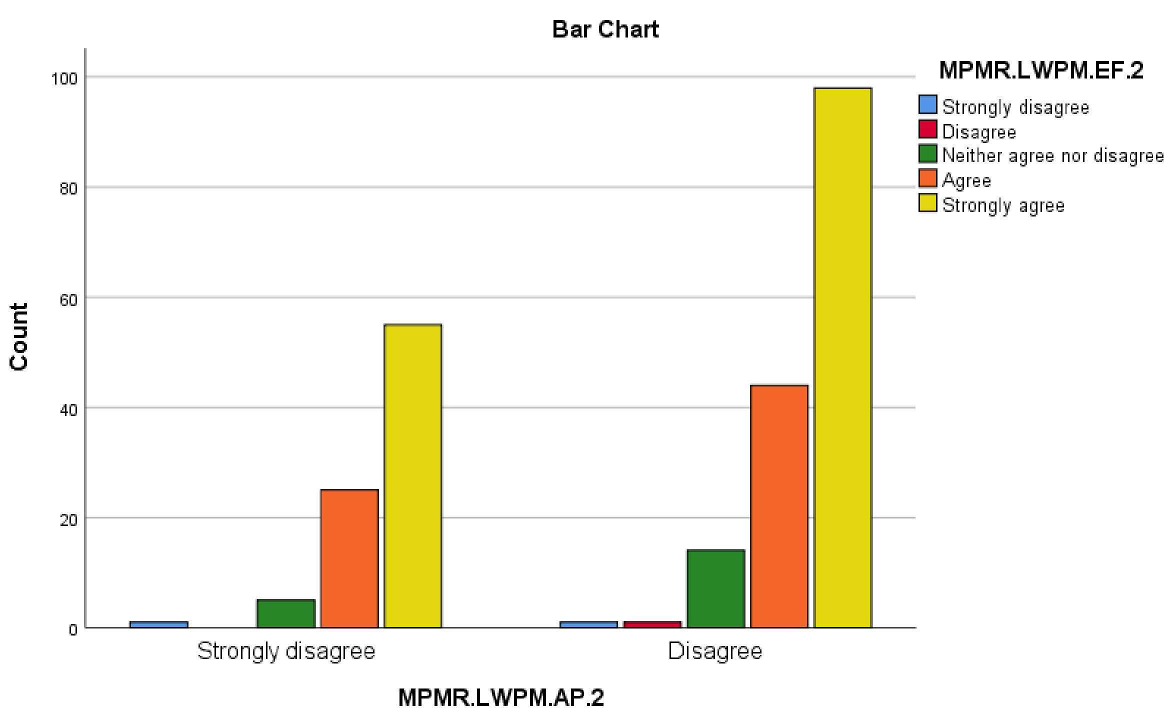
Count

		MPMR.LWPM.EF.2					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.LWPM.AP.2	Strongly disagree	1	0	5	25	55	86
	Disagree	1	1	14	44	98	158
Total		2	1	19	69	153	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.461[a]	4	.833
Likelihood Ratio	1.809	4	.771
Linear-by-Linear Association	.227	1	.634
N of Valid Cases	244		
Fisher's Exact Test			0.875

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .35.



MPMR.LWPM.AP.3 * MPMR.LWPM.EF.3 Crosstabulation

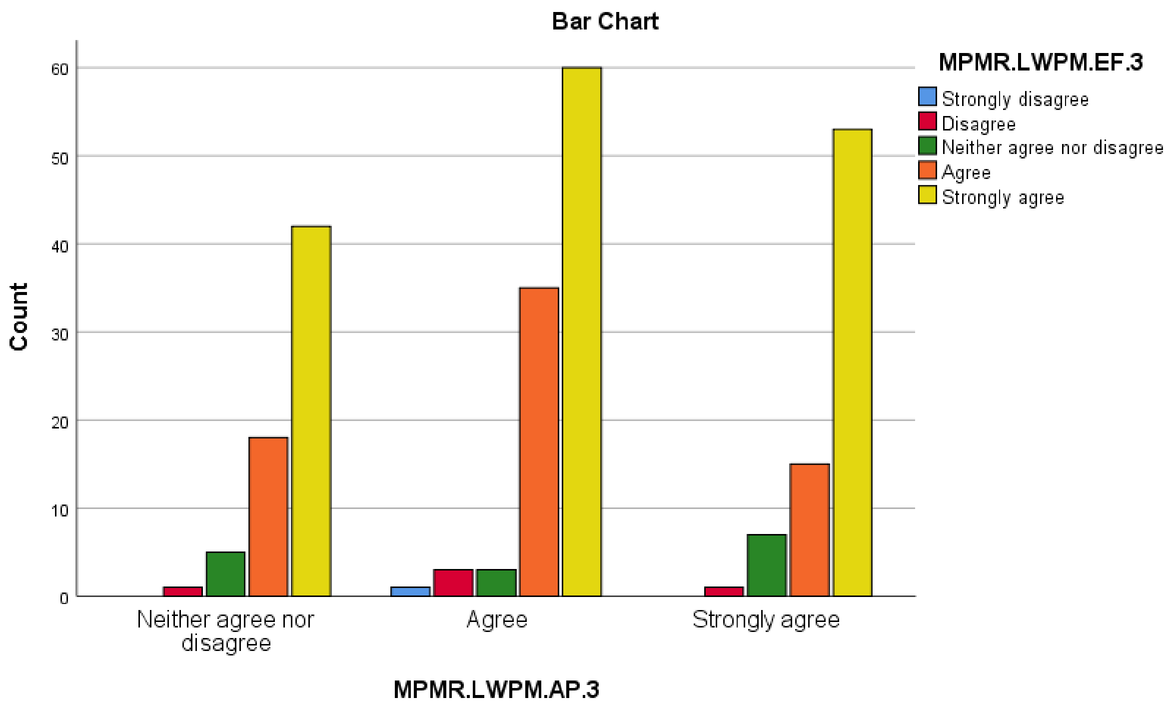
Count

		MPMR.LWPM.EF.3					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.LWPM.AP.3	Neither agree nor disagree	0	1	5	18	42	66
	Agree	1	3	3	35	60	102
	Strongly agree	0	1	7	15	53	76
Total		1	5	15	68	155	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.313[a]	8	.317
Likelihood Ratio	9.993	8	.265
Linear-by-Linear Association	.186	1	.666
N of Valid Cases	244		
Fisher's Exact Test			0.238

a. 8 cells (53.3%) have expected count less than 5. The minimum expected count is .27.



MPMR.LWPM.AP.4 * MPMR.LWPM.EF.4 Crosstabulation

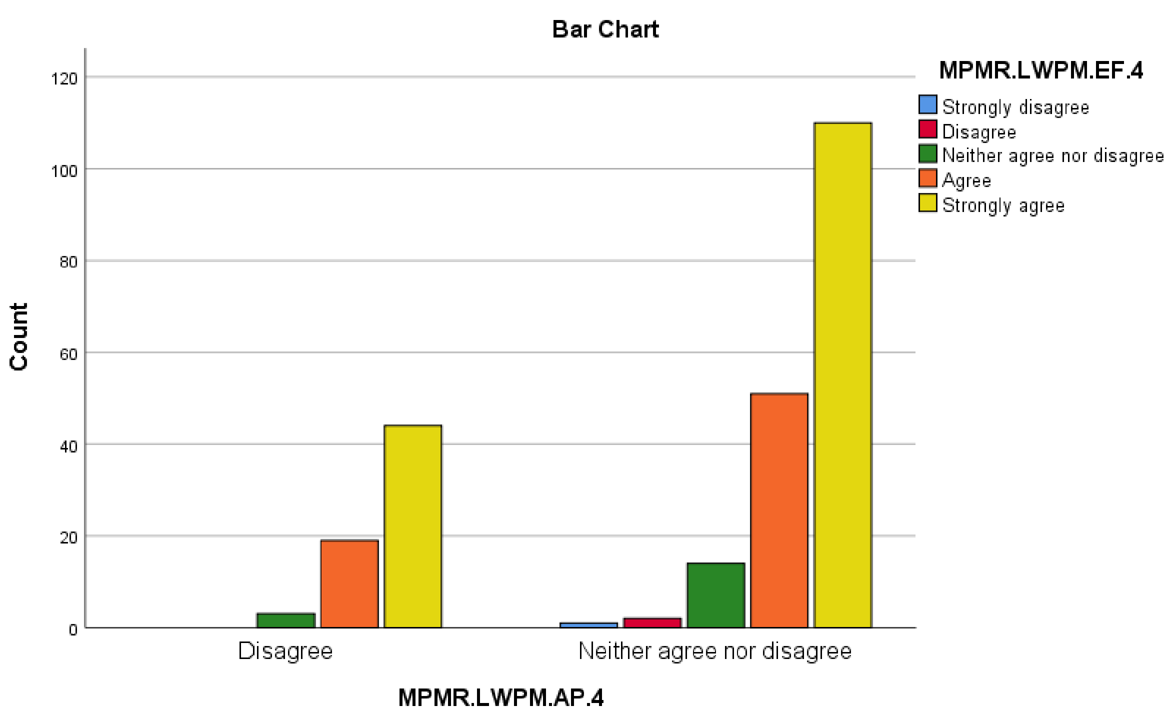
Count

		MPMR.LWPM.EF.4					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.LWPM.AP.4	Disagree	0	0	3	19	44	66
	Neither agree nor disagree	1	2	14	51	110	178
Total		1	2	17	70	154	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.055[a]	4	.726
Likelihood Ratio	2.903	4	.574
Linear-by-Linear Association	1.448	1	.229
N of Valid Cases	244		
Fisher's Exact Test			0.842

a. 5 cells (50.0%) have expected count less than 5. The minimum expected count is .27.



