QATAR UNIVERSITY

COLLEGE OF ENGINEERING

CONSTRUCTION WASTE MANAGEMENT PERFORMANCE MEASUREMENT IN INFRASTRUCTURE PROJECTS BY STRUCTURAL EQUATION MODELLING SEM

BY

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ABSTRACT

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Title: Construction Waste Management Performance Measurement in Infrastructure Projects by Structural Equation Modelling SEM

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This research aimed to identify the factors that contribute to Construction Waste Management in Infrastructure Projects (CWMIIP) and their effective weight in this aspect. The objectives are summarized to identify the factors affecting construction waste management in infrastructure projects and categorize them under groups, understanding the relationships between the factors and group along with the relationships between groups and CWMIIP, and finally suggesting recommendations for reducing the construction waste. From the literature review, 26 factors were selected to be the major contributors of construction waste in infrastructure projects. These factors were used to designate an online questionnaire to collect the required data to initiate this research, where around 167 participators responded. A Structural Equation Model was developed that represented the relationships between the groups which were identified through the literature review and CWMIIP. This model was examined during model development to ensure that it meets Goodness of Fit (GOF), multivariate normality, construct validity, reliability, and hypotheses examinations. The model results have showed that all pre-defined hypotheses were supported except for the positive effect of Logistics group on CWMIIP which was dropped during achieving model acceptance criteria. Finally, the groups that are responsible of construction waste management in infrastructure projects were ranked based on their effective weight. Management was the most effective group which was followed by Execution, Others, Procurement and Design groups, respectively. Finally, recommendations are provided to industry people based on research outcomes.

DEDICATION

I hereby declare that this master thesis entitled "Construction Waste Management Performance Measurement in Infrastructure Projects by SEM" was carried out by me for the degree of Master of Science in Engineering Management in Qatar University under the guidance and supervision of Dr. Murat Gunduz and Dr. Khalid Naji.

Munther Hamaidi

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CHAPTER 1. INTRODUCTION

1.1 Background:

Construction is one of the most industries that are affecting global economy and countries development. It plays a vital role in employment, as it employs around 7% of global workforce, and in global economy growth, as it forms around 10% of global Gross Domestic Product GDP (Kraatz et al. 2014). The construction industry can be divided into three main sectors which are building, infrastructure and industrial. Each of these sectors can be divided into many other sub-sectors, for instance, infrastructure sector and be divided into highways, railways, wastewater, utilities, etc… All these construction sectors are the reason behind developing a modern human life, improving facilities of human needs, and providing smooth and luxury lifestyle.

However, due to the tremendous growth of construction worldwide, construction waste generation has been increased significantly and estimated to be around 30-40% of total solid wastes (Islam et al. 2019). Infrastructure projects form a big portion of construction industry (around 35% of construction sectors), therefore the construction wastes produced by them are important to be properly controlled. The reason behind that refers to the nature of these projects and difficulty in implementation.

Thus, the importance of this study came from the fact the construction waste generated during construction process is being increased tremendously and environment, cost and project delivery are being affected negatively due to that reason. As a result, this research will help in representing the effects of construction waste, identify the factors contributing construction waste and suggest for recommendations that will help in controlling this behavior. By doing that, construction waste and construction waste management knowledge will be spread through construction industry and will help in increasing CWM awareness. Construction Waste Management (CWM) strategy was being followed by many countries in a shape of institutions in Advanced Industrialized Countries AICs such as Australia, Germany, Denmark, Netherland, UK, and USA. The main objectives of implementing CWM are eliminating wastes where possible, minimizing wastes where feasible, and reusing materials which might be suitable for re-use. Following the strategy will result in reduction in the amount of wastes generated during Construction and Demolition C&D processes, and hence, improve countries' economy, environment, climate, and resources consumption.

1.2 Problem Statement

Construction Wastes is a crucial issue and a potential problem that most construction projects may face without giving it a serious attention or even knowing. Around 50-75% of construction and demolition wastes are being dumped at landfills which is resulting through time in a tangible issue of landfill usage (Letcher and Vallero 2019). Dumping of construction wastes at landfills has a dangerous impact on surface and ground waters, quality of air and soil, and may alert for public health issues. Aside of the environmental impact of construction wastes, it has a tangible impact on projects' cost. Although most of construction projects estimate waste to be within the range of 10-15% but in fact construction wastes are becoming way more than estimation by the end of the project. This increase in wastes will affect the projects' cost negatively and lead to a drop in estimated profit. At the same time, a lot of construction wastes are considered as suitable materials to be reused or recycled. Construction process requires many types of materials and among that around 20% of required materials can be achieved by reused/ recycled materials (T and Karunasena 2015).

As a result, Construction Waste Management (CWM) is the strategy to mitigate and control the over generation of construction wastes by focusing on the root causes of wastes. The engagement of CWM in projects starts from the design phase till handing over, and the implementation of it will provide a guidance for the project team to minimize and control wastes generation. It can be done by identifying the causes of construction wastes and improving the awareness of CWM to project team. At the end, implementing CWM will save environment, improve projects delivery, reduce construction cost, and resources consumption.

1.3 Thesis Objective

The main objectives of this research are listed as following:

I. Identifying the factors (Indicators) that are responsible of producing construction wastes in infrastructure projects and listing them under groups.

II. Understanding the effects and the relationships between these factors and groups, and between the groups and Construction Waste Management in Infrastructure Projects by analyzing the collected data and modeling them using Structural Equation Modeling (SEM) technique.

III. Providing a course of recommendations that will help in reducing construction wastes in infrastructure projects and spread the awareness of Construction Waste Management.

1.4 Thesis Outline:

Below is the outline of this research with a brief description of the content of each chapter:

- Chapter 1- Introduction: This chapter goes through a brief background of construction industry in countries development and what is the impact of producing construction wastes. Also, it discusses the challenges of construction wastes and how CWM contribute to mitigate this challenge. Finally, it defines the purpose of this research and expected outputs.

- Chapter 2- Literature Review: This chapter goes through the literature review of the meaning of construction waste and its types and defining construction waste management system through previous research. Also, it sorts some factors which were identified through other researchers that are contributing to construction waste management in infrastructure projects. Furthermore, it discusses some mitigation techniques which could be used to minimize and reduce the generation of construction waste.
- Chapter 3- Data Collection and Methodology: This chapter discusses how factors that produce construction wastes were selected to be the core of this research. Additionally, it discusses data collection methodology along with questionnaire design. Moreover, research methodology which will be followed within this research was explained at the end of this chapter.
- Chapter 4- Data Analysis and Discussion: This chapter demonstrates the descriptive statistics of respondents, analyzes level of importance of all factors (indicators), states the steps that will be followed to test and examine the model, and develops the Structural Equation Model which represents the results. Furthermore, a brief discussion about the final SEM will be the last part of this chapter.
- Chapter 5- Recommendation and Conclusion: This chapter contains the conclusion of the output and results of this research along with some recommendations that are helpful in controlling of construction waste generating and better implementation of CWM. Additionally, it suggests recommended future studies that might be useful as an extension of this research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This section inculcates the detailed review of numerous studies that have been conducted by many researchers in the past related to the topic of current research study. A research by Narayanamurthy & Gurumurthy (2016) depicted that literature review refers to the survey of scholarly sources that provides significance to an overview of a specific topic. In this context, it has been identified that literature review is considered as the process and the product as it is summary in terms of descriptive and analytical manner. In accordance with this, the chapter has been designed to take into consideration various studies in relation with the underlying research topic i.e. Construction Waste Management Performance Measurement in Infrastructure Projects by Structural Equation Modelling (SEM).

Construction industry plays an essential role in generating of waste in bulk quantity around the world. This statement has been taken into account in relation with another research study conducted by Islam et al. (2019) stated that the industry of construction is crucial for enhancement in economic activities, however, it also contributes towards the generation of waste material. In addition, it has been identified that construction waste is being produced by infrastructure projects, at the same time, these projects play a vital role in increasing economic activities. For this purpose, this section pertains to the views and opinions of past researchers by analyzing different journal articles, published research papers and surveys related to construction waste management in infrastructure projects. In this manner, the section begins with the history of construction waste management along with types of construction waste. Also, it demonstrates the importance and benefits of construction waste management. In addition to that, it highlights various factors that contribute to the cause of construction waste that includes issues related to designs, management, logistics, execution and procurement. Then it inculcates brief overview of Structure Equation Modelling and its significance to analyze the factors related to this topic. Moreover, this chapter will discuss impact of construction waste management in different industries. It will also identify the role of construction waste management in infrastructure projects.

2.2 Construction Waste Management CWM

During the last few years, many researchers were interested in the problems that are facing building construction and infrastructure projects due to their importance in the success of a project. Likewise, CWM plays an essential role in reducing the waste of construction from the feasibility of the project until the maintenance of project. This statement has been considered in accordance with a research study carried out by Mubarak (2015) which highlighted that a construction company can set-up CWM system to allocate the right amount of materials in order to complete the project in an effective manner. In this context, it has been determined that the waste which is left over could be recycled and utilized in future. In addition, this can be done by providing knowledge to stakeholders and by taking advantage of implementing construction waste management system which will result in helping in the reduction of the waste and providing effectiveness to construction industry. In this perspective, another research study proposed by Galvez-Martos et al. (2018) suggested that the application of construction waste management plan is effective to reduce the amount of materials used in constructing in order to divert the waste of construction.

Furthermore, it has been examined that CWM helps in reuse of recyclable resources. These resources could be wasted during construction process if CWM is not implemented. For this purpose, the construction waste management plan requires regular submittals that can be utilized in the process of tracking those recyclable resources. In accordance with this, a research study of Abu, Abudi & Bukari (2019) argued that construction waste is being used frequently in construction as a replacement of materials that need to be purchased in order to reduce harms. Considering this statement, it has been analyzed that the practices of construction waste management enable construction industry to keep the environment in an economic-friendly manner. Various studies have been carried out that describes the history of construction waste management and their contribution in the industry of construction. In this manner, another research study was put forward by Crawford, Mathur & Gerritsen (2017) which depicted that recycling is considered as the technique of construction waste management as it helps the industry to reduce the materials required to be disposed at landfills.

The increasing importance for the issues of environmental has enabled the construction to take into consideration the construction waste management seriously. Furthermore, from the survey of Statista (2021), it has been observed that in Australia, the total volume of construction and demolition waste recycled approximately was 13.6 million tons in the year 2017 and it was 11.1 million tons in the year 2009. Figure 1 provided the detailed view of recycled volume of construction and demolition in Australia.

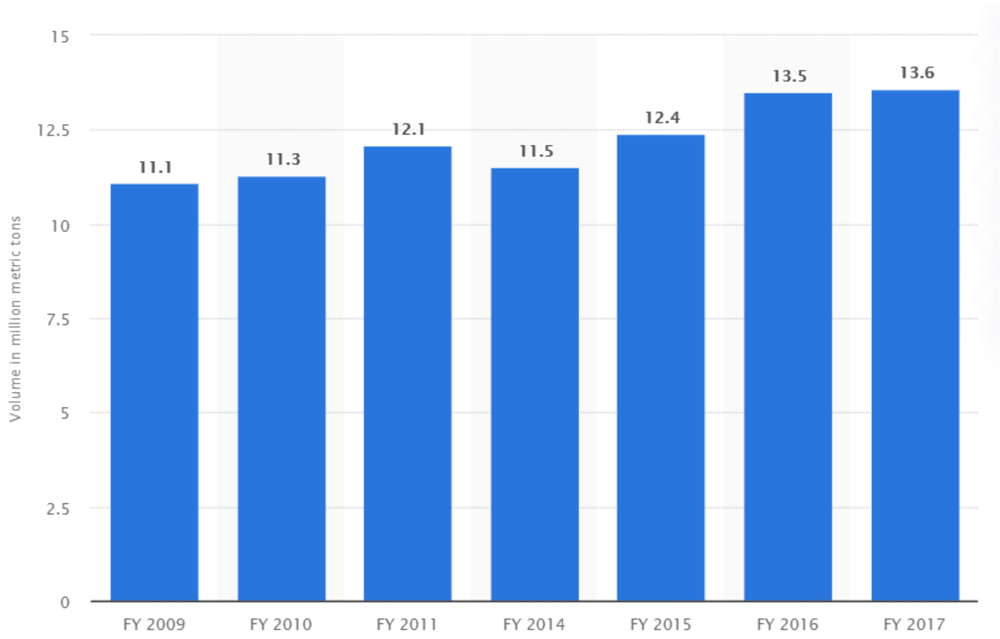

Figure 1. Total volume of construction and demolition waste recycled in Australia from financial year 2009 to 2017, Source: Statista (2021)

2.3 Types of Construction Waste

By reviewing the management of construction waste, it has been identified that waste is described as the material which is unwanted and has no value in terms of residual. Taking into view this aspect, a research study conducted by Ajayi et al. (2016) stated that construction waste is the result of utilization of excess resources than the need of necessary resources in order to execute a project. Within this context, it has been determined that construction waste has a significant impact on the aspects of life in terms of environmental and social loss. Hereby, construction wastes have been divided into two types which are physical and non-physical wastes.

2.3.1 Physical Construction Waste

The industry of construction has been developing at a rapid rate across the globe. Due to that, construction projects are generating physical construction waste in a tremendous volume. According to Ponnada & Kameswari (2015), physical construction waste is described as waste that arises from construction, renovation and demolition activities that includes excavation of land, construction of civil and building, clearance of site, activities of demolishing etc. In this context, it has been identified that physical waste is mainly related to materials waste. Many researchers have defined physical waste in a manner that it is considered as waste of solids. Another research study conducted by Bhardwaj & Kumar (2017) stated that physical construction waste is comprises of sand, bricks, blocks, steel, and related organic materials. Accordingly, it has been determined that physical waste is acted as debris that can be appeared at any project of construction. However, it is considered contingent for construction industries to take into account exhaustion of construction materials with certain limits. It is important to mention here that construction physical waste will be the interest of this research study.

2.3.2 Non-Physical Construction Waste

In the perspective of a research study revealed by Jain, Shingan & Paraspatki (n.d.) which highlighted that non-physical construction waste takes place in the process of construction in terms of rework, mismanagement, transportation of unnecessary materials etc. Considering this statement, it has been determined that non-physical construction waste is considered significant at the time of constructing any project. This due to the fact that during construction process, it is vital to take into consideration the non-physical waste as it minimizes the efficiency and effectiveness and hence results in increasing costs. At the same time, another research study of Omotayo et al. (2020) proposed that non-physical construction waste is also known as activities of non-value adding which are generally the outcomes of time and overrun costs in a project of construction. In this regard, it has been identified that non-physical construction waste leads to the ineffective completion of project. For this reason, it is considered vital for construction industries improvise their non-physical waste in order to get better project deliverables.

2.4 Benefits of Construction Waste Management

In the era of 21st century, due to the increasing development of practices of construction waste management, it is considered essential for construction industry to make a plan that provides significance in recycling of waste materials. The advantages of construction waste management cannot be neglected as it is considered beneficial for environmental and social aspects. In accordance to this, a research study was put forward by Levy (2018) which depicted that the construction company has an ability to utilize right materials in order to deliver the project. In this context, it has been analyzed that sustainable consumption and production patterns are associated with implementation and development of reverse system of logistics on the construction site. Another research study conducted by Kofoworola and Gheewala (2009) stated that if construction waste management has been implemented effectively, there are enormous benefits in terms of economic and social. Keeping in view of these benefits, it was estimated that between 70 and 400 jobs had been developed between 2002 and 2005 in Thailand.

Moreover, according to a research study carried out by Kucukvar, Egilmez & Tatari (2016), construction waste management minimizes the CO2 emissions for instance, by producing, transporting, and consuming materials and recycling the waste materials. The practices of construction waste management are considered highly lucrative and keep the environment eco-friendly. A research study conducted by Amaral et al. (2020) stated that the recycled building materials can be helpful in minimizing the environmental impact and more importantly saving required energy by 30%. Similarly, the significance of construction waste management cannot be denied as it takes part in reducing the costs and enhances the opportunities for projects in construction. In this manner, another research study revealed by Wong, San Chan & Wadu (2016) which highlighted that the active reduction of waste from the projects of construction enables them to become a green builder. In this context, it has been concluded that the implementation and the practices of construction waste management helps in planning and building the regulations in an effective manner.

Also, it has been demonstrated that it is considered significant for construction projects that need to meet legal requirements of waste to enhance their ability and efficiency. In accordance with the report of Statista (2020), the online source outlines the waste management operating revenue streams for the fiscal year of 2019. It was stated that during a fiscal year, a Texas-based Company, generated 3.85 billion U.S. dollars in revenue from just their landfills. From Figure 2, it has been observed also that these companies are providing effective solutions for waste management through utilization of services that includes, procuring and optimizing the waste, management of site service and managing waste services and data.

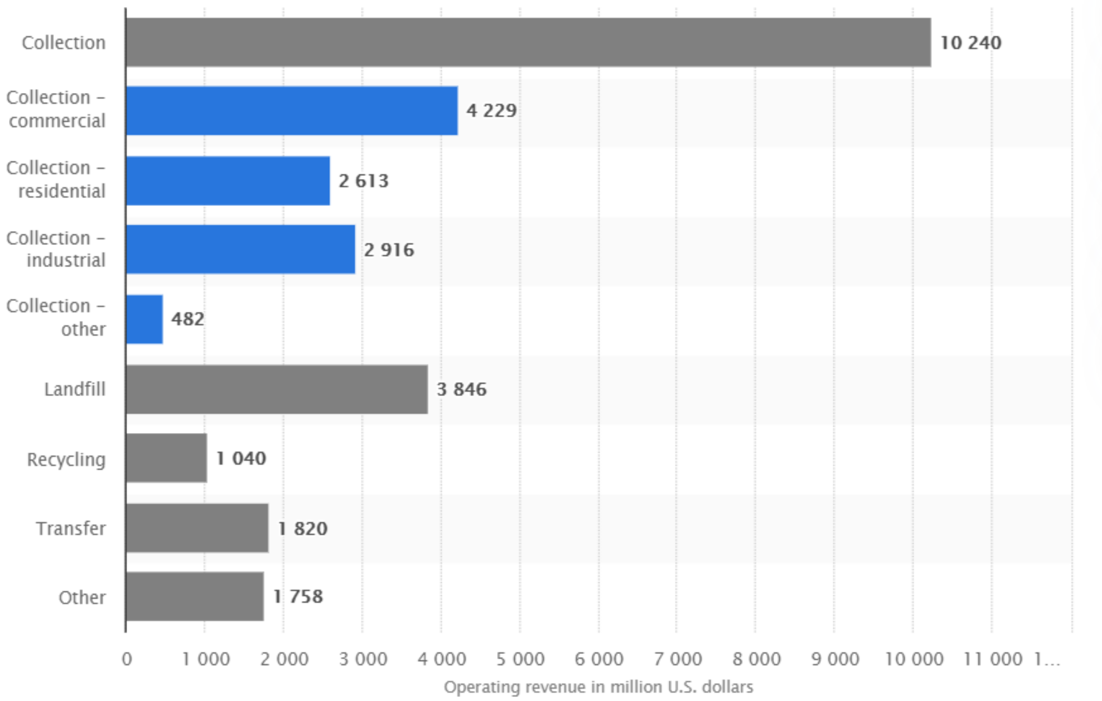

Figure 2. Operating revenue of waste management in FY2019, by segment (in billion U.S. dollars), Source: Statista (2020)

2.5 Factors Contributing Construction Waste

Waste is considered as one of the serious challenges that construction industry has been facing in the era of 21st century. Numerous researchers and practitioners have indicated that there are various activities that are resulting in waste which takes place in design and construction. In this regard, a research study of Arashpour & Arashpour (2015) depicted that construction waste significantly impacts the productivity, loss of materials and negatively affects the completion time of projects. As a result, there are a lot of factors that contributes to construction waste management in a causative manner. Some of these factors as discussed and explained as following:

2.5.1 Lack of Design Information

It is considered important in construction industry that they have enough information regarding the design of building or infrastructure. According to Peurifoy et al. (2018), plan of a design plays an essential role for the success of any commercial construction project. In this context, it has been identified that design is considered as an essential stage as it provides significance to the activities of construction. Many research have been conducted related to wasteful activities whilst designing the project. Without the effective information of design of construction project, it does not complete on a specified time (Liu, Van Nederveen & Hertogh, 2017). As a result, it has been determined that there has a significant negative impact of lack of design information on construction waste management.

2.5.2 Lack of Knowledge

Delay in projects takes place due to the lack of knowledge which can be presented in various types that includes poor skills, changes in designs, errors and omissions. This fact has been taken into account in accordance with a research study proposed by Yang, Yu & Zhu (2020), which suggested that lack of knowledge of construction projects leads to construction waste and inefficient projects. Taking into view this context, it has been identified that knowledge management plays an essential role in contributing to the success of construction project. Additionally, ineffective utilization of knowledge results in internal failure that has a significant impact on the poor quality of construction project (Okere, 2017). Due to this reason, it is considered efficient to provide significance to transference of knowledge among management in order to minimize the miscommunication among project team which will result in construction wastes.

2.5.3 Utilization of Unsuitable Tools Leading to Damage of Material

Equipment of construction is considered as an important factor to run the project in an effective manner (Taofeeq, Adeleke & Hassan, 2019). In this aspect, it is significant for construction industry to utilize machine properly and match their capabilities to the specific requirements of the project. Considering this perspective, a research study of Manikandan, Adhiyaman & Pazhani (2018) argued that construction companies are facing issues related to the utilization of unsuitable tools that leads to the damage of material. Within this context, it has been found that poor training of operators of equipment is considered as a fundamental cause of accidents related to equipment. Also, using unsuitable tools and equipment have a significant impact on the management of construction waste due to the reason that it develops ineffectiveness and failure to the construction project in addition to damages of completed/ partially completed works.

2.5.4 Poor Handling of Materials

Material management is one of the major problems that takes place in the construction industry. According to a research done by Dixit et al. (2017), poor management of materials leads to development of challenges with the timeline of the construction project. In this context, it has been determined that wastage of construction materials take major expenses and enhances the efficiency in completing the project on time. Accordingly, it is considered important for construction industry to provide proper training and awareness to people in order to improve materials handling in an effective manner. Another research study was put forward by Yadeta & Eshetie (n.d.) which depicted that effective management of materials lead to the substantial savings in the costs of project. As a result, it has been concluded that the failure of material management has a significant impact on time, quality, and cost of construction projects that results in construction waste.

2.5.5 Procurement of Materials

Like ineffective handling of material, procurement of materials is another factor that causes construction waste in construction projects. By reviewing numerous studies, it has been observed that effective management of project in the industry of construction means utilization of labor, material, and equipment in an efficient manner. Considering this perspective, a research study conducted by Subramani & Prabhu (2018) stated that the problem of procurement of materials takes place with the changing demand of materials in terms of the increase in external values and unsuitable storage of materials. In this context, it has been identified that the ordering of wrong materials results in delays that has a direct effect on project construction. In this manner, the limitations of availability of resources leads to the increase in construction waste (Gulghane & Khandve, 2015). For this purpose, it is considered essential for procurement team to take into consideration construction waste management plan while ordering materials for the construction of a project.

2.5.6 Extreme Weather Conditions Damaging Completed Works

Damages of completed works at construction project due to the extreme conditions of weather might occur at the time of execution of a project. Hereby, a research study revealed by Dalton et al. (2012) highlighted that extreme and unforeseen condition of weather have an adverse impact on the project execution that is considered as the fundamental factor of construction waste. In this context, extreme conditions of weather results in disruption of work, resources wastage, delays in project completion and losses in terms of financial resources. Due to this reason, this factor is considered vital for management to take into account as it has a direct impact on contractor and the project owner of construction projects. In addition, it is the responsibility of project management to set clear risk management plan that includes extreme weather conditions that cause negative affect on the completed work of construction project. Another research study proposed by Ballesteros-Perez et al. (2016) suggested that the clauses of weather-related conditions are to be placed in the contracts of construction projects in order to avoid any wastage or damage during the execution process. However, the influence of weather on the productivity of construction projects is relatively scarce to occur but it has a significant impact of construction waste if it happens. Therefore, it is important for project management to provide significance to weather conditions to minimize construction waste.

2.5.7 Poor Quality Management System

According to the research conducted by Akhund et al (2018), one of the major factors that attributed to the waste management is the poor-quality management system which resulted in increasing the inefficiency and rising up the costs of the projects construction. The inefficient planning, improper scheduling, and the lack of coordination between the management that has been deployed on-site, that has resulted in the increase in the cost. As per the study of Nagapan, Rahman and Asmi (2011), the poor managements system has frequency score in the management group of 7.4%, and the management group is the most dominant one in generating waste.

The organization needs to align the project as per the quality management systems set as the standards. The Enterprise Quality Management System EQMS is the standard that has been set to cater the waste management, which requires certain actions to be taken. When the projects do not fall within this standard, the wastage tends to raise, thus standard based quality management system, which is certified globally and as per the state controls the quality and environmental degradation. Thus, the quality management is the key managerial function that is effective in elimination of the waste, which is the most heeded factor in eliminating the construction waste.

2.5.8 Improper Transportation Cause Damage to Materials

In terms of the logistics, according to Al-Hajj and Hamani (2011), the improper transportation plays a vital role in causing damage to the material especially those which are fragile and needed to be handled with care. Generally, the safe and secure transportation techniques are not being used and the sources which are cheap are used instead. The rationale behind using cheap transportation is preferred especially in the developing nations where resources are not ample to support it. As per the research conducted by Karim, K. and Marosszeky (1999), the major factor contributing in the waste is the inappropriate handling at the logistics along with improper transportation as below par transport mediums are used. The transportation of the materials from the manufacturing site to construction is carried out without any procedures that not only damage the material but turn into the waste. Thus, the money invested in the quality of transport and standard handling can save up for the waste management.

2.5.9 Inexperienced Workers

The study of Nagapan, Rahman and Asmi (2011) stated that the inexperienced workers soak up much time and contributes to the construction waste. The role of management is highly valuable in this case, as the real problem arises due to the poor planning skills by management which tends to hire and work with the inexperienced workforce.

Moreover, according to the study of Bakchan et al. (2016), the inexperienced workers are more likely to make mistakes, which is the key cause for generating construction waste. This carries the highest frequency among all the other causes in the workers group. The inexperienced workforce generally is untrained with lack of skills and poor working attitudes. These workers generate material waste such as bricks, light weight concrete, plaster, and tiles. Thus, for the mega projects, the practice of employment should hire trained staff that have vast experience and a good working culture and must take the ownership and responsibility of their daily works. If the previous notes are being taken, the waste generation can be minimized.

2.5.10 Minimum Order Requirement by Suppliers

As per the research undertaken by Adewuyi and Otali (2013), the waste management is also resulted from the suppliers' end, when they set a minimum order requirement that needs to be fulfilled to achieve the economies of scale. This leads to ordering errors as more than the required order is being procured. In procurement aspects, ordering error score the highest frequency. Mostly the studies have revealed that over ordering is in bricks and cement. Thus, in order to combat the issue, the construction management must order with the suppliers that have a flexible approach and does not have restrictions of the minimum order to minimize the construction waste. Moreover, the wastage occurs when the logistics giant is demanding for a certain quantity to be ordered, which at times exceed the quantity required. This in turn leads to wastage of the bricks and cement as the desired quantity is being utilized leaving behind leap of the raw material which is of no use. Thus, the procurement needs to be planned accordingly to utilize the quantity required to avoid wastage and the budgeting as well.

2.6 Impact of Construction Waste Management in different Industries

A research study was put forward by Li et al. (2020) which depicted that many countries are using recycling of construction and demolition waste under the regulation of law and policy. Taking into view this aspect, it has been identified that by utilizing construction waste management, industries can provide economic incentives that include low cost of disposal that result in low rate of recycling. In this aspect, another research study conducted by Albert, Shakantu & Ibrahim (2018) stated that the government of Nigeria made it mandatory that construction firms need to take into consideration legislation in order to provide significance to construction waste management. In this context, it has been determined that the practices of construction waste management enable the industries to promote the protection to environment. From these prospects, it has been evaluated that there is a significant positive impact of construction waste management on industries of different countries. Additionally, many researchers have conducted studies on identifying the impact of construction waste management on many industries.

Due to the aforementioned reason, it has been determined that there is a growing need of effective construction waste management due to the fact that there has an adverse impact of construction waste on an environment. Within this context, a research study revealed by Freitas & Magrini (2017) which highlighted that Brazil has adopted different waste management strategies in its projects of industrial construction. From the results of this study, it has been analysed that 9% of waste was recovered by utilizing industrial symbiosis. In this regard, it has also been demonstrated that if the construction waste is not managed in an effective manner then they will cause destructive effects on the environment. This fact has been taken into account in accordance with a research study of Wahi et al. (2016) which argued that the governments of East Asia and Pacific regions, Hong Kong and Malaysia have introduced different policies and regulations that includes, Waste Disposal Ordinance (WDO, 1980), Environmental Impact Assessment (EIA) Ordinance (1998), Solid Waste and Public Cleansing Management Act 2007 (Act 672), Environmental Quality Act 1974 (Act 127) and Pembinaan Malaysia Act 1994 (Act 520) in order to make sustainable activities in construction. For this purpose, the emergence of construction waste management has considered beneficial for industries of various countries.

2.7 Waste Management Strategies

2.7.1 Reuse

The major developed countries such as United Kingdom, North America, Europe and various Asian countries have adopted the 3R principle which is to Reduce, Reuse and Reprocess. The rationale behind the successfulness of waste management strategies in these developed countries is that they have adapted the 3R principle which in turn brings numerous economic and environmental benefits. The recycled materials being used in construction projects extend the lifespan of natural resources as well as reduce the environmental pollution, which is harmful to human health and well-being (Luangcharoenrat et al, 2011). The economic advantage of this strategy is that it reduces the project costs, increases the business opportunities, reduce the litigation risk, as well as showcase the commitment to minimize the environmental degradation. According to Iacovidou and Purnell (2016), the primary objective is retention of the function, with many structural components that can be reused in the recovery and storage while the produced wastes due to construction and demolition can be recycled as illustrated in below figure. This practice offers the possibility to conserve resources through the reclamation of structural components and the material embedded in them, as well as opportunities for the development of waste management. Figure 3 illustrates the processes of reusing and recycling of different materials which can be used in infrastructure projects.

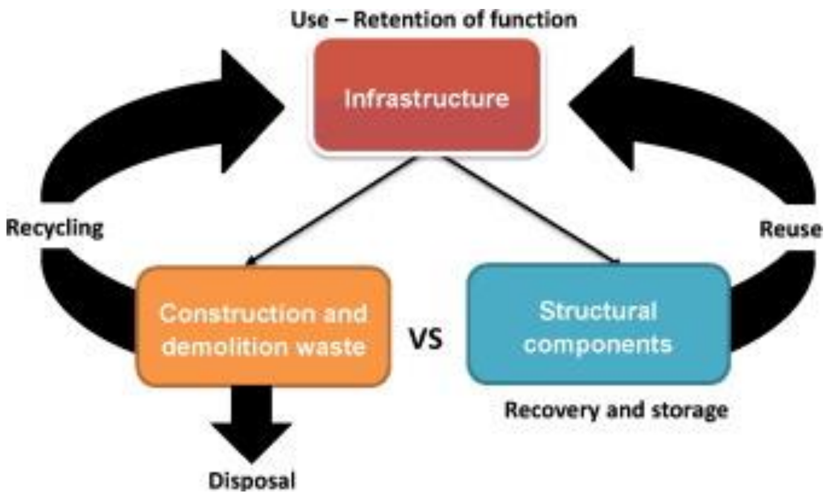

Figure 3. Reusing and recycling processes, Source: Iacovidou and Purnell (2016).

2.7.2 Recycle

Recycling is another waste management strategy that is being applied globally especially for the construction materials such as glass, plastics, paper, wood and metals, with the incorporation into fabrication of new products. Thus, according to the study of Ajayi et al (2016), the greater incorporation of recycled materials leads to the identical applications of the projects that aim to be carried out in the construction in the future. The benefits of recycling are that it reduces the need of the natural resource exploitation, as well as it allows the waste materials to be recovered and makes an optimum use as the valuable resource materials.