MPMR.LWPM.AP.5 * MPMR.LWPM.EF.5 Crosstabulation

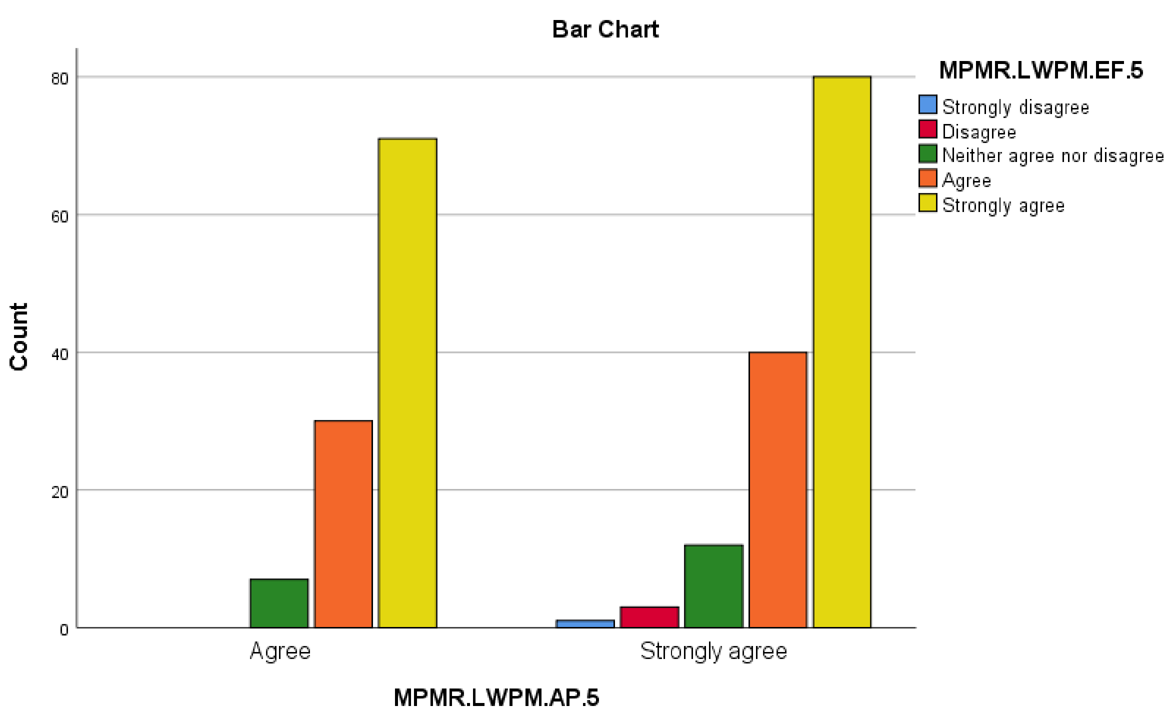
Count

		MPMR.LWPM.EF.5					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.LWPM.AP.5	Agree	0	0	7	30	71	108
	Strongly agree	1	3	12	40	80	136
Total		1	3	19	70	151	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.122[a]	4	.390
Likelihood Ratio	5.627	4	.229
Linear-by-Linear Association	2.858	1	.091
N of Valid Cases	244		
Fisher's Exact Test			0.461

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .44.



MPMR.EMDM.AP.1 * MPMR.EMDM.EF.1 Crosstabulation

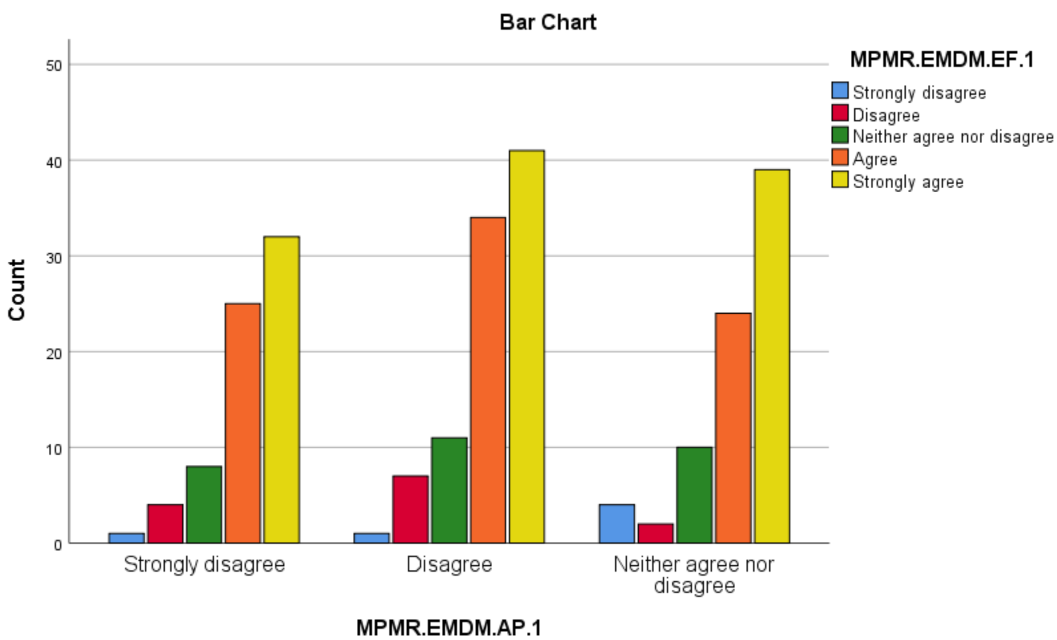
Count

		MPMR.EMDM.EF.1					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.EMDM.AP.1	Strongly disagree	1	4	8	25	32	70
	Disagree	1	7	11	34	41	94
	Neither agree nor disagree	4	2	10	24	39	79
Total		6	13	29	83	112	243

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.031[a]	8	.644
Likelihood Ratio	5.995	8	.648
Linear-by-Linear Association	.014	1	.905
N of Valid Cases	243		
Fisher's Exact Test			0.709

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is 1.73.



MPMR.EMDM.AP.2 * MPMR.EMDM.EF.2 Crosstabulation

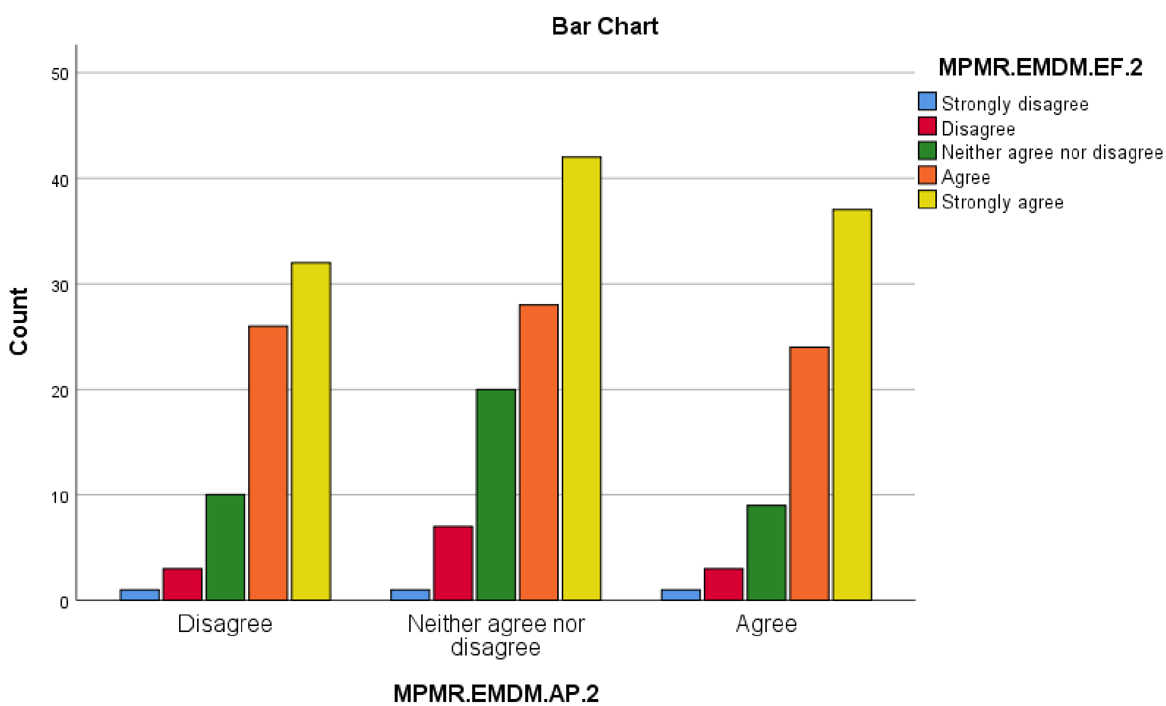
Count

		MPMR.EMDM.EF.2					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.EMDM.AP.2	Disagree	1	3	10	26	32	72
	Neither agree nor disagree	1	7	20	28	42	98
	Agree	1	3	9	24	37	74
Total		3	13	39	78	111	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.389[a]	8	.820
Likelihood Ratio	4.330	8	.826
Linear-by-Linear Association	.242	1	.623
N of Valid Cases	244		
Fisher's Exact Test			0.819

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .89.



MPMR.EMDM.AP.3 * MPMR.EMDM.EF.3 Crosstabulation

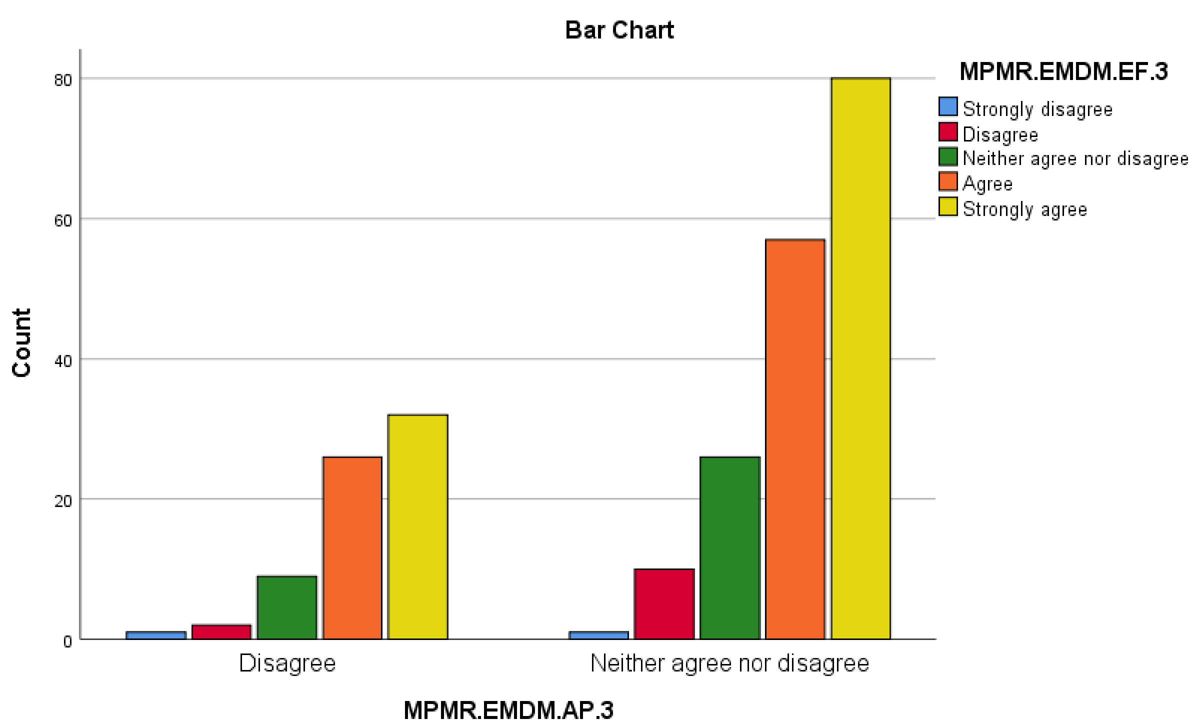
Count

		MPMR.EMDM.EF.3					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.EMDM.AP.3	Disagree	1	2	9	26	32	70
	Neither agree nor disagree	1	10	26	57	80	174
Total		2	12	35	83	112	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.726[a]	4	.786
Likelihood Ratio	1.777	4	.777
Linear-by-Linear Association	.151	1	.697
N of Valid Cases	244		
Fisher's Exact Test			0.754

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is .57.