As per the study of Chini (2007), conducted in US, about 80% of the recovered material is currently recycled while 20% is going to the landfill. In terms of the recycled material, one third of the recycled materials are used as the aggregated for new asphalt hot mixes while remaining two-third is used as the solid base for the construction. Moreover, it has estimated as per the study of Ajayi et al (2016), that 50% (91 MMT) of waste concrete is recycled annually into usable aggregates. This is roughly 5% of 1.8 billion metric tons total aggregates market.

The recycling of the waste directly conserves the natural renewable resources, while it lessens the energy consumption and emission that is being generated by the extraction of the virgin material and its subsequent that is manufactured into finished products (Magalhães et al., 2017). It contributes to reduction of the incineration or the landfilling of materials that have been recycled. Apart from this, the economic benefits derived are job markets are developed and tend to become the driving force to the economic growth.

2.7.3 Incineration

Waste degradation not only produces the essential solid-end disposals such as compost, but the degradation by-products that can be used as the beneficial energy source. The incineration incorporates the anaerobic digestion of the waste materials that can generate biogas, which can further be captured and incorporated into electricity generation. Similarly, the incineration comprises of the waste combustion that is being treated at very high temperature to produce electrical energy from the waste product (Cherubini, 2010). The biproduct of the incineration strategy is the ash, which deems proper characterization which is needed before any disposal or in some cases benefits the re-usage. This strategy is widely adopted in the developed countries, as there are landfill space limitations. It is estimated that about 130 million tons of the waste is annually combusted in more than 600 plants that is in 35 countries of the world. Moreover, the incineration benefits from mitigating the dangerous waste such as the chlorinated hydrocarbons, oils, solvents, medical wastes, and pesticides (Havukainen et al, 2017).

2.7.4 Landfill

Despite the advancement in the reusing and recycling, the landfill disposal still is the primary waste management and disposal method in the United States. As the rate of the construction wastes generation persistently increases, the capacity of the landfill decreases. There are new regulations, that have continued to increase, but still the overall land capacity has reduced (Agovino, Ferrara, & Garofalo, (2016). As per the new regulations that are concerned over proper waste disposal and innovate lining system that has minimized the leachate infiltration of the construction waste and the mitigation that has resulted in the substantial increase in the costs involving the cost of landfill disposal. Whereas the public opposition to the landfill continues to increase as it is inspired by the series of the historic unprecedented and uncontrollable dumping events that have resulted in the undesirable side effects polluted groundwater, absolute odors, and ensuing moderated property values (Kamaruddin et al, 2017).

2.8 Construction Waste Mitigation Techniques

As per the study of Hasmori et al (2020), the Construction Industry Development Board Malaysia, have drastically encouraged the technique of the Industrialized Building System (IBS), along with other off sit construction techniques in the infrastructure projects. This method is commonly used to combat the construction waste, along with the conservation of the landfill capacity.

Moreover, this technique is widely used to impose the concept of sustainable development. Another off-site technique used is the prefabrication technique, which tends to be a perceived answer to the major causes of the waste that is being caused in the design and construction. This can prove to the benefits on-site as well as it can lead to improved quality control, develop a safer and hygienic working environment, minimize the environmental degradation as well as contribute to reduce the construction time and save up the cost as well.

While another method for the on-site waste management is deemed as the C1 method, which offers to provide waste segregation for the specific materials. In this construction method, which is on-site waste management technique, the Hasmori et al (2020) research deduces that 13 out of the 20 researchers validated this method to reduce on-site wastage. As per this method, the waste management teams need to effectively separate waste by providing waste skips. This is based on the considerations that recycling construction material is one of the best options to reduce adverse impact on the environment which also includes in 3R concept of waste minimization.

2.9 Structure Equation Modelling SEM

Structure Equation Modelling (SEM) is widely acclaimed multivariate statistical analysis technique that is being used to perform Confirmatory Factor Analysis CFA, confirmatory composite analysis, path analysis and other useful analyses. It is based on generating computer algorithms, mathematical model and statistical methods which are helpful in representing and understanding the relationships between latent and observed variables. It is commonly used in social science due to its ability in imputing the relationships between latent variables (unobserved constructs) and indicators (observed variables). Performing structural equation modelling can be done using some useful software nowadays such LISREL, SAS PROC CALIS, lavaan, OpenMx, EQS, Mplus and AMOS. The key difference of the software is the inclusion of a model specification graphical interface and the presentation of data.

Using SEM technique starts with developing measurement model which reflects the relationships between latent and observed variables based on the collected data. Consequently, this model is being modified in a manner to ensure that collected data and the relationships are meeting acceptable indices. When the measurement model is modified, structural model will be developed accordingly. Structural model developed is usually used to understand the behavior of latent variables on certain topic.

A research conducted by Selomo et al (2019) indicated using the SEM model that knowledge variable influenced the waste along with the attitude variables and infrastructural variables thus deducing the SEM method effective in identifying the waste generation factors as per the statistical results. While a Confirmatory Factor Analysis CFA is then carried out to establish the relationship between different indicators and constructs as a measurement model using the SEM. CFA tests the assumption that the relationship within and among the factors and the variables can be expressed in the form of an equation. Apart from SEM, the researchers have incorporated both the Harman's Single Factor (HSF) and Common latent Factor (CLF) procedures in SPSS 21 and AMOS 17 for sound waste management techniques (MacKenzie and Podsakoff, 2012).

2.10 Conclusion

To conclude this section, it has been noticed that construction industry has been growing significantly for the past few decades. For this purpose, many researchers have conducted various studies in order to analyze and evaluate the impact of construction activities on social life perspectives. In this manner, the section provided detailed overview regarding the significance of construction waste management. By reviewing different studies, it has also been observed that waste has considered a major concern in the industry of construction in terms of financial and environmental impacts. Due to this reason, many construction firms are using different strategies that help them in reducing waste. The attention of construction and demolition waste has been taking keen interest by the researchers and specialists across the world. Therefore, the section highlighted different types of construction waste that are in form of physical and non-physical. Additionally, many studies have been published in journals that are related to waste management to provide significance to sources of waste, cost, and how to reduce it. In this aspect, the section also highlighted factors that contribute to construction waste and have an adverse impact on construction industry. However, to minimize these risks different strategies related to waste are also being discussed in this section.

Finally, SEM is the technique used to analyze the factors and to develop the model which will represent the relation between indicators and construct along with the importance of them. The results of this model will help to spot the light on the important aspects that must be considered during construction that will minimize the generation of construction waste.

CHAPTER 3: DATA COLLECTION AND METHODOLOGY

3.1 Overview

This chapter will represent how construction waste factors have been selected and how questionnaire was developed. Besides that, it will discuss the methodology of data collecting along with research methodology.

3.2 Factors Selecting

As a result of searching the main factors contributing construction wastes generation in infrastructure projects in literature, 26 factors were selected to be the core of this research as they are considered as the major factors contributing construction wastes generation. These factors were categorized into six groups which are Design, Logistics, Execution, Management, Procurement and Others. The main groups and factors that are contributing construction wastes generation are listed in Table 1.

Table 1. Main Factors and Groups Contributing Construction Waste Management in Infrastructure Porjects

Group	**Code**	**Factors**	**References**
Design	DES1	Frequent Design Changes	(Luangcharoenrat et al. 2019) (Tongo et al. 2020) (Ajayi et al. 2016)
	DES2	Design Errors	(Luangcharoenrat et al. 2019) (Aminu et al 2016) (Ghafourian et al. 2018)

Group	Code	Factors	References
	DES4	Lack of Design Information	(Tongo et al. 2020) (Magalhães et al. 2017) (Ghafourian et al. 2018)
	DES4	Uneconomic Design or Shapes	(Adewuyi and Otali 2013) (Fadiya et al. 2014) (Wahab and Lawal 2011)
Logistics	LOG1	Improper Storage of Materials	(Kabirifar et al. 2020) (Lu and Yuan 2010) (Aminu et al 2016)
	LOG2	Poor Handling of Materials	(Kabirifar et al. 2020) (Al-Hajj and Hamani 2011) (Najafpoor et al. 2014)
	LOG3	Improper transportation causing damages to materials	(Al-Hajj and Hamani 2011) (Najafpoor et al. 2014) (Ghafourian et al. 2018)
Execution	EXC1	Using Unsuitable Tools Leading to Material Damage	(Kabirifar et al. 2020) (Liu et al. 2020) (Abdul Rahman et al. 2015)
	EXC2	Inexperienced Workers	(Nikmehr et al. 2015) (Bakchan et al. 2016) (Aminu et al 2016)
	EXC3	Improper installation techniques causing damages to on-going work	(Nagapan et al. 2011) (Khaleel and Al-Zubaidy 2018) (Jamaludin et al.

Group	Code	Factors	References
			2017)
	EXC4	Inappropriate Construction Works Execution Strategy for Site Activities	(Nikmehr et al. 2015) (Liu et al. 2020) (Elizar et al. 2017)
	EXC5	Rework	(Abdul Rahman et al. 2015) (Nikmehr et al. 2015) (Wahab and Lawal 2011)
	EXC5	Contractors Working on Site Without Approval by Client or Consultant	(Al-Rifai and Amoudi 2016) (Nagapan et al. 2011) (Polat et al. 2017)
	MNG1	Poor communication among project parties	(Nagapan et al. 2012) (Nagapan et al. 2011) (Nagapan et al. 2012)
	MNG2	Lack of Construction Waste Management Knowledge	(Bakchan et al. 2016) (Elizar et al. 2017) (Lu and Yuan 2010)
Management	MNG3	Poor Planning of Site Layout	(Kaliannan et al. 2018) (Nagapan et al. 2012) (Ikau et al. 2016)
	MNG4	Poor Quality Management System	(Akhund et al. 2018) (Fadiya et al. 2014) (Al-Rifai and Amoudi 2016)
	MNG5	Improper Controlling and	(Elizar et al. 2017) (Lu and

Group	Code	Factors	References
		Supervision Strategy to monitor and guide workers	Yuan 2010) (Liu et al. 2020)
	MNG6	Improper daily site management leading to leftover materials on site	(Nagapan et al. 2011) (Fadiya et al. 2014) (Polat et al. 2017)
Procurement	PRC1	Wrong ordering of materials by procurement team	(Nagapan et al. 2011) (Kaliannan et al. 2018) (Ajayi et al. 2016)
	PRC2	Quantity Take-off Error by Contractor	(Ajayi et al. 2017) (Akhund et al. 2018) (Magalhães et al. 2017)
	PRC3	Minimum Order Requirement by Suppliers	(Adewuyi and Otali 2013) (Ajayi et al. 2017) (Sasidharani and Jayanthi 2015)
Others	OTR1	Extreme Weather Conditions Damaging Completed Works	(Kaliannan et al. 2018) (Akhund et al. 2018) (Jamaludin et al. 2017)
	OTR2	Unforeseen Incidents Damaging Site and/or Completed Works	(Nagapan et al. 2018) (Jamaludin et al. 2017) (Nagapan et al. 2011)
	OTR3	Poor Subcontractor performance causing damages to completed	(Polat et al. 2017) (Nagapan et al. 2018) (Ikau et al. 2016)

Group	Code	Factors	References
		works by others	
	OTR4	Theft and Vandalism	(Khaleel and Al-Zubaidy 2018) (Abdul Rahman et al. 2015) (Adewuyi and Otali 2013)

3.3 Questionnaire Design

Research questionnaire was divided into two parts which are General Information, Groups and Factors Contributing Construction Wastes Management. The first part was discussing general information about respondents and their organizations. The questions were about respondents' years of experience, background and designation, in addition to organizations' sectors, type and division. On the other hand, second part was demonstrating the level of importance of 26 factors which were identified in previous section along with the importance level of each of the six groups in the generation of construction wastes in infrastructure projects. The following question was used to determine the level of importance of all factors:

- What is the Level of Importance of "The Factor" in Generating Construction Wastes?

The answer to this question was in the form of rating each factor as shown in Table 2.

Table 2. Level of Importance Rating System

	1	2	3	4	5
Rating	Not at all Important	Slightly Important	Moderately Important	Very Important	Extremely Important

3.4 Sampling Technique

Defining research sample size for SEM is not straightforward but most researchers agree that sample size should be "large". On the other hand, most researchers and students prefer using "Rule of Thumb" in determining the minimum sample size required for a particular application of Confirmatory Factor Analysis CFA. Ratio of observations (N) to estimated parameters (q) can be a useful tool to be used in determining sample size. The desired ratio required to achieve minimum sample size can be as low as 5:1 (Bentler & Chou. 1987). Based on that, the approximate minimum required sample size is 130 observations.

This research questionnaire was distributed to more than 500 participants to achieve better results accuracy.

3.5 Data Collection

Research data was collected through an online survey which was developed on Survey Monkey Software. Around 196 respondents responded to survey worldwide. The survey was developed in October 2020 and kept open for respondents for almost 60 days till the end of November 2020. Out of 196 responses, only 167 were considered and 29 responses were dismissed due to incomplete survey. A copy of questionnaire was attached to Appendix A.

3.6 Research Methodology

This section will discuss the methodology in which this research will be accomplished. This research methodology is based on collecting data from recent and previous sources, analyzing, and validating these data to end up with research outcome objective. The research will go through four stages as shown in Figure 4.

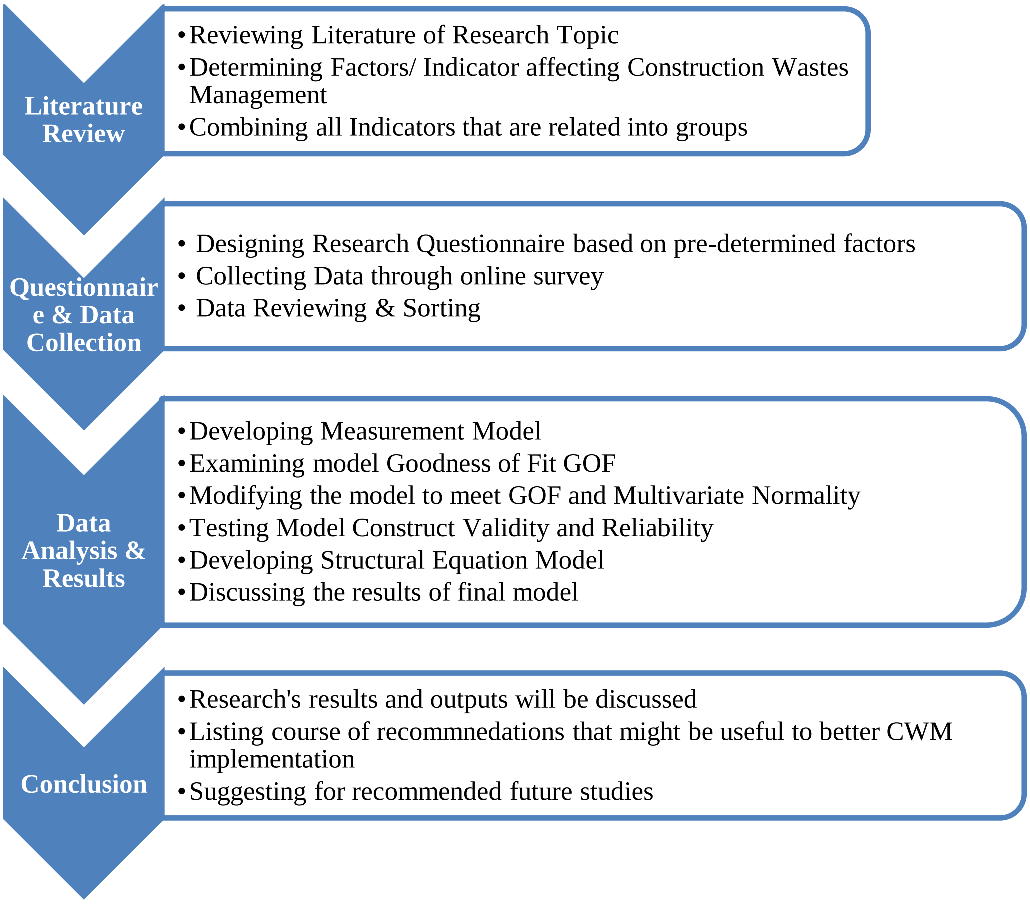

Figure 4. Research methodology stages.

3.7 Research Hypotheses

As construction waste factors (indicators) which were identified in this chapter are categorized into groups, it is assumed that they are having a positive effect on their groups (constructs). Consequently, it is assumed that all these groups are having a positive impact on construction waste management in infrastructure projects. These hypotheses are stated as following:

I. Design has a positive impact on construction waste management in infrastructure projects.

II. Logistics has a positive impact on construction waste management in infrastructure projects.

III. Execution has a positive impact on construction waste management in infrastructure projects.

IV. Management has a positive impact on construction waste management in infrastructure projects.

V. Procurement has a positive impact on construction waste management in infrastructure projects.

VI. Other issues have a positive impact on construction waste management in infrastructure projects.

Above hypotheses will be examined at the end of this research to verify whether they are supported or not.

CHAPTER 4: DATA ANALYSIS AND DISCUSSION

4.1 Descriptive Statistics of Respondents

This section will discuss a descriptive statistics of respondents General Information (Questionnaire part 1). The discussion will include respondents' years of experience, professional registration, organization type and sector, their positions at organization, projects division and their awareness of Construction Waste Management.

4.1.1 Respondents' years of Experience

In this research, the majority total years of experience of respondents was between 6-10 years as they formed around 31% of total respondents. On the other hand, respondents with 16-20 years of experience were the least with only 8% approximately. The table below represents the number of respondents of each group of experience.

Table 3. Respondents Years of Experience Results

Years of Experience	**No. of Responses**	**Percentage**
Less than or equal 5	35	20.96%
(6-10)	52	31.14%
(11-15)	29	17.37%
(16-20)	13	7.78%
(21-25)	19	11.38%
More than 25	19	11.38%

4.1.2 Professional Registration

Figure 5 represents the percentage of professional registration of respondents. Among all respondents, around 68% were professionally registered in at least one authority of institute. This high percentage will help in getting a more reliable data which will end up with a better outcome from this research.

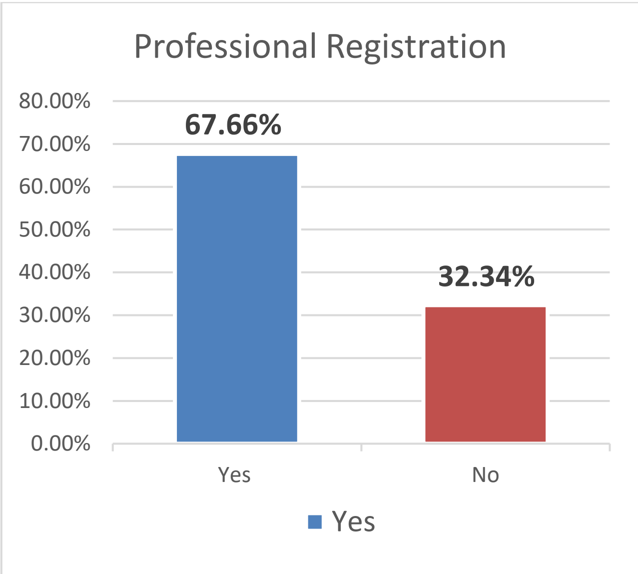

Figure 5. Respondents professional registration results.

4.1.3 Type of Organization

The majority of respondent were working in Contracting companies with 52% of total responses. However, only 3% were working in Designing companies which is very less comparing to other organization types. Below figure represents the number of respondents for each type of organization.

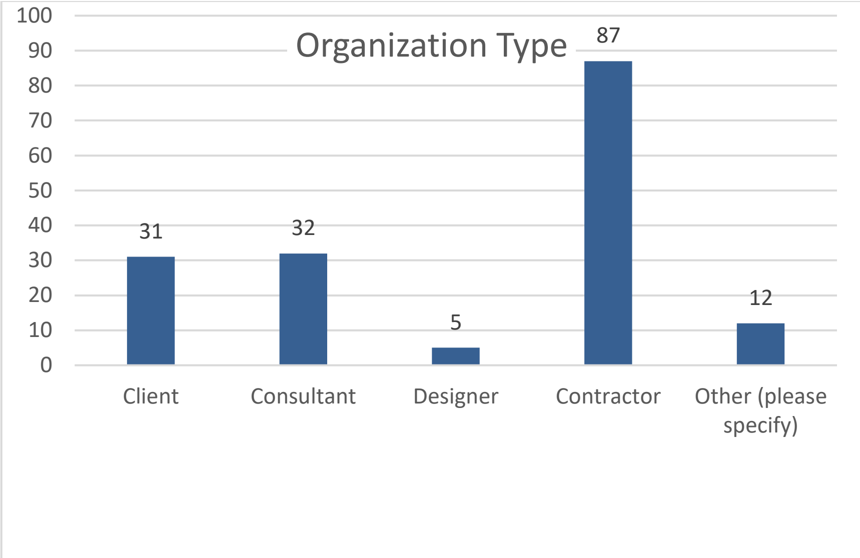

Figure 6. Respondents organization type results.

4.1.4 Organization Sector

The sector of an organization defines its ownership and mainly organization are either public or private. In this research, around 75% of participants were from private organization whereas the remaining 25% are from public or governmental organizations as shown in Figure 7.

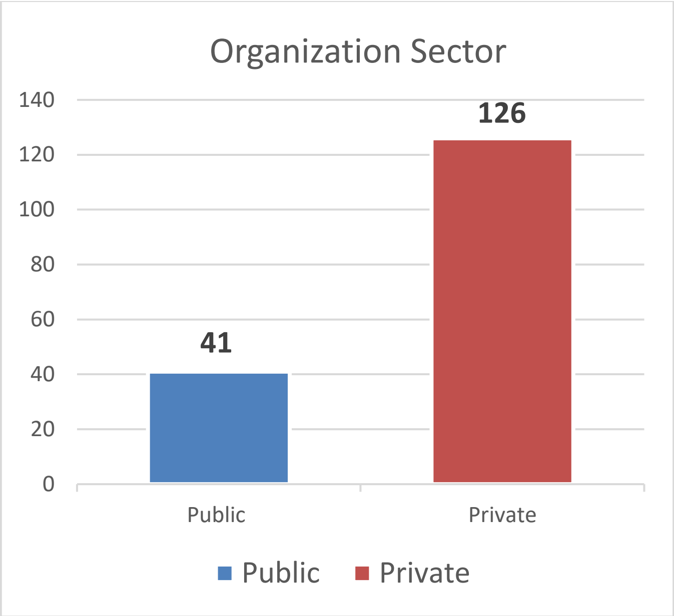

Figure 7. Respondents organization sector results.

4.1.5 Respondents Position

It is important to mention that around 85% of respondents were engineers and 55% of them were at the higher management level or seniors. However, the remaining 15% were from different backgrounds such as environmental and sustainability, business development, etc.… Table 4 shows the percentage distribution of all positions.

Table 4. Respondents Position Results

Position	**No. of Responses**	**Percentage**
Executive Manager	14	8.38%
Department Manager	16	9.58%
Project Director	3	1.80%
Project Manager	18	10.78%
Senior Engineer	40	23.95%

Position	No. of Responses	Percentage
Engineer	50	29.94%
Safety	1	0.60%
Other (please specify)	25	14.97%

4.1.6 Project Division

This part is about the division of the projects where respondents are working at. Almost half of the respondents were from Infrastructure division which is the targeted division for this research. Building Construction is coming at the second place with 35% of total respondents. The figure below represents the details of project division distribution.

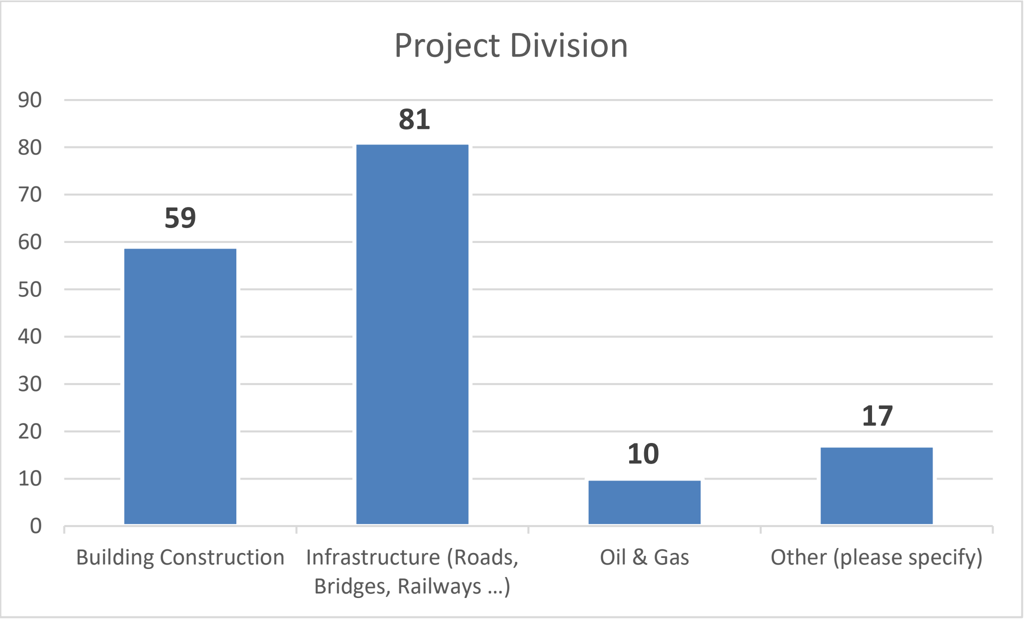

Figure 8. Respondents project division results.

4.1.7 Awareness of Construction Waste Management and Its Role in Project Performance

Both Table 5 and 6 represent the awareness of participants of Construction Waste Management and its effect on projects performance. It was noticed that approximately 80% of respondents are aware of what is Construction Waste Management is. Additionally, around 95% of them believe that CWM plays a significant role in project performance which makes this research very powerful to enhance projects performance.

Table 5. Respondents Awareness of CWM Results

Awareness of CWM	**No. of Responses**	**Percentage**
Yes	134	80.24%
No	33	19.76%

Table 6. Effectiveness of CWM on Project Performance Results

Effect of CWM on Project Performance	**No. of Responses**	**Percentage**
Yes	157	94.01%
No	10	5.99%

4.2 Analyzing Construction Waste Management Indicators

In this section, factors contributing construction waste management in infrastructure project in Qatar will be analyzed. The data collected in part 2 of the questionnaire shows the importance level of all indicators in each group based on respondents' experience. This data will help at later stage in developing the Structural Equation Model SEM and it will help in understanding the relations between indicators.

Table 7 represents the summary of results for indictors related to first group "Design". It was noticed that the indicator of "Lack of Design Information" had the highest rank when it comes to construction waste management generation where 45.51% of respondents evaluate it as Extremely Important. On the other hand, respondents believe that "Uneconomic Design & Shapes" is the least important indicator with total of 29.34%.

Table 7. Level of Importance Results for Design Factors

Indicator Code	**Level of Importance**				
	NI	**SI**	**MI**	**VI**	**EI**
DES-1	0.00%	3.59%	16.77%	46.11%	33.53%
DES-2	0.00%	1.20%	13.77%	43.11%	41.92%
DES-3	0.00%	4.79%	14.37%	35.33%	45.51%
DES-4	1.20%	5.99%	23.95%	39.52%	29.34%

NI: Not at all Important SI: Slightly Important MI: Moderately Important VI: Very Important EI: Extremely Important

For Logistics group, it was found that "Improper Storage of Materials" is the Extremely Important Indicator for generating CWM with 46.11% responds. However, all of the three indicators which are related to Logistics are too close to each other where the difference is less than 5% as shown in below table.

Table 8. Level of Importance Results for Logistics Factors

Indicator Code	Level of Importance				
	NI	SI	MI	VI	EI
LOG-1	0.00%	2.40%	13.17%	38.32%	46.11%
LOG-2	0.00%	2.40%	11.98%	42.51%	43.11%
LOG-3	0.00%	5.39%	14.97%	37.72%	41.92%

The responds of the third group "Execution" are represented in Table 9. "Rework" was considered as the most important indicator for generating CWM from Execution group where almost half of the responds evaluate it as Extremely Important. Additionally, "Working on Site Without Approval by Client or Consultant" indicator is so close to the highest indicator with a difference of only three responds.

Table 9. Level of Importance Results for Execution Factors

Indicator Code	Level of Importance				
	NI	SI	MI	VI	EI
EXC-1	0.60%	4.79%	19.76%	42.51%	32.34%
EXC-2	0.00%	3.59%	18.56%	41.32%	36.53%
EXC-3	0.60%	4.19%	9.58%	44.31%	41.32%
EXC-4	0.60%	2.99%	20.96%	40.72%	34.73%
EXC-5	0.00%	4.79%	14.37%	29.94%	50.90%
EXC-6	0.60%	10.78%	13.17%	26.35%	49.10%

When it comes to Management, "Poor Communication Among Project Parties" was the major cause of construction wastes which more than half of them responded that it is extremely important in generating construction wastes. On the other hand, the remaining five indicators were almost same in importance in generating construction wastes. Table 10 represents the detailed percentage of each indicator of "Management" Group.

Table 10. Level of Importance Results for Management Factors

Indicator	**Level of Importance**				
Code	**NI**	**SI**	**MI**	**VI**	**EI**
MNG-1	0.00%	4.19%	13.17%	30.54%	52.10%
MNG-2	0.00%	2.99%	13.77%	41.92%	41.32%
MNG-3	0.00%	6.59%	13.77%	40.72%	38.92%
MNG-4	0.00%	2.99%	18.56%	40.12%	38.32%
MNG-5	0.00%	5.99%	16.77%	41.92%	35.33%
MNG-6	0.00%	3.59%	19.16%	41.32%	35.93%

Table 11 represents the percentage of importance of each indicator of "Procurement" Group. It was noticed that "Wrong Ordering of Material by Procurement Team" was the major factor in generating construction wastes as around 55% of respondents consider it a extremely important indicator. However, the indicator of "Minimum Order Requirement by Supplier" was considered as the least important indicator of this group as only 20% of respondents consider it as extremely important factor while around 30% consider it as moderately important.

Table 11. Level of Importance Results for Procurement Factors

Indicator Code	Level of Importance				
	NI	SI	MI	VI	EI
PRC-1	0.60%	1.80%	12.57%	29.34%	55.69%
PRC-2	1.20%	4.79%	20.36%	31.14%	42.51%
PRC-3	0.60%	9.58%	29.94%	38.92%	20.96%

The last group "Others" was a collection of some indictors that are not related to above groups; however, they are still contributing construction wastes generation. All indicators were evaluated as Very Important in generating construction wastes but "Poor Subcontractor Performance Causing Damages to Completed Works by Others" was the most important as almost 36% of respondents consider it as Extremely Important indicator as shown in below table.

Table 12. Level of Importance Results for Other Factors

Indicator Code	Level of Importance				
	NI	SI	MI	VI	EI
OTR-1	1.80%	10.18%	24.55%	35.33%	28.14%
OTR-2	1.80%	12.57%	25.15%	35.33%	25.15%
OTR-3	1.20%	2.40%	19.16%	41.32%	35.93%
OTR-4	6.59%	13.17%	27.54%	31.74%	20.96%

4.3 Analyzing Construction Waste Management Groups

After analyzing the importance of each indicator separately, it is important to determine the importance of the groups which are related to construction wastes generation in infrastructure project in Qatar. This section will go through to importance of all above mentioned groups as per the experience of respondents which is the continuation of Part 2 in the questionnaire. However, “Others” group will be excluded from this part due to the irregular relationship between its indicators.

Table 13 summarize the importance level of all groups (except Others Group) that are contributing construction wastes generation. From Table 13, it is noticed that “Management” Group is coming at the top priority where 49.10% of respondents consider it as extremely important group. Execution was the second important group with 48.50% of respondents consider it as extremely important. Procurement, Logistics and Design groups are coming at the third, fourth and fifth levels of importance, respectively.