MPMR.EMDM.AP.4 * MPMR.EMDM.EF.4 Crosstabulation

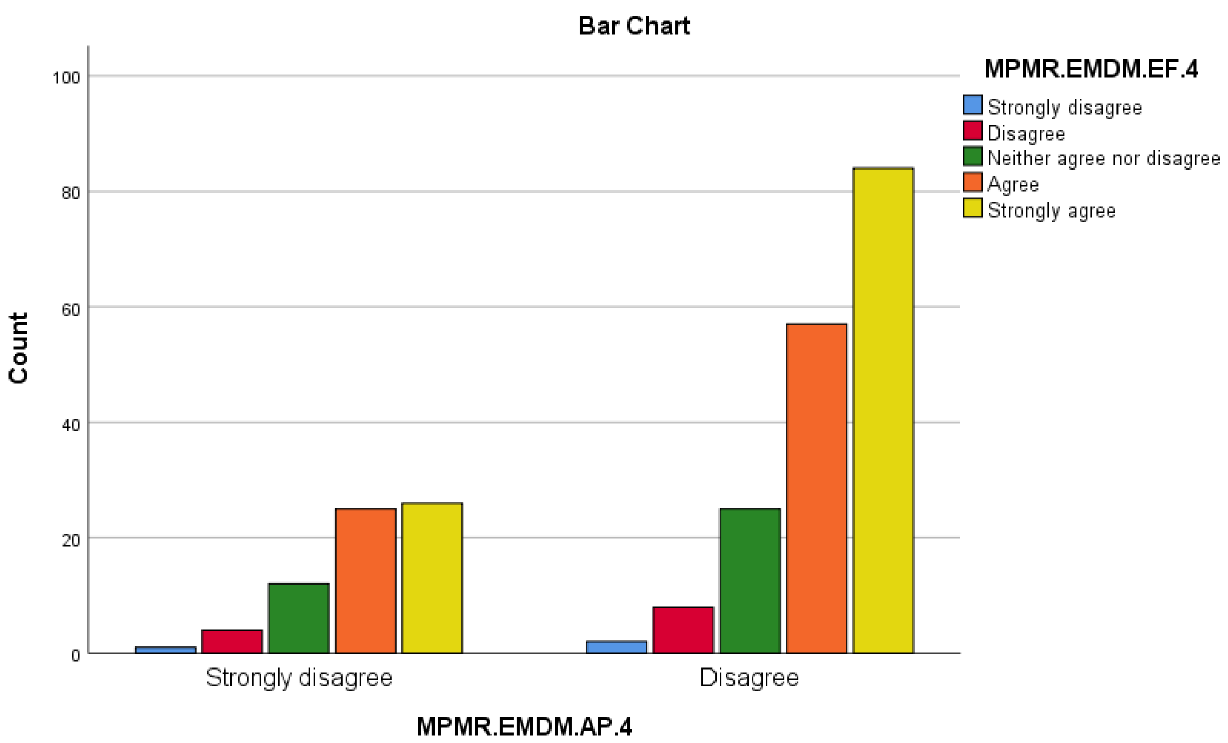
Count

		MPMR.EMDM.EF.4					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.EMDM.AP.4	Strongly disagree	1	4	12	25	26	68
	Disagree	2	8	25	57	84	176
Total		3	12	37	82	110	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.866[a]	4	.760
Likelihood Ratio	1.875	4	.759
Linear-by-Linear Association	1.526	1	.217
N of Valid Cases	244		
Fisher's Exact Test			0.677

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is .84.



MPMR.WEBOQ.AP.1 * MPMR.WEBOQ.EF.1 Crosstabulation

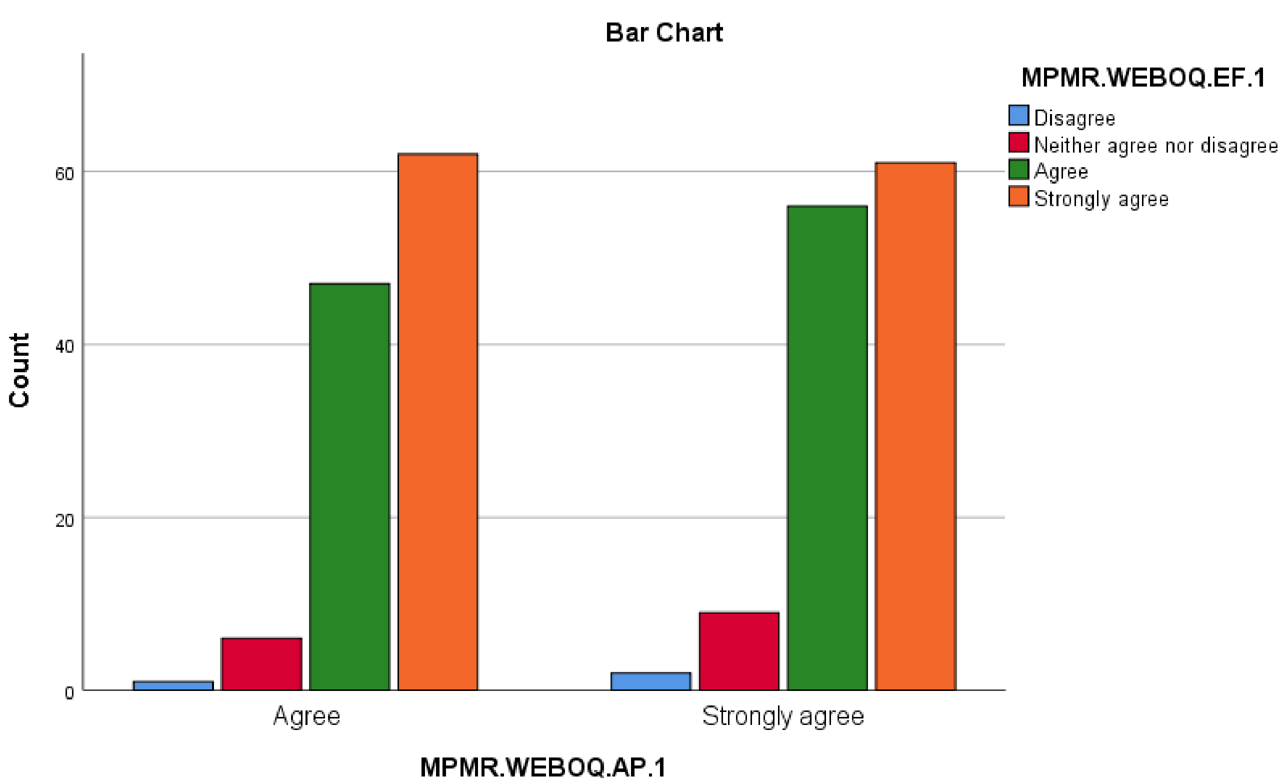
Count

		MPMR.WEBOQ.EF.1				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.WEBOQ.AP.1	Agree	1	6	47	62	116
	Strongly agree	2	9	56	61	128
Total		3	15	103	123	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.140[a]	3	.767
Likelihood Ratio	1.149	3	.765
Linear-by-Linear Association	1.129	1	.288
N of Valid Cases	244		
Fisher's Exact Test			0.767

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 1.43.



MPMR.WEBOQ.AP.2 * MPMR.WEBOQ.EF.2 Crosstabulation

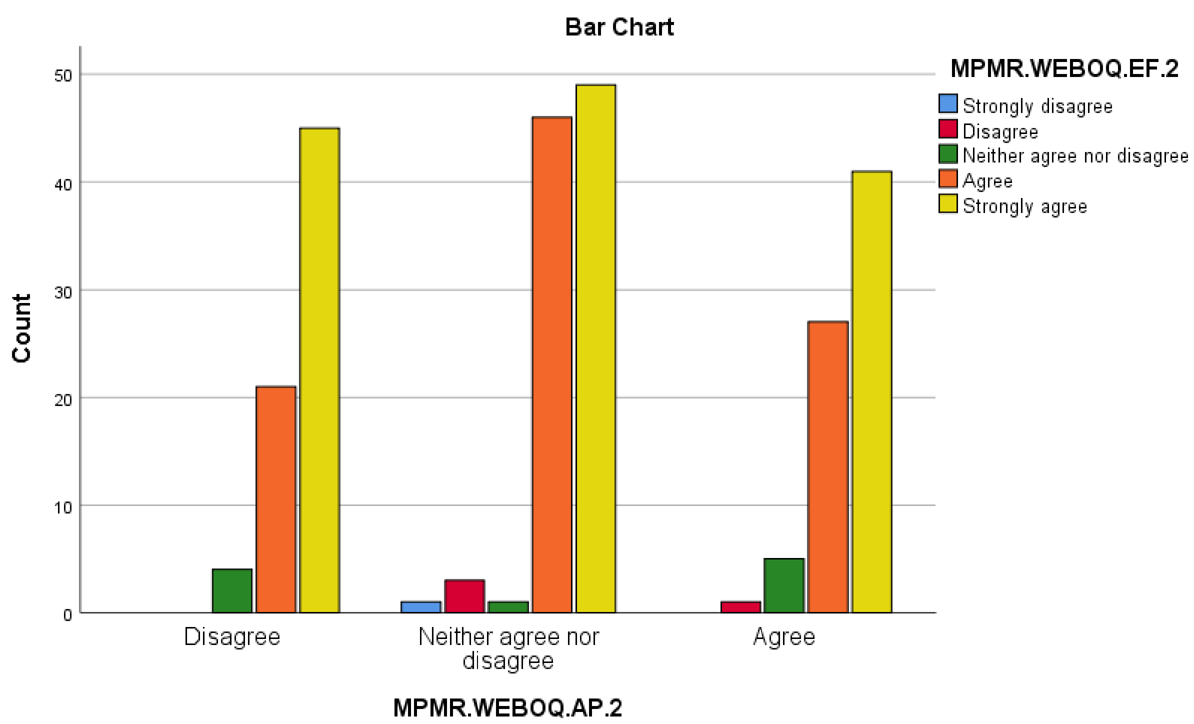
Count

		MPMR.WEBOQ.EF.2					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.WEBOQ.AP.2	Disagree	0	0	4	21	45	70
	Neither agree nor disagree	1	3	1	46	49	100
	Agree	0	1	5	27	41	74
Total		1	4	10	94	135	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	12.408[a]	8	.134
Likelihood Ratio	14.455	8	.071
Linear-by-Linear Association	1.138	1	.286
N of Valid Cases	244		
Fisher's Exact Test			0.074

a. 9 cells (60.0%) have expected count less than 5. The minimum expected count is .29.