Table 13. Level of Importance Results for All Groups

Group	**Level of Importance**				
Name	**NI**	**SI**	**MI**	**VI**	**EI**
Design	0.60%	3.59%	13.17%	40.12%	42.51%
Logistics	0.00%	3.59%	19.16%	33.53%	43.71%
Execution	0.60%	1.20%	12.57%	37.13%	48.50%
Management	0.00%	1.80%	13.77%	35.33%	49.10%
Procurement	0.60%	1.20%	14.37%	38.92%	44.91%

4.4 Model Development

In this section, a model will be developed for Construction Waste Management indicators based on the collected data of 167 respondents. Structural Equation Modeling (SEM) method will be used to present these correlations. Firstly, a measurement model will be developed to understand the correlation between indicators and groups followed with checking of model fit based on some indices. Secondly, the model will be modified to be more fit by eliminating poor correlation indictors to develop a Modified Model. Finally, Structural Equation Model will be developed after ensuring a good fitness of model which will be the results of this research.

4.4.1 Stages of Model Development

The steps followed in this research for developing the model are shown in Figure 9:

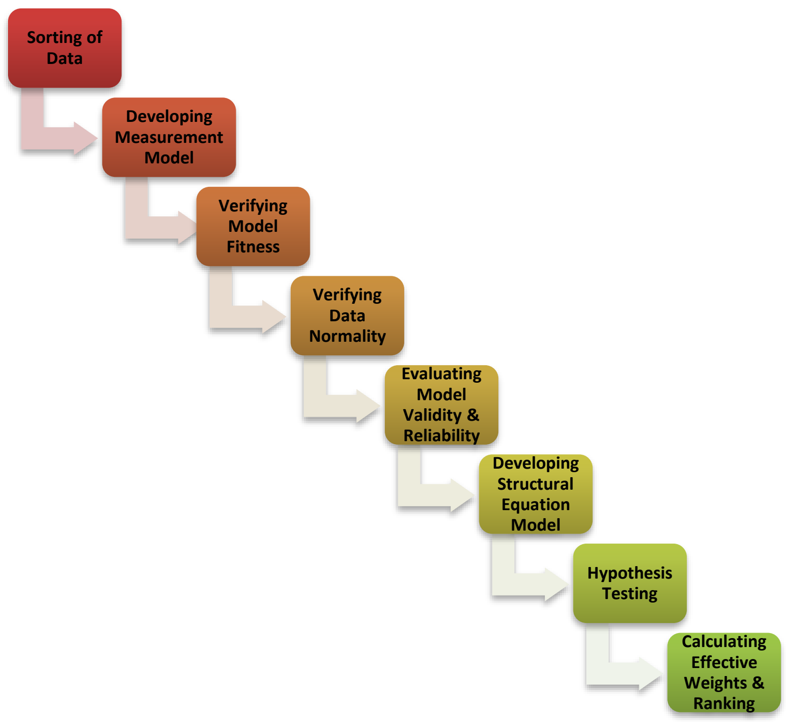

Figure 9. Model development stages.

- Step One: Sorting of Data

  In this step the collected data was sorted in a manner to eliminate incomplete questionnaires. As mentioned before, 196 responds were collected through online questionnaire and it was found that 29 respondents did not complete it. Hence, the collected data was dropped off to 167 responds which will be used to develop the model.

- Step Two: Developing Measurement Model

  IBM SPSS AMOS 26 software will be used to develop the measurement model based on collected data and research objective and hypotheses.

- Step Three: Verifying Model Fitness

  This step will capture the covariance between indicators within the model and evaluates the Goodness of Fit by using range of model fit indices. In this research, five main indices will be used to verify the measurement model. These indices are Relative Chi-Square, Comparative Fit Index CFI, The Standardized Root Mean Square Residual SRMR, Root Mean Square Error of Approximation RMSEA and PCLOSE. The use and purpose of each indices are explained below.

  1. Relative Chi-Square (*X2/df)*:

     Among the potential tests of fit in SEM, the chi-square test is special index because it is a test of statistical significance. The Chi-Square fit index assesses the fit between the hypothesized model and data from a set of measurement items (the observed variables) (Alayi et al. 2020). The value of Chi-Square is related to the discrepancy between the model and data where a significant value indicates a poor model fit. Since Chi-Square is affected by the sample size, it is recommended to use the ratio of the chi-square statistic to correspond degrees of freedom (*X2/df).* A value between 1-3 is a good indicate of model fit (Xiong et al. 2015).

2. Comparative Fit Index CFI:

This test will help to determine whether the model produced by data sample fits more than the independence model or the opposite (Cangur, 2015). CFI values range from 0 to 1 with better fit if CFI value is higher. This index is relatively independent of the sample size and provides better results with small sample size studies (Chen, 2007). The acceptable value of CFI should be 0.90 or greater which indicates of a good model fit (Hair et al. 2014).

3. Root Mean Squared Error of Approximation RMSEA:

RMSEA is an index of the discrepancy between the covariance matrix observed per degree of freedom and the covariance matrix hypothesized to denote the model (Chen, 2007). Unlike CFI, RMSEA index is affected by sample size where larger sample size produces better results. It is believed that RMSEA value of 0.08 or less is a reasonable indication of model fit with an acceptable error of approximation (Rigdon, 1996). Cognate with RMSEA, PCLOSE index testing examines the null hypothesized that RMSEA value is 0.05 in which considered as a one-sided test.

4. Standardized Root Mean Square Residual SRMR:

It measures the difference between the residual of observed and hypothesized covariance matrices. Standardized RMR test is used to overcome the problem of scales of the variables in Root Mean Square Residual RMR test because it is virtually impossible to determine whether RMR value indicates a good model fit or not. A value of 0.05 or less indicates a good model fit (Schermelleh-Engel et al. 2003).

- Step Four: Verifying Data Normality

When using Maximum Likelihood estimation in SEM, it is very important to verify multivariate normality assumption after achieving model GOF. This will help in producing better results if data are normally distributed. Non-normal data may inflate chi-square, deflate standard error, and bias the coefficient significance.

Skewness and Kurtosis values will be used to examine data normality. The value of Critical Raito C.R.. is a good indication of data normality where a value less than 5 indicates a good validity of multivariate normality (Byrne, 2010). In AMOS Software, it is quite easy to examine multivariate normality by using Bootstrapping technique where Bollen-Stine p-value will be determined. If p-value is greater than 0.05 then multivariate normality is achieved.

- Step Five: Evaluating Model Validity and Reliability

After achieving model GOF and confirming model normality, it is very important to evaluate model validity and reliability which are related to the quality of the model. Model validation is usually referring to the task of confirming that measurement model output is acceptable with respect to real data. In other words, it tests how accurate is the developed measurement model. On the other hand, Reliability indicates how consistence is the measurement model which can reproduce the same results when the measurements are done under the same conditions. Generally, valid measurement is reliable, but it is not necessary the opposite is true.

In this research two tests will be conducted to ensure a proper validation of the measurement model which are Convergent Validity and Discriminant Validity. The first test will be used as an assessment of for the degree of correlation of multiple indicators of the same construct (Hamid et al. 2017). When all indicators in a measurement model are statistically significant, this validity is achieved. Average Variance Extracted AVE is the index used to evaluate the model convergent validity where its value ranges from 0 to 1, and a value greater that 0.5 is a good indicator of model validation (Hamid et al. 2017). However, if in some cases AVE value was found less than 0.50 but Composite Reliability CR value was greater than 0.60, model convergent validity is considered acceptable (Fornell & Larcker, 1981) (Lam, 2012).

On the other hand, discriminant validity measures how constructs differing from each other, in addition to the level of differences between overlapping constructs. Fornell-Lacker criterion will be used to evaluate discriminant validity where AVE will be compared with the Average Shared Variance ASV and Maximum Shared Variance MSV. ASV is representing the average squared correlations between a construct and other constructs while MSV is representing the maximum squared correlation between a construct and other constructs. In order to say that discriminant validity is achieved, AVE should be greater and ASV and MSV

(Farrell, 2010). The equation below represents the parameters involved in determining AVE.

$$AVE = \frac{\sum Li^2}{n} \text{ ……… (Equation 1)}$$

Li= Standardized Factor Loading
n= Total Number of Items

When it comes to reliability, Composite Reliability CR test will used to examine the degree to which the said measurement model is accurate in the measurement of the intended latent construct. In order to say that the measurement model reliability is great, Composite Reliability CR value should be greater than 0.70 (Hwui and Lay 2018). However, CR value of less than 0.70 and above 0.50 are still acceptable (Daud et al. 2018). CR can be calculated using the following formula.

$$CR = \frac{(\sum Li)^2}{(\sum Li)^2 + (\sum 1 - Li^2)} \text{ ……… (Equation 2)}$$

Li= Standardized Factor Loading

- Step Six: Developing Structural Equation Model

  After ensuring that all tests which were mentioned before in previous steps are achieved, structural model will be developed which will represent the final correlation between indicators and constructs within the model. This model will help in understanding the behavior of indicators and constructs in generating construction wastes in infrastructure project.

- Step Seven: Testing of Hypothesis

  Hypothesis testing examines the fit of the whole model and verify whether the hypotheses stated at the early stage of the research are valid or not. Standardized Factor Loading SFL and R-Square are used for this purpose.

- Step Eight: Calculating the Effective Weight and Ranking

  This step is divided into three parts which are calculating effective weight and ranking of constructs, calculating effective weight, and ranking of indicators and finally calculating overall effective weight and ranking of indicators. Below are the formulas which will be used to calculate effective weights where first two formulas will be used to calculate effective weight for constructs and indicators and the third formula for calculating overall effective weight of indicators.

$$EWc = \frac{SFL\ c}{\sum SFLc} \text{ ……… (Equation 3)}$$

$$EWi = \frac{SFL\ i}{\sum SFLi} \text{ ……… (Equation 4)}$$

$$OEWi = EWi\ x\ EWci \text{ ……… (Equation 5)}$$

EWc= Effective weight of constructs
SFLc= Standardized Factor Loading of constructs
EWi= Effective weight of indicators
SFLi= Standardized Factor Loading of indicators
OEWi= overall effective weight of indicators.

The following step will be ranking these constructs and indicators as per their weights from highest to lowest value.

4.4.2 Development of Measurement Model

Developing a Measurement Model will help to examine the relationship between the observed variables and latent variables (constructs). The research data was going through the series of steps which were mentioned in previous section to develop measured model. AMOS Software was used to develop the measurement model as shown in Figure 10.

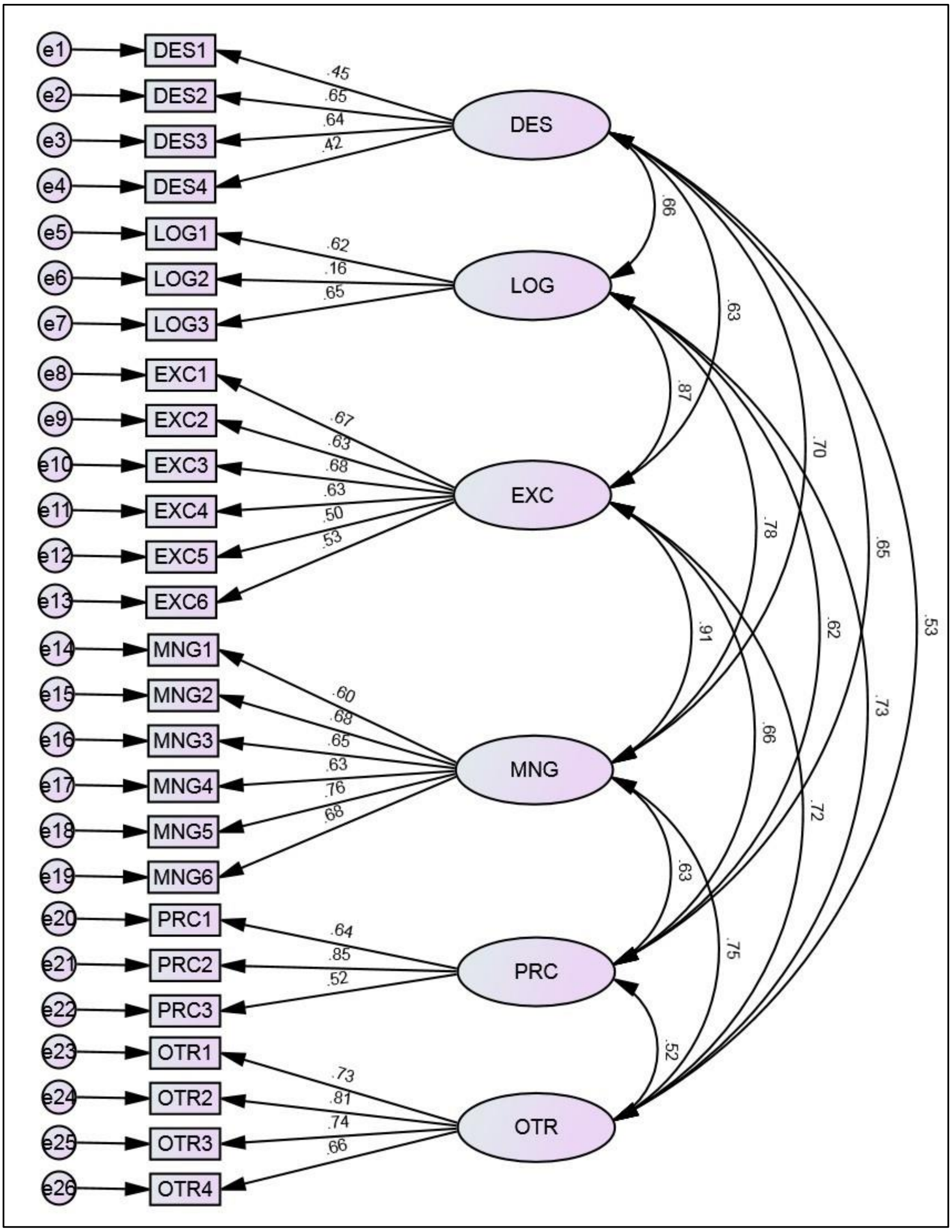

Figure 10. The measurement model.

Figure 10 represents the correlation between indicators and constructs along with their standardized factor load. In some cases, it is noticeable that the correlation is somehow strong between indicator and construct as is the case of indicator (PRC2). On the other hand, some correlations are so weak as is the case of (LOG2).

Once the measurement model has been developed, it important to verify the GOF of the model as per the pre-defined indices. The value of Relative Chi-Square *(X^2/df)* was found 1.89 which is within the acceptable range. However, Comparative Fit Index CFI value was 0.842 which indicates a poor mode fit as it is less than 0.90. Also, the model fails to fit in the term of Pclose as the value obtained was 0 which is less than the minimum value of 0.05. The Measurement Model GOF result and Threshold are summarized in Table 14.

Table 14. GOF Results for Measurement Model

Model Fitness Indices		**Model Value**	**Threshold**	**Goodness of Fit**
Chi-Square	X^2	536.75	-	-
	df	284	-	-
	X^2/df	1.89	[1,3]	FIT
Comparative Fit Index	CFI	0.842	> 0.90	UNFIT
Root Mean Square Error of Approximation	RMSEA	0.073	< 0.08	FIT
PCLOSE	PCLOSE	0.000	> 0.05	UNFIT
The Standardized Root Mean Square Residual	SRMR	0.065	< 0.08	FIT

The table above concludes that the model GOF was not achieved as some of the indices were not met such as CFI and Pclose. In addition to that, some correlation between indicators and constructs were found below 0.50 which indicates a poor correlation. Additionally, model multivariate normality was checked, and data was found non-normally distributed as shown in Figure 11. Skewness and Kurtosis also were checked, and the result of CR was not indicating a proper multivariate normality as it was greater than 5. Table 15 represent Skewness & Kurtosis values of measurement model. As a result, Measurement Model should be modified in a manner which make it more fit and meet all indices requirements.

```
                                 |--------------------
                      198.383    |*
                      239.124    |*****
                      279.866    |*************
                      320.608    |********************
                      361.349    |******************
                      402.091    |**********
                      442.833    |****
N = 1000              483.574    |****
Mean = 435.904        524.316    |*******
S. e. = 4.286         565.058    |**********
                      605.799    |************
                      646.541    |*******
                      687.283    |****
                      728.024    |**
                      768.766    |*
                                 |--------------------
```

Figure 11. Multivariate normality of measurement model.

Table 15. Skewness & Kurtosis values of Measurement Model

Variable	min	max	skew	c.r.	kurtosis	c.r.
OTR1	1.000	5.000	-.520	-2.743	-.438	-1.156
OTR2	1.000	5.000	-.429	-2.265	-.595	-1.570
OTR3	1.000	5.000	-.829	-4.375	.673	1.776

Variable	min	max	skew	c.r.	kurtosis	c.r.
OTR4	1.000	5.000	-.428	-2.257	-.580	-1.531
PRC1	1.000	5.000	-1.254	-6.617	1.271	3.353
PRC2	1.000	5.000	-.831	-4.386	.053	.139
PRC3	1.000	5.000	-.280	-1.477	-.556	-1.467
MNG1	2.000	5.000	-1.009	-5.321	.177	.467
MNG2	2.000	5.000	-.766	-4.041	.027	.072
MNG3	2.000	5.000	-.813	-4.290	-.044	-.117
MNG4	2.000	5.000	-.586	-3.092	-.439	-1.159
MNG5	2.000	5.000	-.674	-3.555	-.243	-.642
MNG6	2.000	5.000	-.560	-2.953	-.425	-1.122
EXC1	1.000	5.000	-.666	-3.513	.054	.141
EXC2	2.000	5.000	-.584	-3.083	-.384	-1.013
EXC3	1.000	5.000	-1.117	-5.894	1.310	3.455
EXC4	1.000	5.000	-.636	-3.356	.027	.072
EXC5	2.000	5.000	-.976	-5.147	.007	.018
EXC6	1.000	5.000	-.945	-4.987	-.257	-.677
LOG1	2.000	5.000	-.839	-4.426	.041	.109
LOG2	2.000	54.000	12.074	63.702	149.805	395.167
LOG3	2.000	5.000	-.808	-4.264	-.119	-.314
DES1	2.000	5.000	-.597	-3.149	-.148	-.391
DES2	2.000	5.000	-.626	-3.303	-.294	-.775
DES3	2.000	5.000	-.877	-4.629	-.035	-.092
DES4	1.000	5.000	-.594	-3.133	-.078	-.207
Multivariate					228.342	**38.666**

4.4.3 Development of Modified Model

The modified model is an enhanced version of the measurement model after taking into consideration some rectifications related to indicators relationships and model theory. Effectively, modifications to the measurement model assert that the items/data are impure measures of the theory-specified latent variables. These modifications will result in improving model fit and make it more reality representative. In AMOS, Modification Index M.I. was used to determine the sources beyond the misfit of the model which might be due to parameters unsupported by theory. MIs measure the reduction amount in Chi-Square if a parameter restriction was removed from the model. This reduction will result in improvement of the model and achieving model fit. Figure 12 represent the modified model by AMOS.

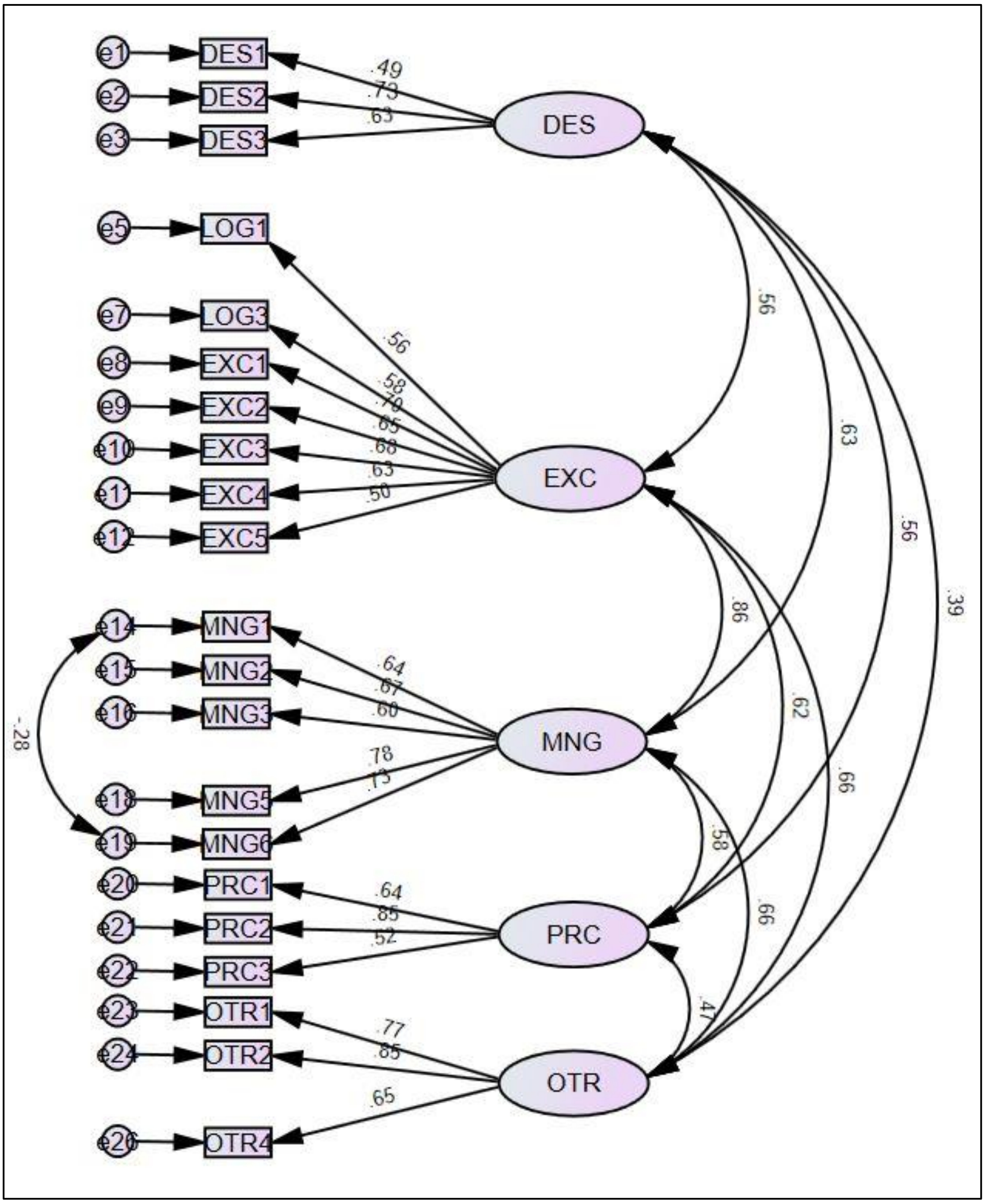

Figure 12. The modified model.

According to Matsunaga (2010), to develop the modified model indicators which are below 0.40 should be eliminated as they represent low factor loading, poor relation with their construct, and this might disrupt the model. Hence, LOG2 indicator was eliminated as its factor load is too low (0.16) as shown in Figure 12. At the same time, it was observed that the correlation between Logistics and Execution groups (constructs) is too high (0.87) and it is not recommended to have a construct with less than three indicators. Therefore, a research study which was conducted by Farrell (2010) stated that when the correlation between constructs is too high, between 0.80 to 0.90) it might be useful to combine the constructs into an overall construct if we make theoretical and logic sense. As a result, it was decided that the remaining factors of Logistics group (LOG1 & LOG3) can be listed under Execution group since they can be considered as part of execution activities. Additionally, some other indicators were eliminated from the model as they are disturbing the model fit such as DES4, EXC6, MNG4 and OTR3. All these modifications were done at multi-stages during the development of modified model.

From above figure, it obvious that all indicators factor loads are above 0.50 which denotes good correlations expect for DES1, 0.49, which is very close to 0.50. Checking GOF of the modified model, it was found that Chi-Square of the model was reduced to 1.544 which is still within the threshold stated earlier. Unlike the case of measurement model, the CFI was improved to be 0.921 which is greater than 0.90 and hence ending up with achievement of CFI index requirement. In addition to that, RMSEA and Pclose values were 0.057 and 0.183, respectively. Both values are meeting the required Threshold of less than 0.08 for RMSEA and greater than 0.05 for Pclose. Finally, SRMR value was found 0.0551 which is acceptable since it is less than 0.08. Table 16 summarizes the output of modified model GOF.

Table 16. GOF Results of Modified Model

Model Fitness Indices		Model Value	Threshold	Goodness of Fit
Chi-Square	X^2	274.753	-	-
	df	178	-	-
	X^2/df	1.544	[1,3]	FIT
Comparative Fit Index	CFI	0.921	> 0.90	FIT
Root Mean Square Error of Approximation	RMSEA	0.057	< 0.08	FIT
PCLOSE	PCLOSE	0.183	> 0.05	FIT
The Standardized Root Mean Square Residual	SRMR	0.0551	< 0.08	FIT

From above table it was found that the values obtained for each test was achieving the threshold values, hence, GOF of the model is achieved.

Since GOF of the model was achieved, multivariate normality was tested again, and it was found that the model is normally distributed and multivariate normality is achieved too as p-value is 0.100 which is greater than 0.05, for 1000 bootstrapped samples. Besides that, Chi-Square value X^2 of the model was 274.753 which lays within normal distribution area of Chi-Square values obtained from Bootstrap as in Figure 13. As a result, the null hypothesis of the model is accepted. Figures 13 represent AMOS output regarding multivariate normality testing using Bollen-Stine Bootstrap.

```
                                  |--------------------
                        111.788   |*
                        133.556   |*
                        155.323   |***
                        177.091   |**********
                        198.859   |*******************
                        220.627   |********************
                        242.395   |***************
N = 1000                264.163   |**********
Mean = 224.877          285.931   |*****
S. e. = 1.223           307.699   |**
                        329.467   |**
                        351.234   |*
                        373.002   |*
                        394.770   |
                        416.538   |*
                                  |--------------------
```

Figure 13. Multivariate normality results of modified model.

The final step in developing the modified model is to test model's validity and reliability. As mentioned at earlier in previous sections, convergent and discriminant tests will be conducted to examine model validity while Composite Reliability CR test will be used to examine model reliability.

Table 17 represents the modified model output which are related to model reliability.

Table 17. Modified Model Reliability Results

Indicator	Latent Variable	Standard Loading	Sum of Standard Loading (A)	Square of Standard Loading	Square of (A)	Measurement Error (ME)	Sum of (ME)	CR
DES1		0.49		0.2401		0.7599		
DES2	DES	0.73	1.85	0.5329	3.42	0.4671	1.83	**0.65**
DES3		0.63		0.3969		0.6031		
LOG1		0.56		0.3136		0.6864		
LOG3		0.58		0.3364		0.6636		
EXC1		0.7		0.49		0.51		
EXC2	M_EXC*	0.65	4.3	0.4225	18.49	0.5775	4.33	**0.81**
EXC3		0.68		0.4624		0.5376		
EXC4		0.63		0.3969		0.6031		
EXC5		0.5		0.25		0.75		
MNG1		0.64		0.4096		0.5904		
MNG2		0.67		0.4489		0.5511		
MNG3	MNG	0.6	3.42	0.36	11.70	0.64	2.64	**0.82**
MNG5		0.78		0.6084		0.3916		
MNG6		0.73		0.5329		0.4671		
PRC1		0.64		0.4096		0.5904		
PRC2	PRC	0.85	2.01	0.7225	4.04	0.2775	1.60	**0.72**
PRC3		0.52		0.2704		0.7296		
OTR1		0.77		0.5929		0.4071		
OTR2	OTR	0.85	2.27	0.7225	5.15	0.2775	1.26	**0.80**
OTR4		0.65		0.4225		0.5775		

*M_EXC: Modified Execution Construct
*M_EXC Construct is indicating the combination of Execution (EXC) and Logistics (LOG) constructs

From above table, it is concluded that CR values are ranging from acceptable, like the case of DES construct, to excellent, like the case of other remaining constructs. As a result, model reliability is achieved as all constructs CR values are above 0.70 except in DES construct.

After model reliability has been achieved, first construct validity will be examined which is convergent validity. This test will be evaluated AVE of each construct that should be greater than 0.50. Below table summarize the results of modified model in regard of convergent validity.

Table 18. Modified Model Convergent Validity Results

Indicator	Latent Variable	Standard Loading	Square of Standard Loading	Average Variance Extracted AVE	Composite Reliability CR	Convergent Validity Remark
DES1	DES	0.49	0.2401	0.39	0.65	Acceptable*
DES2		0.73	0.5329			
DES3		0.63	0.3969			
LOG1	EXC	0.56	0.3136	0.38	0.81	Acceptable*
LOG3		0.58	0.3364			
EXC1		0.7	0.49			
EXC2		0.65	0.4225			
EXC3		0.68	0.4624			
EXC4		0.63	0.3969			
EXC5		0.5	0.25			
MNG1	MNG	0.64	0.4096	0.47	0.82	Acceptable*
MNG2		0.67	0.4489			
MNG3		0.6	0.36			
MNG5		0.78	0.6084			
MNG6		0.73	0.5329			
PRC1	PRC	0.64	0.4096	0.47	0.72	Acceptable*
PRC2		0.85	0.7225			
PRC3		0.52	0.2704			
OTR1	OTR	0.77	0.5929	0.58	0.80	Achieved
OTR2		0.85	0.7225			
OTR4		0.65	0.4225			

*Convergent Validity is acceptable based on (Fornell & Larcker, 1981) (Lam, 2012).

From Table 18, convergent validity is achieved perfectly for OTR construct as AVE is 0.58 which is greater than 0.50. However, all other constructs AVE values were found below 0.50 but their CR values are greater than 0.60 which indicates an acceptable convergent validity. In other words, the correlations between the indicators and their constructs are not very strong but it is acceptable, except the case of OTR construct where its indicators are correlating perfectly with it.

The last step of validating the model is examining discriminant validity. In this test AVE will be compared with ASV and MSV where AVE should be greater than both values. If this is the case, then it is concluded that model discriminant validity is achieved. Table 19 shows the output of modified model in regard of discriminant validity.

Table 19. Modified Model Disriminant Validity Results

		Shared Variance SV Latent Variables					AVE	ASV	MSV	Remark
		DES	M_EXC	MNG	PRC	OTR				
Latent Variables	DES	1					0.39	0.29	0.40	Achieved
	M_EXC	0.31	1				0.38	0.47	0.74	Not Achieved
	MNG	0.40	0.74	1			0.47	0.42	0.38	Achieved
	PRC	0.31	0.38	0.33	1		0.47	0.31	0.38	Achieved
	OTR	0.15	0.44	0.22	0.22	1	0.58	0.26	0.44	Achieved

The results of discriminant validity in above table indicates a good achievement expect for the correlation between Management MNG and Modified Execution M_EXC latent variables as AVE is smaller than both ASV and MSV. The reason behind that can be explained by the strong relation between management and execution processes as some indicators in Management MNG group can be interpreted as part of management and execution at the same time. In this context, a research study conducted by Pace (2019) represented the strong relation between management and execution as they both form around 54% of project success.

4.4.3 Structural Equation Model

In this section, Structural Equation Model will be developed which will represent the impact of all constructs on CWMIIP. The correlations between constructs will be dismissed and direct relations will be established between all constructs and CWMIIP. Figure 14 shows the final structural model.