MPMR.WEBOQ.AP.3 * MPMR.WEBOQ.EF.3 Crosstabulation

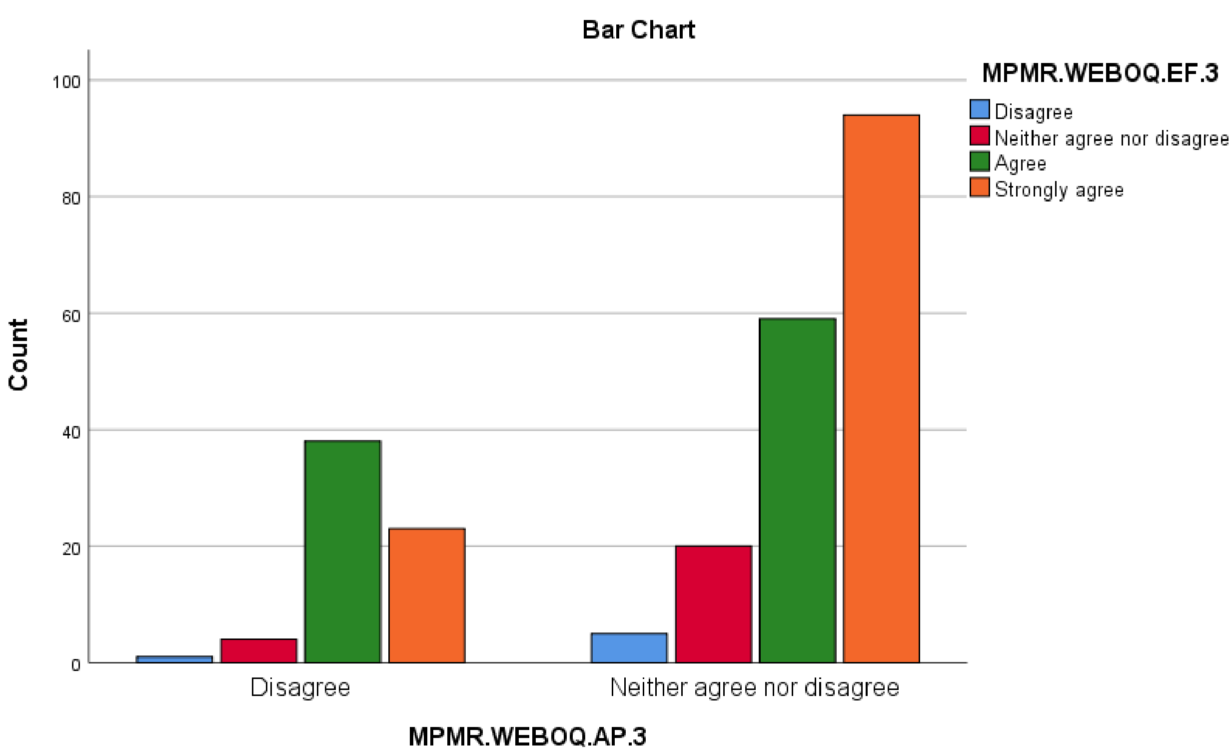
Count

		MPMR.WEBOQ.EF.3				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
MPMR.WEBOQ.AP.3	Disagree	1	4	38	23	66
	Neither agree nor disagree	5	20	59	94	178
Total		6	24	97	117	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	12.106[a]	3	.007
Likelihood Ratio	11.971	3	.007
Linear-by-Linear Association	.881	1	.348
N of Valid Cases	244		
Fisher's Exact Test			0.007

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 1.62.



GBPR.AP.1 * GBPR.EF.1 Crosstabulation

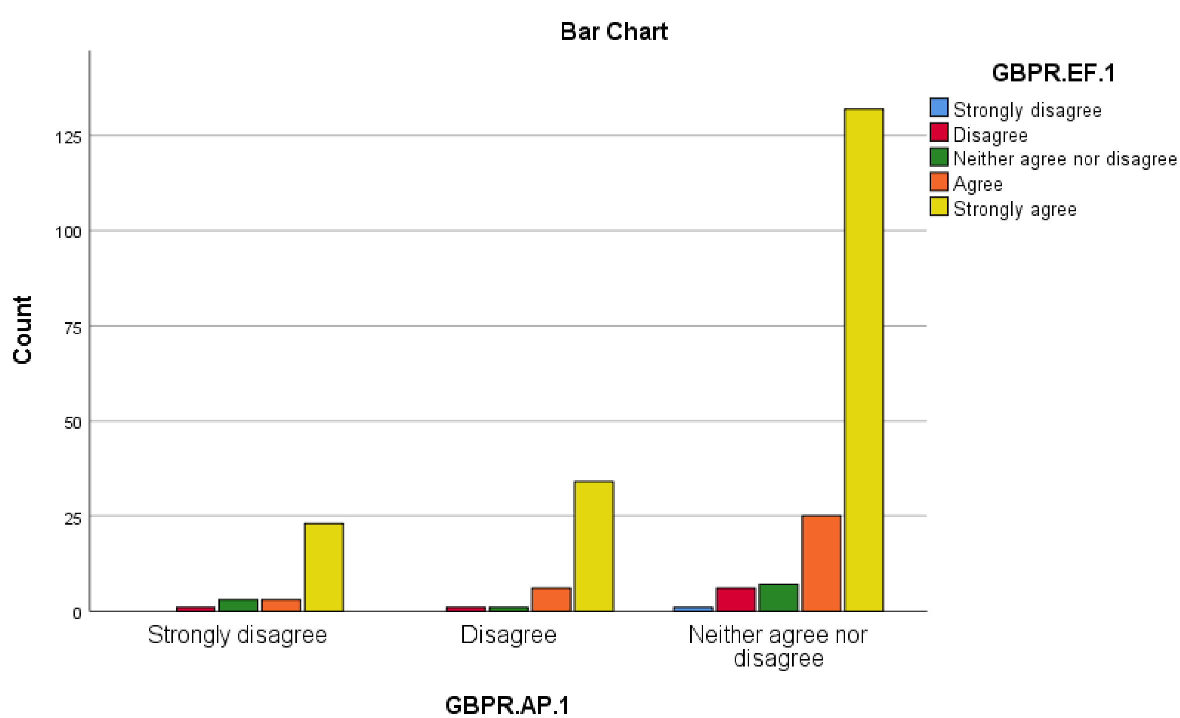
Count

		GBPR.EF.1					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
GBPR.AP.1	Strongly disagree	0	1	3	3	23	30
	Disagree	0	1	1	6	34	42
	Neither agree nor disagree	1	6	7	25	132	171
Total		1	8	11	34	189	243

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.494[a]	8	.900
Likelihood Ratio	3.402	8	.907
Linear-by-Linear Association	.001	1	.975
N of Valid Cases	243		
Fisher's Exact Test			0.919

a. 8 cells (53.3%) have expected count less than 5. The minimum expected count is .12.



GBPR.AP.2 * GBPR.EF.2 Crosstabulation

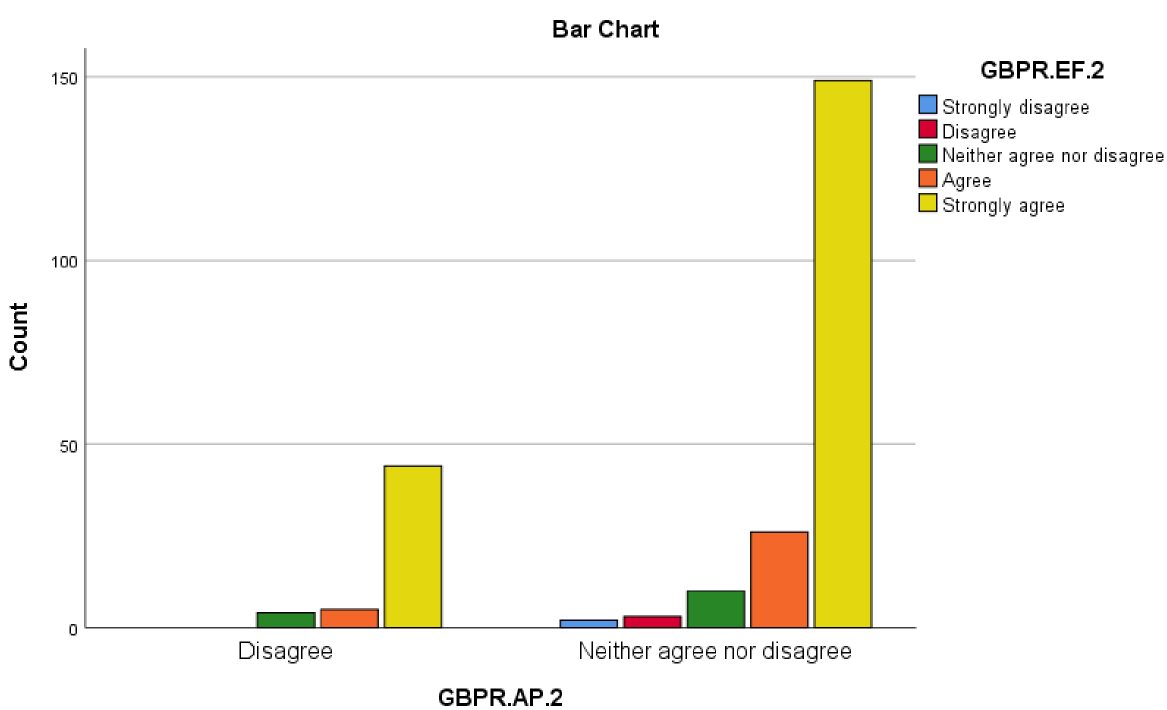
Count

		GBPR.EF.2					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
GBPR.AP.2	Disagree	0	0	4	5	44	53
	Neither agree nor disagree	2	3	10	26	149	190
Total		2	3	14	31	193	243

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.467[a]	4	.651
Likelihood Ratio	3.551	4	.470
Linear-by-Linear Association	.611	1	.434
N of Valid Cases	243		
Fisher's Exact Test			0.432

a. 5 cells (50.0%) have expected count less than 5. The minimum expected count is .44.