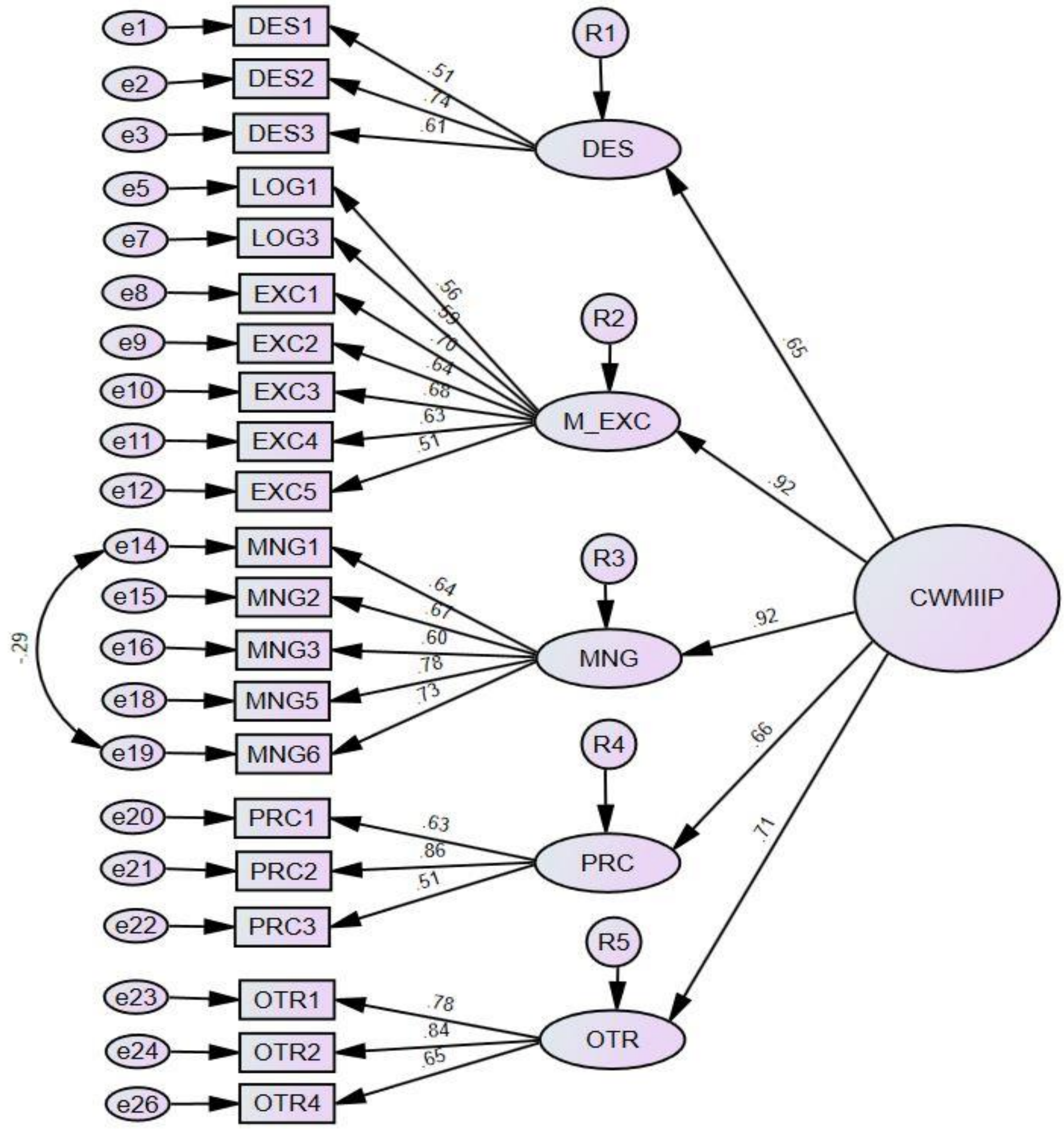

Figure 14. The structural model.

The model fit outputs of above structural model are summarized in Table 20 were all GOF indices are met.

Table 20. GOF Results for Structural Model

Model Fitness Indices		Model Value	Threshold	Goodness of Fit
	X^2	280.551	-	-
Chi-Square	*df*	183	-	-
	X^2/df	1.533	[1,3]	FIT
Comparative Fit Index	CFI	0.920	> 0.90	FIT
Root Mean Square Error of Approximation	RMSEA	0.057	< 0.08	FIT
PCLOSE	PCLOSE	0.199	> 0.05	FIT
The Standardized Root Mean Square Residual	SRMR	0.0568	< 0.08	FIT

After achieving model goodness of fit, the relationships between CWMIIP and constructs will be examined by checking the percent of variance explained R^2 which should be greater than 0.50. Table 21 represents the results of the standardized factor loading values between constructs and CWMIIP. The results obtained indicates strong relations between CWMIIP and Modified Execution, Management and Others constructs while the relations between CWMIIP and Design and Procurement are considered acceptable as their values are slightly less than 0.50.

Table 21. Standardized Factor Loading Values of Constructs with CWMIIP

	Constructs	Standard Factor Loading SFL	Variance Explained R^2
CWMIIP	DES	0.650	0.423
	M_EXC	0.922	0.850
	MNG	0.925	0.856
	PRC	0.663	0.440
	OTR	0.707	0.500

Also, the relationships between indicators and constructs will be examined by the same way done in previous sections. Table 22 represents the results of the relationships between indicators and constructs. The results obtained are showing strong relationships between the indicators and their constructs as all SFL values are above 0.50.

Table 22. SFL Values of All Indicators with heir Groups

Constructs	Indicators	SFL
DES	DES1	0.510
	DES2	0.735
	DES3	0.608
M_EXC	LOG1	0.562
	LOG3	0.586
	EXC1	0.700
	EXC2	0.645

Constructs	Indicators	SFL
	EXC3	0.684
	EXC4	0.629
	EXC5	0.506
	MNG1	0.640
	MNG2	0.665
MNG	MNG3	0.605
	MNG5	0.776
	MNG6	0.730
	PRC1	0.635
PRC	PRC2	0.859
	PRC3	0.514
	OTR1	0.777
OTR	OTR2	0.844
	OTR4	0.647

4.4.4 Hypotheses Testing

After the model achieved goodness of fit, multivariate normality, construct validity and reliability, Structural Model will be used to examine the pre-stated hypotheses of this research. CWMIIP is considered as second-order construct loaded with 5 first-order constructs which are Design, Execution, Management, Procurement and Others. The factor loading values between first and second order constructs, which are showed in Table 15, is above 0.50 which indicates a strong relationship between them. As a result, the hypotheses which are related to these second-order constructs are supported. However, Logistics construct was dropped during the process of achieving the overall model fitness to meet GOF and validity thresholds. Below table summarizes hypotheses testing results.

Table 23. Hypothese Examination Results

Code	Hypothesis Statement	Result
I	Design has a positive impact on construction waste management in infrastructure projects	Supported
II	Logistics has a positive impact on construction waste management in infrastructure projects	Not Supported
III	Execution* has a positive impact on construction waste management in infrastructure projects	Supported
IV	Management has a positive impact on construction waste management in infrastructure projects	Supported
V	Procurement has a positive impact on construction waste management in infrastructure projects	Supported
VI	Other issues have a positive impact on construction waste management in infrastructure projects	Supported

*The Execution construct stated in research hypotheses was modified to be including some Logistic indicators under the new name of "Modified Execution".

Based on the results of above table, it is important to mention and discuss the reason behind the not supported hypothesis of Logistics. During the development of modified model, it was noticed that the correlation between Logistics and Execution constructs was too high which means that the indicators of one construct are interacting with the other construct. At the same time, the SFL of one of Logistics indicators was too low which was interrupting the model fit, thus, there was a need to eliminate it. On the other hand, Logistics construct had three indicators so if one was eliminated, two will remain which is not recommended. Hence, based on the logic sense, it was concluded that logistics can be considered as one of execution activities where Logistics indicators can be fitted under Execution construct.

The reasons behind this strong correlation can be due to many interpretations. First, it could be due to unclarity of factor statements of Logistics group or not providing enough factors to explain the Logistics group fairly. Another reason might be an overlapping between Logistics and Execution factors which may result in strong interaction of these factors will other groups.

4.5 Discussion of Results

This section will discuss and sort the results obtained from the Structural Model in which the indicators and constructs are affecting the construction waste management in infrastructure projects. It will be divided into three parts which are ranking of constructs, ranking of indicators within each construct and finally an overall summary of indicators and constructs ranking.

4.5.1 Constructs Ranking

The five constructs will be ranked as per their importance of influencing on construction waste management in infrastructure projects. Equation 3 will be used to determine the effective weight of each construct. Table 24 represents the ranking result of these constructs.

Table 24. Effective Weight and Ranking of Constructs

Construct Code	Construct Name	Standardized Factor Loading SFL	Sum of SFL	Effective Weight EWc	Ranking*
MNG	Management	0.925	3.867	0.240	1
M_EXC	Modified Execution	0.922		0.238	2
OTR	Others	0.707		0.183	3
PRC	Procurement	0.663		0.171	4
DES	Design	0.650		0.168	5

*Ranking (1= Most Important, 5= Least Important)

Above table, illustrates that Management is the most important construct in construction waste management in infrastructure projects where it contributes with 24% followed with Modified Execution construct with a slight difference. Other issues which are related to weather, unforeseen conditions and vandalism are coming at the third place which their effective weight is 0.183. Procurement and Design are coming at the bottom of the list with an effective weight of 0.171 and 0.168, respectively. It is concluded that by focusing on improving construction management and execution, construction waste in infrastructure projects can be minimized by almost 50%.

Referring to section 4.3 in this research and particularly Table 13, it is noted that the results of the structural model is matching with the importance order of these groups as per the ranking of respondents. This gives an indication of good outputs of the model.

4.5.2 Indicators Ranking

In this section, indicators within each construct will be ranked based on the same procedures followed in previous section. This will include the constructs of Design, Modified Execution, Management, Procurement and Others. The following tables will represent the results of indicators ranking of all groups (constructs).

Table 25. Effective Weight and Ranking of Design Indicators

Construct Name	**Indicator Code**	**Indicator Description**	**SFL**	**Sum of SFL**	**Effective Weight EWi**	**Ranking***
Design	DES2	Design Errors	0.735	1.853	0.397	1
	DES3	Lack of Design Information	0.608		0.328	2
	DES1	Frequent Design Changes	0.510		0.275	3

*Ranking (1= Most Important, 5= Least Important)

Table 25 shows that Design Errors factor is the most important factor among Design group as it has an effective weight of 0.397. The second important factor is Lack of Design Information with an effective weight of 0.328, and finally Frequent Design Changes factors which has an effective weight of 0.275.

Table 26. Effective Weight and Ranking of Modified Execution Indicators

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
Modified Execution	EXC1	Using Unsuitable Tools Leading to Material Damage	0.700	4.312	0.162	1
	EXC3	Improper installation techniques causing damages to on-going work	0.684		0.159	2
	EXC2	Inexperienced Workers	0.645		0.150	3
	EXC4	Inappropriate Construction Works Execution Strategy for Site Activities	0.629		0.146	4
	LOG3	Improper transportation causing damages to materials	0.586		0.136	5
	LOG1	Improper Storage of Materials	0.562		0.130	6
	EXC5	Rework	0.506		0.117	7

From above table, it is noticed that Using Unsuitable Tools Leading to Material Damage factor is the most highly ranked indictor with effective weight of 0.162. The following factors after it, in order, are Improper installation techniques causing damages to on-going work, Inexperienced Workers, Inappropriate Construction Works

Execution Strategy for Site Activities, Improper transportation causing damages to materials, and Improper Storage of Materials. The least ranked factor of this group is Rework as it has an effective weight of 0.117.

Table 27. Effective Weight and Ranking of Management Indicators

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
Management	MNG5	Improper Controlling and Supervision Strategy to monitor and guide workers	0.776	3.416	0.227	1
	MNG6	Improper daily site management leading to leftover materials on site	0.730		0.214	2
	MNG2	Lack of Construction Waste Management Knowledge	0.665		0.195	3

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
	MNG1	Poor communication among project parties	0.640		0.187	4
	MNG3	Poor Planning of Site Layout	0.605		0.177	5

Table 27 represents the ranking results of Management group indicators. Improper Controlling and Supervision Strategy to monitor and guide workers factor is coming at the first place as it has an effective weight of 0.227, followed by Improper daily site management leading to leftover materials on site, Lack of Construction Waste Management Knowledge, and Poor communication among project parties, respectively. However, Poor Planning of Site Layout factor is coming at the fifth place with an effective weight of 0.177.

Table 28. Effective Weight and Ranking of Procurement Indicators

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
Procurement	PRC2	Quantity Take-off Error by	0.859	2.008	0.428	1

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
		Contractor				
	PRC1	Wrong ordering of materials by procurement team	0.635		0.316	2
	PRC3	Minimum Order Requirement by Suppliers	0.514		0.256	3

Table 28 illustrates the ranking results of Procurement group indicators where Quantity Take-off Error by Contractor factor form more than two third of group weight as it has an effective weight of 0.428. The remaining two factors which are Wrong ordering of materials by procurement team and Minimum Order Requirement by Suppliers are followed with effective weight of 0.316 and 0.256, respectively.

Table 29. Effective Weight and Ranking of Other Indicators

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
Others	OTR2	Unforeseen Incidents Damaging Site	0.844	2.268	0.372	1

Construct Name	Indicator Code	Indicator Description	SFL	Sum of SFL	Effective Weight EWi	Ranking
		and/or Completed Works				
	OTR1	Extreme Weather Conditions Damaging Completed Works	0.777		0.343	2
	OTR4	Theft and Vandalism	0.647		0.285	3

The ranking results of indicators of the last group, Other, is represented in Table 29. Unforeseen Incidents Damaging Site and/or Completed Works factor is the highest weighted with an effective weight of 0.372. Extreme Weather Conditions Damaging Completed Works factor is coming on the second place with a slight difference as it has an effective weight of 0.343. Lastly, Theft and Vandalism factor is coming with an effective weight of 0.285.

4.5.3 Overall Effective Weight of Indicators

In this section and after ranking constructs and indicators individually, all indicators will be ranked in an overall manner to represent the final ranking of indicators of this research. The effective weight of each indicator obtained from previous section will be multiplied with its group effective weight as indicated by Equation 5. The results obtained from this section will help to ranking the indicators in overall in which they are contributing construction waste management in infrastructure projects. Table 30 illustrates the results of overall effective weight of all indicators while Table 31 illustrates the final ranking of all indicators.

Table 30. Overall Effective Weight for All Indicators

Construct Code	Indicator Code	Construct Effective Weight EWc	Indicator Effective Weight EWi	Indicator Overall Effective Weight OEWi
DES	DES1	0.168	0.275	0.0462
	DES2		0.397	0.066696
	DES3		0.328	0.055104
M_EXC	LOG1	0.238	0.130	0.03094
	LOG3		0.136	0.032368
	EXC1		0.162	0.038556
	EXC2		0.150	0.0357
	EXC3		0.159	0.037842
	EXC4		0.146	0.034748
	EXC5		0.117	0.027846
MNG	MNG1	0.240	0.187	0.04488
	MNG2		0.195	0.0468
	MNG3		0.177	0.04248
	MNG5		0.227	0.05448
	MNG6		0.216	0.05184
PRC	PRC1	0.171	0.316	0.054036
	PRC2		0.428	0.073188
	PRC3		0.256	0.043776
OTR	OTR1	0.183	0.343	0.062769
	OTR2		0.372	0.068076
	OTR4		0.285	0.052155

Table 31. Overall Ranking for All Indicators

Indicator Code	Indicator Description	Indicator Overall Effective Weight OEWi	Ranking
PRC2	Quantity Take-off Error by Contractor	0.073188	**1**
OTR2	Unforeseen Incidents Damaging Site and/or Completed Works	0.068076	**2**
DES2	Design Errors	0.066696	**3**
OTR1	Extreme Weather Conditions Damaging Completed Works	0.062769	**4**
DES3	Lack of Design Information	0.055104	**5**
MNG5	Improper Controlling and Supervision Strategy to monitor and guide workers	0.05448	**6**
PRC1	Wrong ordering of materials by procurement team	0.054036	**7**
OTR4	Theft and Vandalism	0.052155	**8**
MNG6	Improper daily site management leading to leftover materials on site	0.05184	**9**
MNG2	Lack of Construction Waste Management Knowledge	0.0468	**10**
DES1	Frequent Design Changes	0.0462	**11**
MNG1	Poor communication among project parties	0.04488	**12**
PRC3	Minimum Order Requirement by Suppliers	0.043776	**13**
MNG3	Poor Planning of Site Layout	0.04248	**14**
EXC1	Using Unsuitable Tools Leading to Material Damage	0.038556	**15**
EXC3	Improper installation techniques causing damages to on-going work	0.037842	**16**
EXC2	Inexperienced Workers	0.0357	**17**
EXC4	Inappropriate Construction Works	0.034748	**18**

Indicator Code	Indicator Description	Indicator Overall Effective Weight OEWi	Ranking
	Execution Strategy for Site Activities		
LOG3	Improper transportation causing damages to materials	0.032368	**19**
LOG1	Improper Storage of Materials	0.03094	**20**
EXC5	Rework	0.027846	**21**

From Table 31, it is concluded that the most two effective factors in construction waste management in infrastructure projects are “Quantity Take-off Error by Contractor”, which has an overall effective weight of 0.0732, followed by “Unforeseen Incidents Damaging Site and/or Completed Works”, over all effective weight of 0.0681. On the other side, the least effective factor is “Rework” which has an overall effective weight of 0.0278. What is important to be mentioned here that all of the factors loaded on Modified Execution group are coming at the bottom of the ranking list.