GBPR.AP.3 * GBPR.EF.3 Crosstabulation

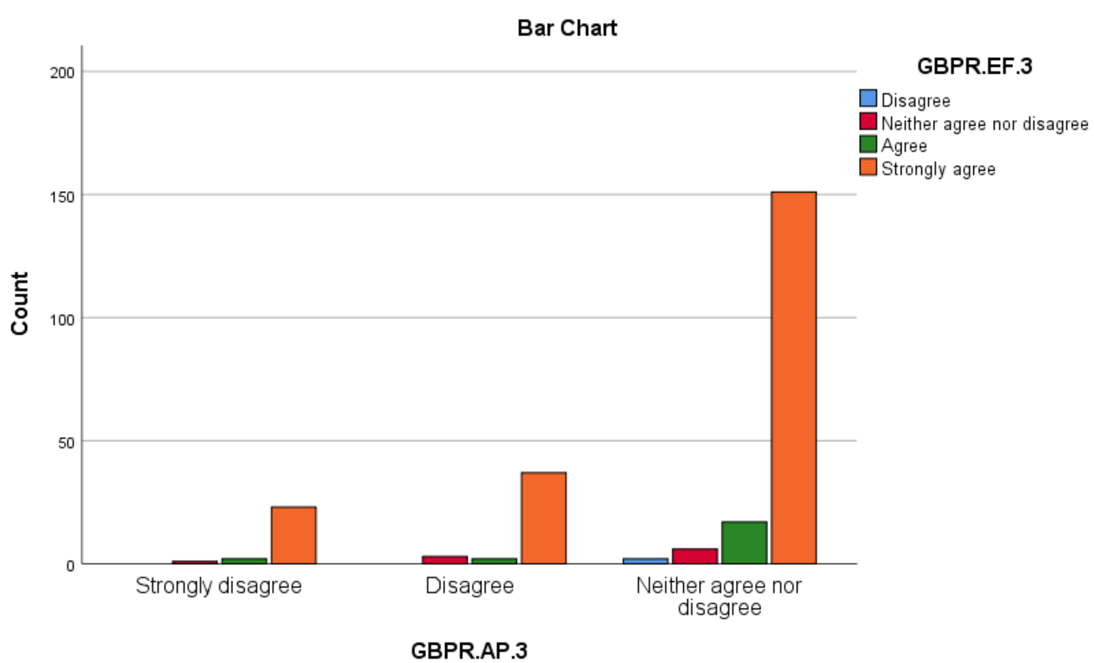
Count

		GBPR.EF.3				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
GBPR.AP.3	Strongly disagree	0	1	2	23	26
	Disagree	0	3	2	37	42
	Neither agree nor disagree	2	6	17	151	176
Total		2	10	21	211	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.938[a]	6	.817
Likelihood Ratio	3.443	6	.752
Linear-by-Linear Association	.140	1	.708
N of Valid Cases	244		
Fisher's Exact Test			0.824

a. 7 cells (58.3%) have expected count less than 5. The minimum expected count is .21.



GBPR.AP.4 * GBPR.EF.4 Crosstabulation

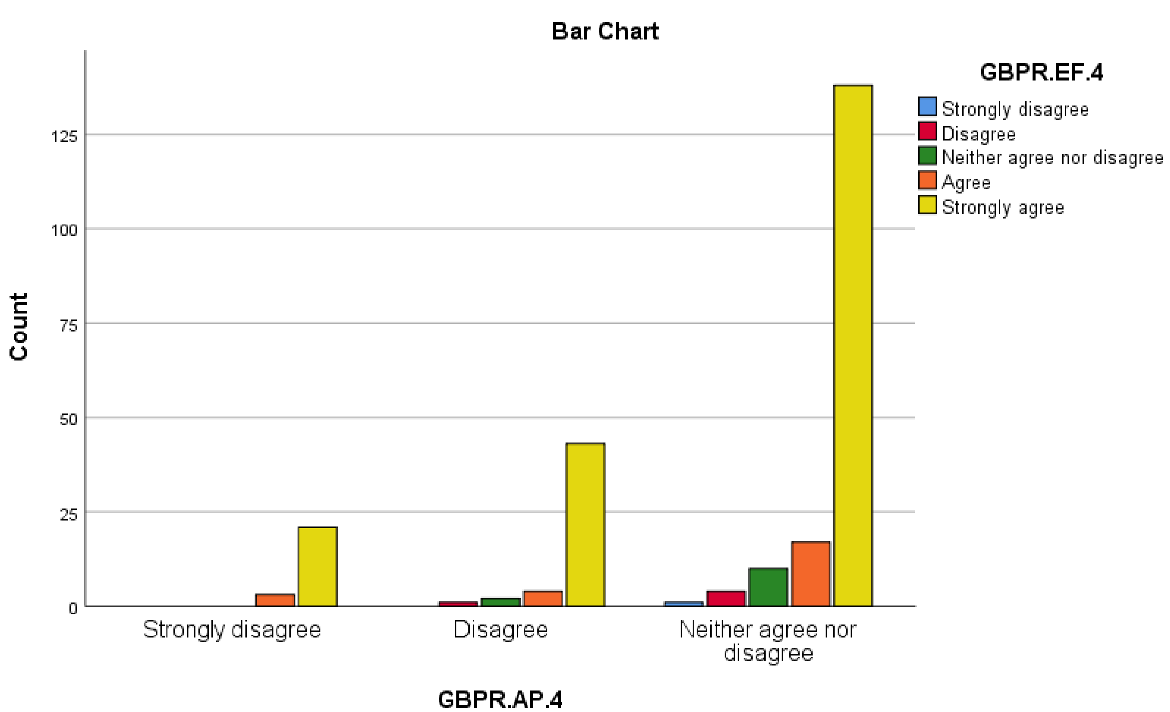
Count

		GBPR.EF.4 Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
GBPR.AP.4	Strongly disagree	0	0	0	3	21	24
	Disagree	0	1	2	4	43	50
	Neither agree nor disagree	1	4	10	17	138	170
Total		1	5	12	24	202	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.121[a]	8	.927
Likelihood Ratio	5.060	8	.751
Linear-by-Linear Association	1.953	1	.162
N of Valid Cases	244		
Fisher's Exact Test			0.967

a. 10 cells (66.7%) have expected count less than 5. The minimum expected count is .10.



GBPR.AP.5 * GBPR.EF.5 Crosstabulation

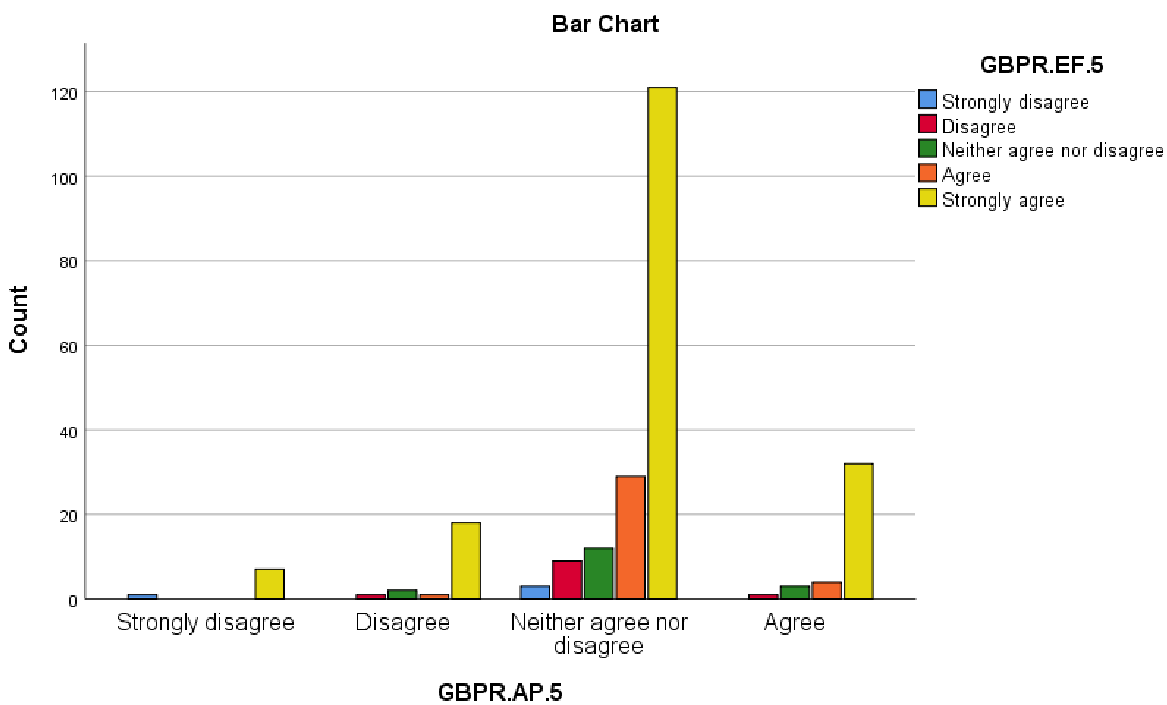
Count

		GBPR.EF.5					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
GBPR.AP.5	Strongly disagree	1	0	0	0	7	8
	Disagree	0	1	2	1	18	22
	Neither agree nor disagree	3	9	12	29	121	174
	Agree	0	1	3	4	32	40
Total		4	11	17	34	178	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.289[a]	12	.348
Likelihood Ratio	13.421	12	.339
Linear-by-Linear Association	.194	1	.660
N of Valid Cases	244		
Fisher's Exact Test			0.607

a. 12 cells (60.0%) have expected count less than 5. The minimum expected count is .13.



LG.AP.1 * LG.EF.1 Crosstabulation

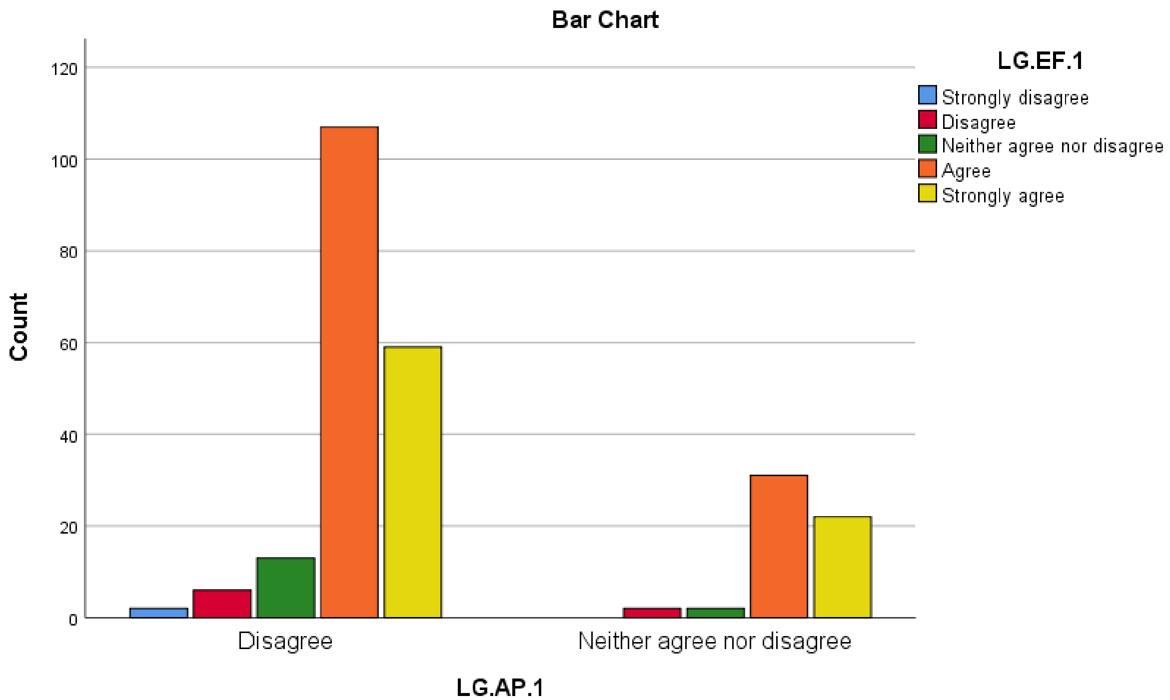
Count

		LG.EF.1					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
LG.AP.1	Disagree	2	6	13	107	59	187
	Neither agree nor disagree	0	2	2	31	22	57
Total		2	8	15	138	81	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.179[a]	4	.703
Likelihood Ratio	2.723	4	.605
Linear-by-Linear Association	1.319	1	.251
N of Valid Cases	244		
Fisher's Exact Test			0.784

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .47.



LG.AP.2 * LG.EF.2 Crosstabulation

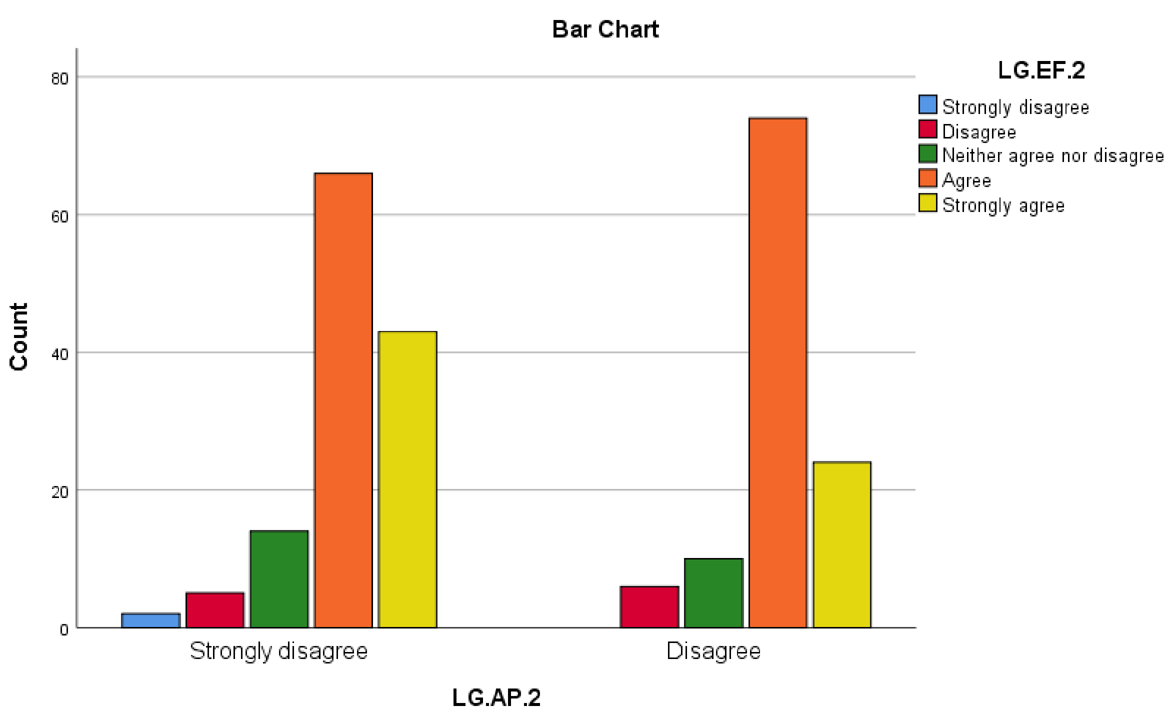
Count

		LG.EF.2					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
LG.AP.2	Strongly disagree	2	5	14	66	43	130
	Disagree	0	6	10	74	24	114
Total		2	11	24	140	67	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.586[a]	4	.108
Likelihood Ratio	8.404	4	.078
Linear-by-Linear Association	.660	1	.417
N of Valid Cases	244		
Fisher's Exact Test			0.101

a. 2 cells (20.0%) have expected count less than 5. The minimum expected count is .93.



AW.AP.1 * AW.EF.1 Crosstabulation

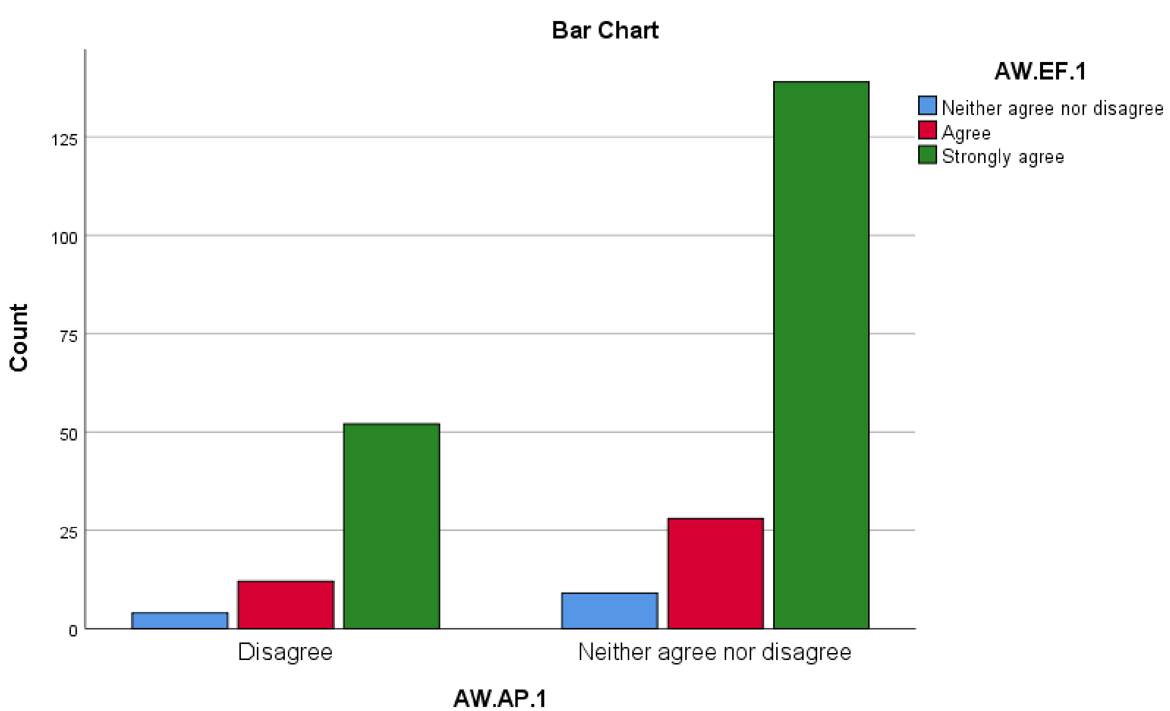
Count

		AW.EF.1			
		Neither agree nor disagree	Agree	Strongly agree	Total
AW.AP.1	Disagree	4	12	52	68
	Neither agree nor disagree	9	28	139	176
Total		13	40	191	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.184[a]	2	.912
Likelihood Ratio	.182	2	.913
Linear-by-Linear Association	.172	1	.678
N of Valid Cases	244		
Fisher's Exact Test			0.825

a. 1 cells (16.7%) have expected count less than 5. The minimum expected count is 3.62.



AW.AP.2 * AW.EF.2 Crosstabulation

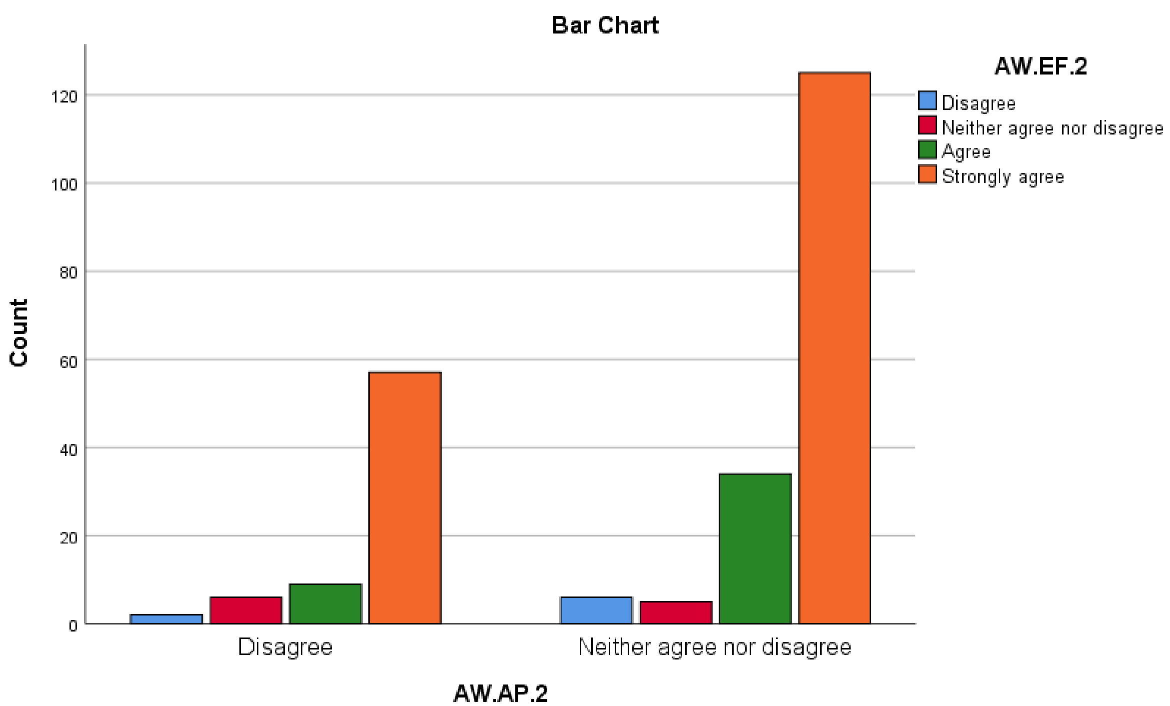
Count

		AW.EF.2				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
AW.AP.2	Disagree	2	6	9	57	74
	Neither agree nor disagree	6	5	34	125	170
Total		8	11	43	182	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	5.042[a]	3	.169
Likelihood Ratio	4.897	3	.180
Linear-by-Linear Association	.000	1	.999
N of Valid Cases	244		
Fisher's Exact Test			0.173

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 2.43.



AW.AP.3 * AW.EF.3 Crosstabulation

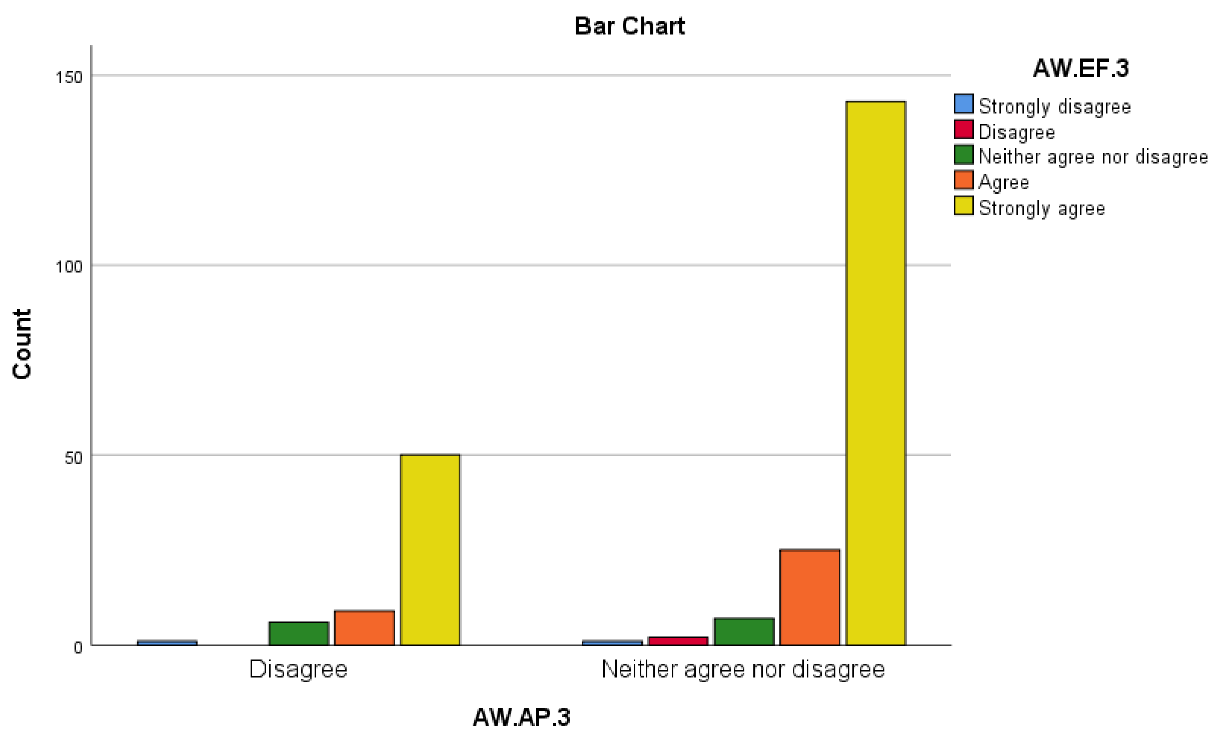
Count

		AW.EF.3					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
AW.AP.3	Disagree	1	0	6	9	50	66
	Neither agree nor disagree	1	2	7	25	143	178
Total		2	2	13	34	193	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.813[a]	4	.432
Likelihood Ratio	4.030	4	.402
Linear-by-Linear Association	1.104	1	.293
N of Valid Cases	244		
Fisher's Exact Test			0.377

a. 5 cells (50.0%) have expected count less than 5. The minimum expected count is .54.



CB.AP.1 * CB.EF.1 Crosstabulation

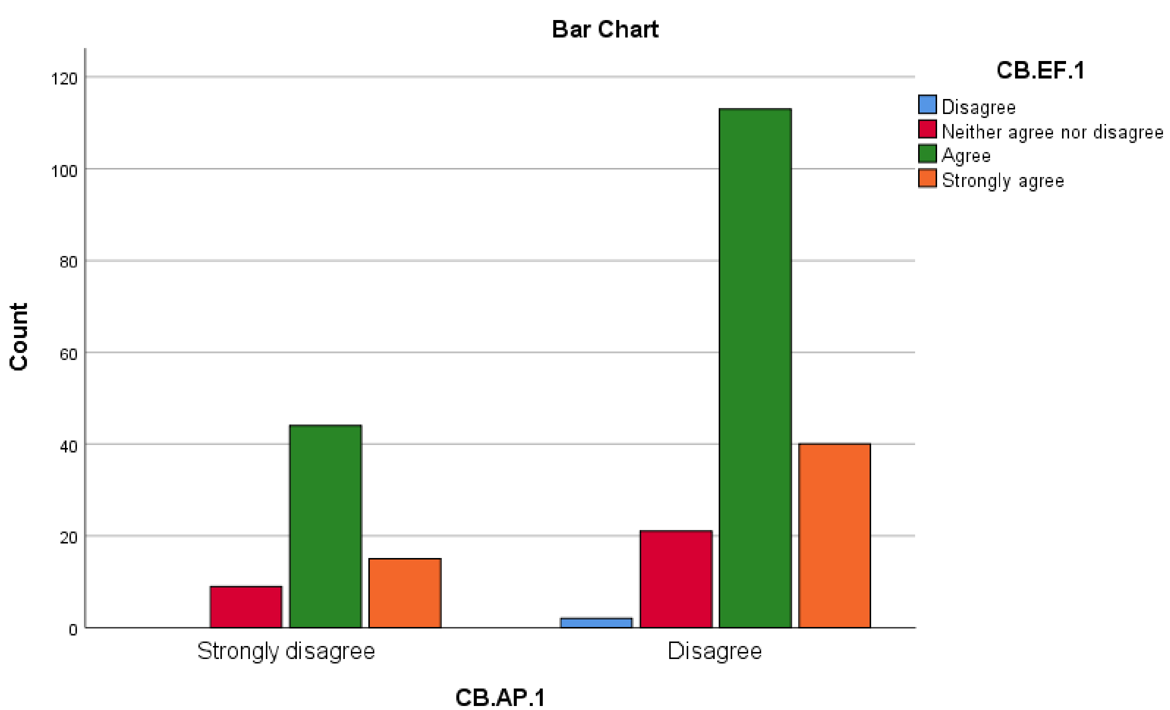
Count

		CB.EF.1				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
CB.AP.1	Strongly disagree	0	9	44	15	68
	Disagree	2	21	113	40	176
Total		2	30	157	55	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.852[a]	3	.837
Likelihood Ratio	1.385	3	.709
Linear-by-Linear Association	.001	1	.973
N of Valid Cases	244		
Fisher's Exact Test			0.976

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .56.



CB.AP.2 * CB.EF.2 Crosstabulation

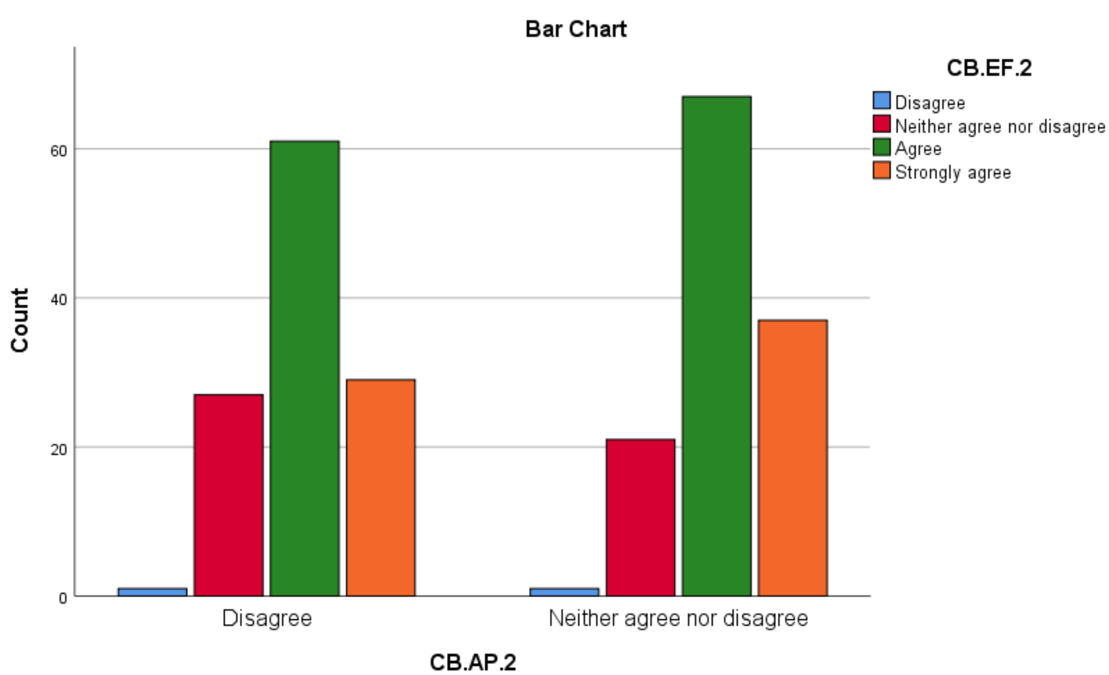
Count

		CB.EF.2				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
CB.AP.2	Disagree	1	27	61	29	118
	Neither agree nor disagree	1	21	67	37	126
Total		2	48	128	66	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.741[a]	3	.628
Likelihood Ratio	1.743	3	.627
Linear-by-Linear Association	1.508	1	.219
N of Valid Cases	244		
Fisher's Exact Test			0.637

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is .97.



CB.AP.3 * CB.EF.3 Crosstabulation

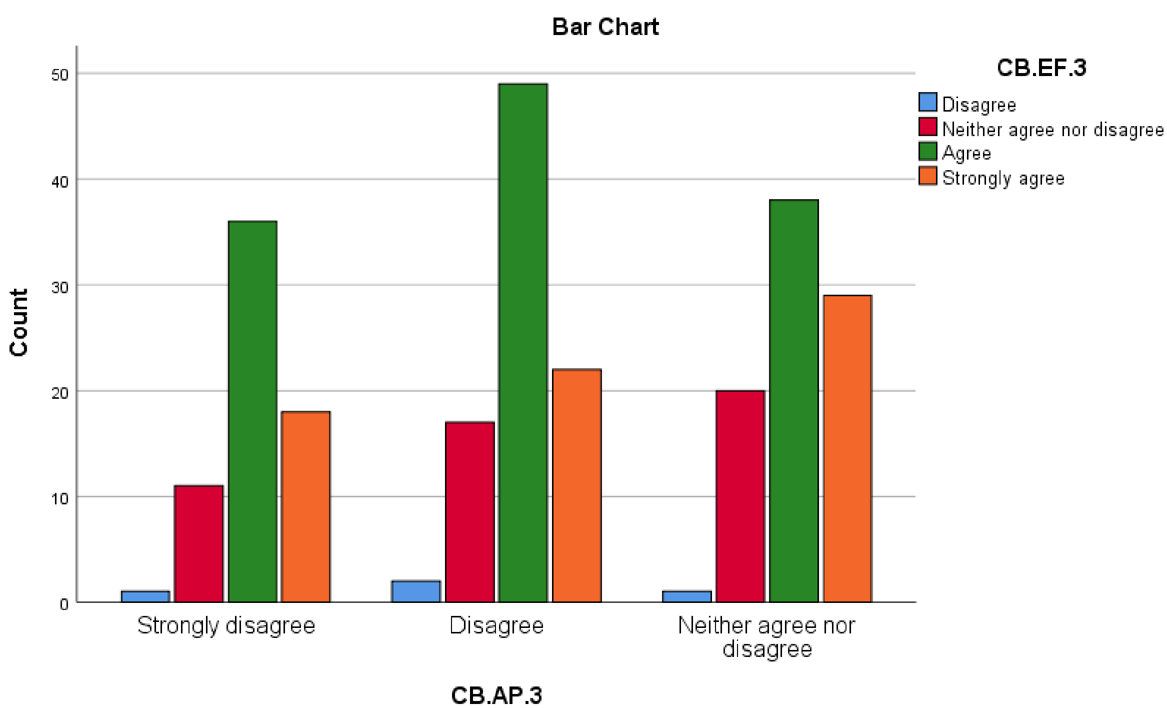
Count

		CB.EF.3				
		Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
CB.AP.3	Strongly disagree	1	11	36	18	66
	Disagree	2	17	49	22	90
	Neither agree nor disagree	1	20	38	29	88
Total		4	48	123	69	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.676[a]	6	.720
Likelihood Ratio	3.692	6	.718
Linear-by-Linear Association	.008	1	.927
N of Valid Cases	244		
Fisher's Exact Test			0.709

a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 1.08.



CB.AP.4 * CB.EF.4 Crosstabulation

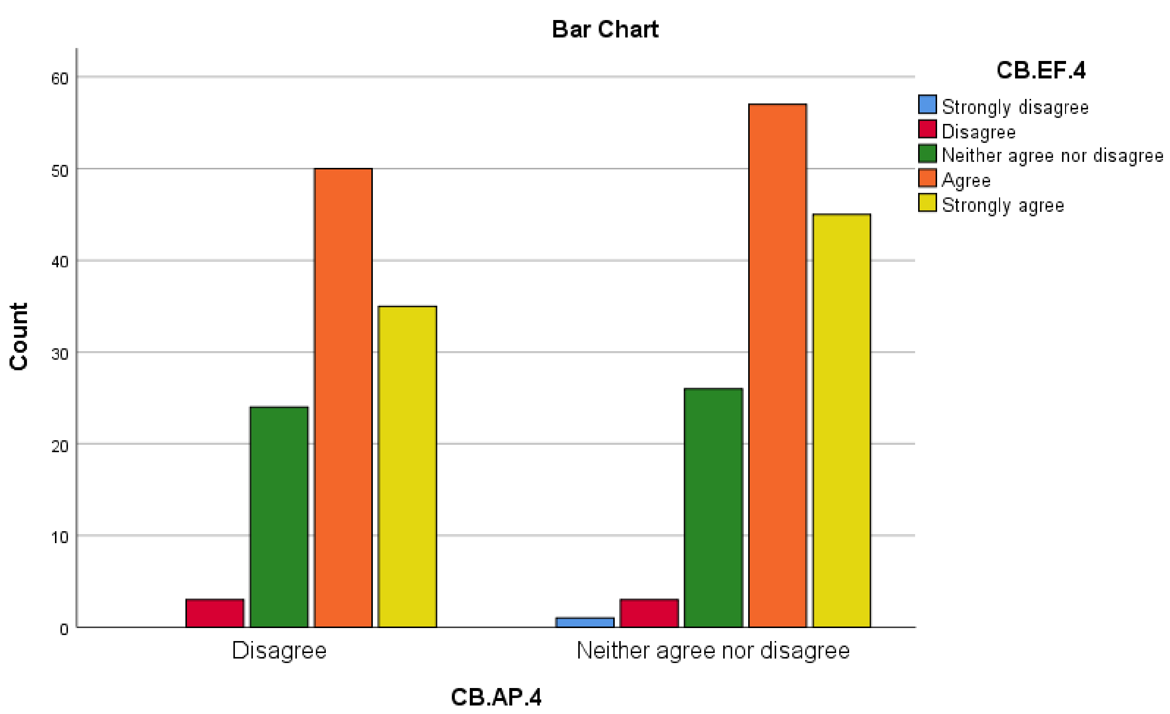
Count

		CB.EF.4					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
CB.AP.4	Disagree	0	3	24	50	35	112
	Neither agree nor disagree	1	3	26	57	45	132
Total		1	6	50	107	80	244

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1.156[a]	4	.885
Likelihood Ratio	1.537	4	.820
Linear-by-Linear Association	.088	1	.767
N of Valid Cases	244		
Fisher's Exact Test			0.981

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .46.



CB.AP.5 * CB.EF.5 Crosstabulation

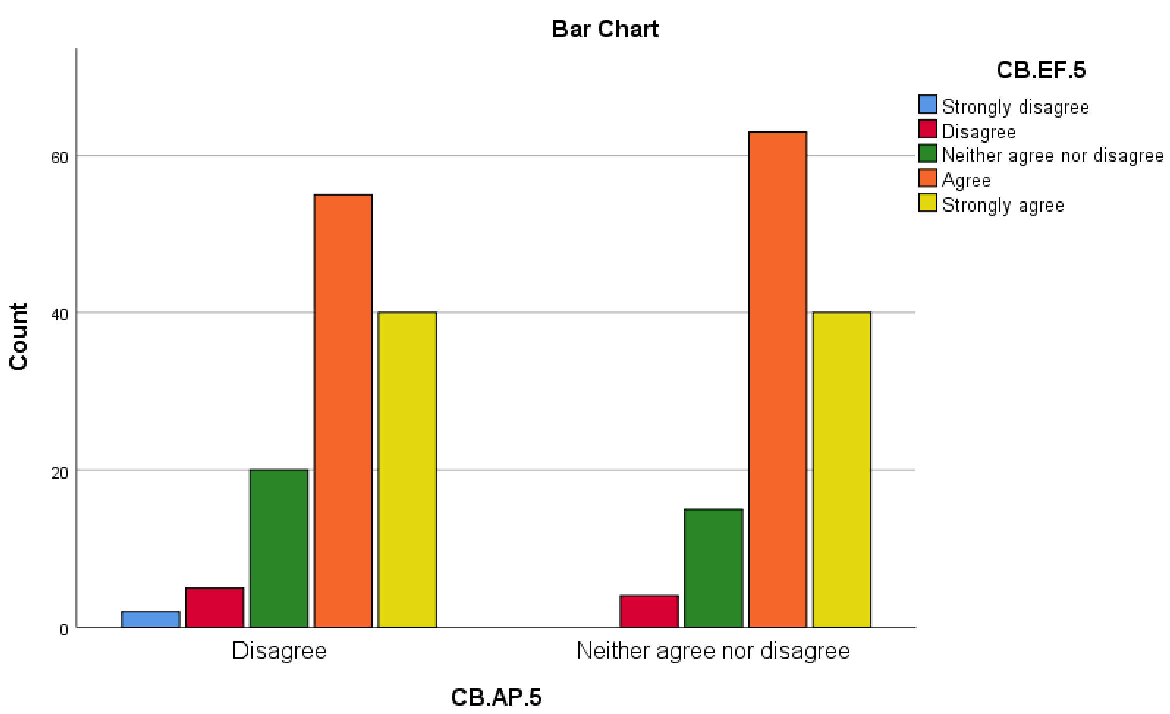
Count

		CB.EF.5					
		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total
CB.AP.5	Disagree	2	5	20	55	40	122
	Neither agree nor disagree	0	4	15	63	40	122
Total		2	9	35	118	80	244

Chi-Square Tests

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.368[a]	4	.498
Likelihood Ratio	4.143	4	.387
Linear-by-Linear Association	1.007	1	.316
N of Valid Cases	244		
Fisher's Exact Test			0.578

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is 1.00.



APPENDIX E: VALIDATION SURVEY QUESTIONNAIRE

MATERIALS PROCUREMENT CONCEPTUAL FRAMEWORK FOR MINIMISING WASTE IN THE EGYPTIAN CONSTRUCTION INDUSTRY – VALIDATION SURVEY QUESTIONNAIRE

Thank you for expressing your willingness to participate in the validation process during the pilot test. We estimate that it will take 5**-15 minutes** to complete the questions.

This questionnaire will be used by a PhD Researcher at London South Bank University for validating the research findings resulting from the PhD study. The research findings are (1) materials procurement conceptual framework (MPCF); and (2) an improvement proposal to the Egyptian green pyramid rating system (GPRS).

Your responses are important to the success of the study, and any additional comments are welcomed. Please do not hesitate to ask the researcher for assistance should you have any questions.

INSTRUCTIONS

Please make sure that you have carefully read the attachments of the MPCF and GPRS improvement proposal.

The questionnaire aims to evaluate the MPCF and GPRS improvement proposal based on different aspects as follows: (1) comprehensiveness and robustness; (2) logicalness and acceptability; (3) applicability and practicality; and (4) strength and completeness. This survey consists of five main questions. Please respond to all questions to the best of your knowledge.

Thank you in advance for your appreciated contribution.

Name of Researcher: **Ahmed Osama Elsayed Daoud**

Email: daouda@lsbu.ac.uk / ahmed.daoud@bue.edu.eg

Q1. To what extent do you agree that the MPCF and GPRS improvement proposal are robust and comprehensive?

1- Strongly disagree with poor results   2- Disagree with fair results   3- Neither agree nor disagree with good results

4- Agree with very good results   5- Strongly agree with excellent results

Q2. To what extent do you agree that the MPCF and GPRS improvement proposal are logical and can be accepted and followed in the Egyptian construction sector?

1- Strongly disagree with poor results   2- Disagree with fair results   3- Neither agree nor disagree with good results

4- Agree with very good results   5- Strongly agree with excellent results

Q3. To what extent do you agree that the MPCF and GPRS improvement proposal are practical and applicable in the Egyptian construction sector?

1- Strongly disagree with poor results   2- Disagree with fair results   3- Neither agree nor disagree with good results

4- Agree with very good results   5- Strongly agree with excellent results

Q4. To what extent do you agree that the MPCF and GPRS improvement proposal are complete and do not lack essential elements?

1- Strongly disagree with poor results   2- Disagree with fair results   3- Neither agree nor disagree with good results

4- Agree with very good results   5- Strongly agree with excellent results

Q5. If you answer Q4 by choosing “1” or “2”, please state your recommendations for improving the MPCF and GPRS improvement proposal.

End of Survey.

Thank you for your kind participation and feedback.