CHAPTER 5: RECOMMENDATIONS AND CONCLUSION

5.1 Overview

This chapter will conclude the outcomes of the research objectives by defining the factors affecting construction waste management in infrastructure projects, determining the influence level of these factors and their relationships with their groups, and finally suggesting for improvements. Aside of that, it will discuss some recommendations which are suggested according to the results obtained from the structural model. These recommendations are expected to have positive impact on reducing the effects of the factors contributing construction waste in infrastructure projects.

5.2 Recommendations

According to the results obtained from the Structural Model which are related to the level of importance of the groups that are affecting construction waste management, it was found that Management was the most effective group (construct). Then it was followed by Modified Execution, Others, Procurement and Design groups, in order as illustrated previously in Table 24. Hence, the focus here will be on suggesting recommendations for these groups that will help in reducing their effect on construction waste management in infrastructure projects. The recommendations of each groups will be discussed separately as per the following sub-sections.

5.2.1 Management Recommendations

Management is considered as the most effective group on construction waste management in infrastructure project. Hence, a special attention must be taken when considering things which are related to this group. The following recommendations are suggested to improve the management related issues which are affecting CWMIIP:

I. Applying Construction Waste Management Implementation Plan CWMIP as a mandatory documentation that the contractor must submit and comply with as a requirement by projects' clients to award the project. CWMIP is known as the plan in which the contractor states the details of what type and amount of wastes will be generated during the construction process of a project and his methodology of how these wastes can be reduced or reused. The project contract documents could specify the minimum expectation of construction waste reduction, recycling, reusing, and disposal which an owner is expecting. During the construction stage, The Engineer assigned for the project should closely monitor the contractor's performance according to his CWMIP and take the needed measurement to ensure a proper implementation of this plan. Implementing such technique may result in managing the materials more efficiently and hence reducing the cost associated. Additionally, it will help in reducing the amount of construction waste which are being disposed to landfill which will result in environmental benefits.

II. Spreading the awareness of Construction Waste Management among project team. This can be achieved by conducting continuous training for project team, and award incentives for those who are performing well in term of CWM. Also, conducting internal audits within the contractor organization will help in a proper implementation and monitoring of CWM.

III. Properly defining the roles and responsibilities of project team and setting a clear reporting system. When responsibility matrix is defined clearly by project management within a project, there will be no gaps of responsibilities, hence, every single personnel in a project will know what is expected from him to do.

Implementing this action will result in improving the monitoring of site activities as site engineers and supervisors are aware that it is part from their job to ensure a proper daily plan for work, closely monitoring the workers at site and guide them for the best ways of performing a job. Also, the materials going out from project store must be monitored precisely to ensure that only the required materials will be issued to working place, as a result, there will be no materials leftover at working place due to over requesting.

IV. Improving communication and collaboration among project parties during managing construction processes. This can be achieved by organizing frequent gathering/ meeting of project stakeholders to ensure that they are all aware of the activities carried on-site and the sequence of work which will be done by each stakeholder. As a result, the conflict between project stakeholders will be eliminated/ reduced as they are collaborating in planning for construction processes, and potential risks might be detected and resolved at early stage. Additionally, using Building Information Modelling BIM might be an effective software to reduce the conflict among project parties.

5.2.2 Execution Recommendations

The second ranked group based on its effect on construction waste management in infrastructure projects was Execution, however, there was a slight difference between the first and second group. The following recommendations are set in a manner that will reduce the effect of this group on CWMIIP:

I. Conducting trainings for contractors' staff and workers by project suppliers who are providing materials to the project. These trainings may include the proper way of handling and installing the materials, and suitable tools to be used for performing the job which will result in better efficiency. It is an important action to involve project's suppliers and sub-contractors in execution stage as they are the experts in performing their job. Additionally, it is not recommended to keep changing the crews how were trained to perform a certain job as these frequent changes will reduce the efficiency of work and increase construction waste.

II. During the preparation of Project Execution Plan PEP, it is very important to get into consideration the input of project's sub-contractors as they are part of the project. This will make the PEP more mature and reflecting the real work that will be carried on site. Additionally, all site construction team must read the PEP carefully to ensure a proper implementation of the most effective execution methods. As a result, the potential conflicts and rework will be minimized to the lowest limit possible.

III. Implementing Just-In-Time JIT concept for issuing the materials to site (working places within the project limits). The expected results of implementing such concept are reducing the unnecessary requested materials which will lead to reduce the amount of damaged materials on site due to poor storage precautions. Also, it will help in reducing the double handling/ transportation of excessive materials which will result in reducing the potential risk of getting the materials damaged during transportation.

5.2.3 Other Issues Recommendations

Some factors were believed are importantly affecting construction waste management in infrastructure projects, but they cannot be classified under any of pre-defined groups., hence, all these factors were combined under Others group. Usually, the factors under this group are unexpected issues that make it difficult to be controlled directly, however, they can be mitigated by following below recommendations:

I. Proper implementation of Health, Safety and Environmental Plan HSEP with a continuous strict monitoring of it on site. Generally, it is very difficult in construction projects, especially mega infrastructure projects, to avoid incidents to happen, but they can be mitigated. Following the safety requirements to start and new activity will help in minimizing the potential risk of occurring incidents. As a result, the damaged materials due to these incidents will be reduced and hence improving construction waste management.

II. Establishing a small sub-department under HSE department that is responsible of forecasting the weather conditions. This department should share a daily report to project team to ensure a proper planning of site activities and taking the necessary measurement to protect completed work on site. This action will help in controlling unforeseen weather condition to a certain limit where in some cases it will be out of control.

5.2.4 Procurement Recommendations

According to this research, Procurement is responsible in almost 17% of construction waste infrastructure projects. Hence, it is recommended that locally purchased materials to be requested at multiple stages during project lifecycle to ensure an accurate quantity ordering. Applying such technique will help in mitigating any changes of total needed materials instead of requesting the full quantity needed at the beginning of the project. However, long lead materials which require international shipment and longer delivery period are excluded from above technique as requesting the materials at once may achieve Economy of Scale. In such cases, it is recommended that to review the final order carefully and only after it is being reviewed by The

Engineer.

5.2.5 Design Recommendations

Finally, Design is considered as the least affecting group on construction waste management in infrastructure projects. However, it is still valid that improving this group may has a positive effect on other groups such execution and procurement. Thus, it is recommended that project design should be studied carefully at the early stage of the project. Additionally, involving sub-contractors and specialists who will be part of the project at design stage is an important matter which will help in minimizing omissions or missed information. Aside of that, it will help in eliminating design changes unless it is requested by project owner.

5.2.6 Recommendations for Future Studies:

During this research, one of the research hypotheses was dropped due to some issues which are expected to the main reasons. The positive effect of Logistics group on Construction Waste Management in Infrastructure Projects hypothesis was dropped during this research since it was found that it is having indirect effect through Execution group. The reasons behind that might be due unclarity of research questionnaire, not providing enough factors to clearly describe Logistics group, or could be due to other reasons.

Based on that, it is recommended to extend this research topic to be specified about understand the effect of Logistics and Execution groups on infrastructure projects to clear the ambiguity that happened during this research. This recommended future study will help in full understanding of the groups and factors that are affecting construction waste management in infrastructure projects.

Additionally, the waste generated through demolition process is consider to be huge in quantity and its effect of landfills and society. Therefore, studying the impact of construction waste generated from demolition process is suggested for future study as it will complete the understanding of construction waste in conjunction with this research.

5.2.7 Recommendations for Qatari Construction Industry

This research was initiative from Qatar University in partial fulfillment of the requirements for the Degree of Master of Science of Engineering Management, hence, this section is specified to suggest recommendations for Qatari construction industry in term of construction waste management. The goal of this section is to spot the light on some aspects to improve the performance of CWM in Qatari construction industry especially with the tremendous growth of construction and infrastructure due to World Cup 2022.

The construction waste generated due to construction and infrastructure enhancement in the State of Qatar is significant and must be considered seriously for better projects delivery and green environment. As a result, Public Works Authority "Ashghal" started the initiative of Lean Construction implementation within its new enhanced projects which mainly results in reduction of non-physical wastes. Therefore, it is suggested to set some regulations and policies at the State of Qatar for better controlling of construction waste management implementation within its projects. This can be achieved by setting a minimum requirements of construction waste management initiatives within the contract documents of new projects. As a result, all contractors who are willing to get awarded must meet these requirements and prove their capabilities of implementing CWM. Furthermore, some construction waste management standards might be added to Qatar Construction Specifications QCS, which is the code being used in the State of Qatar of construction.

These initiatives will help in reducing the construction waste produced by construction industry in the State of Qatar by allowing the reuse and recycling of some materials in the execution of a new project.

5.3 Conclusion

At the end, the results of this research must clarify and clearly answer the objectives which were set at the beginning of this study. The main objectives were identifying the factors affecting construction waste management in infrastructure project and categorize them under groups, understanding the relationships between these groups and CWMIIP, and finally suggesting for recommendations to improve construction waste management in infrastructure projects based on the outcomes of this research.

The first objective was achieved by identifying 26 factors which were believed they are having positive effect on CWMIIP. Also, all the factors were categorized under 6 groups which are Design, Logistics, Execution, Management, Procurement and Others. On the other hand, the second objective was achieved by developing a Structural Model which represented the relationships between two level of constructs along with the effective weight of each factor and group that are affecting Construction Waste Management in Infrastructure Projects. It was found that Management is the highest effective weight group followed by Modified Execution group with very slight difference which make them both very important to be considered during project lifecycle. Others, Procurement and Design groups are following in the same order. However, when it comes to factors ranking, it was determined that “Quantity Take-off Error by Contractor” is the most effective factor, which is belong to Procurement group, with an overall effective weight of 7.3%. The second factor in importance was “Unforeseen Incidents Damaging Site” from Others group with an overall effective weight of 6.8%. These unforeseen incidents are happening mainly due to not following the required safety precautions during project construction. "Design Error" is considered as the third factor in term of importance which is one of Design group factors where it counts an overall effective weight of 6.7%. "Extreme Weather Conditions Damaging Completed Works", "Lack of Design Information", "Improper Controlling and Supervision Strategy to monitor and guide workers", "Wrong ordering of materials by procurement team", "Theft and Vandalism", "Improper daily site management leading to leftover materials on site", and "Lack of Construction Waste Management Knowledge" are the following previous factors in order. Previously mentioned factors are the 10 most effective factors determined within this research. Therefore, focusing on improving the performance of a project based on these factors will result in a reduced amount of construction waste produced. Finally, the third objective was fulfilled clearly and in details in previous section where some recommendations were suggested to improve the performance of each construct within this research.

Additionally, SEM technique was very useful tool to examine and understand the relationships between the factors and their groups along with the relationships between the groups themselves. The results obtained from the structural model by SEM was closely reflecting the results collected from the respondents. This indicates that choosing SEM technique to represent the model of this research was successful especially that the objective of this research was to perform confirmatory factors analysis.

The outcomes of this research study might be useful for designing, consulting, and contracting firms that are interesting in reducing construction waste generated during the construction of infrastructure project. This interest will eventually result in green environment and better world.

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APPENDIX A: COPY OF THE QUESTIONNAIRE

Construction Waste Management Performance Measurement on Infrastructure Projects

Dear Esteemed Participant,

This questionnaire has been prepared in the scope of an on-going research study "Construction Waste Management Performance Measurement on Infrastructure Projects" in the Department of Engineering Management at Qatar University. Your kind participation is highly required to achieve the purpose of this research. By answering this questionnaire, it is assured that all collected information will absolutely be **confidential.** The expected time required to complete the survey is 5-8 minutes.

Thank you for the time you invested in our research.

Best Regards,

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This survey will be divided into two parts which will be as following:

Part 1: General Information

Part 2: Groups & Factors Contributing Construction Waste Management

Part 1: General Information

This part consists of general questions related to you and your organization. Please select the suitable choices by ticking the box next to them.

1. **What is your total number of years of work experience?**

☐ Less than or equal 5

☐ (6-10)

☐ (11-15)

☐ (16-20)

☐ (21-25)

☐ More than 25

2. **Are you a registered professional (Authority registration, Syndicate Membership, Chartered, PE …)?**

☐ Yes (please specify, ……………………………………)

☐ No

3. Which of the following describes the type of your organization?

☐ Client

☐ Consultant

☐ Designer

☐ Contractor

☐ Others (please specify, ………………………………)

4. Which one of the following describes your organization's sector?

☐ Public

☐ Private

5. What is your position at your organization?

☐ Executive Manager

☐ Department Manager

☐ Project Director

☐ Project Manager

☐ Senior Engineer (specify department, …………………)

☐ Safety

☐ Engineer

☐ Others (please specify, ……………………..

6. Which division describes your project?

☐ Building Construction

☐ Infrastructure (Roads, Bridges, Railways …)

☐ Oil & Gas

☐ Others (please specify, ………………………)

7. Are you aware of Construction Waste Management?

☐ Yes

☐ No

8. Do you think that Construction Waste Management play a significant role in project performance?

☐ Yes

☐ No

Part 2: Groups & Factors Contributing Construction Waste Management

This part will focus on the importance of some groups and factors that contribute the generation of construction wastes. 6 groups (Design, Logistics, Execution, Management, Procurement and Others) and 26 factors were identified as the major contributors to construction wastes. Please select the suitable expression next to each variable taking into consideration its **Importance Level** on Construction Wastes Generation.

What is the importance level of the following Groups & Factors on the generation of Construction Wastes?

Group 1: Design

9. What is the Level of Importance of Frequent Design Changes in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

10. What is the Level of Importance of Design Errors in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

11. What is the Level of Importance of Lack of Design Information in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

12. What is the Level of Importance of Uneconomic Design or Shapes in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

Group 2: Logistics

13. What is the Level of Importance of Improper Storage of Materials in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

14. What is the Level of Importance of <u>Poor Handling of Materials</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

15. What is the Level of Importance of <u>Improper Transportation Causing Damages to Materials</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

Group 3: Execution

16. What is the Level of Importance of <u>Using Unsuitable Tools Leading to Material Damage</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

17. What is the Level of Importance of Inexperienced Workers in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

18. What is the Level of Importance of Improper Installation Techniques Causing Damages to On-going Work in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

19. What is the Level of Importance of Inappropriate Construction Works Execution Strategy for Site Activities in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

20. What is the Level of Importance of <u>Rework</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

21. What is the Level of Importance of <u>Contractor Working on Site Without Approval by Client or Consultant</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

Group 4: Management

22. What is the Level of Importance of <u>Poor Communications Between Project Parties</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

23. What is the Level of Importance of <u>Lack of Construction Waste Management Knowledge</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

24. What is the Level of Importance of <u>Poor Planning of Site Layout</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

25. What is the Level of Importance of <u>Poor Quality Management System</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

26. What is the Level of Importance of Improper Controlling and Supervision Strategy to Monitor and Guide Workers in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

27. What is the Level of Importance of Improper Daily Site Management Leading to Leftover Materials On-site in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

Group 5: Procurement

28. What is the Level of Importance of Wrong Ordering of Materials by Procurement in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

29. What is the Level of Importance of <u>Quantity Take-off Error by Contractor</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

30. What is the Level of Importance of <u>Minimum Order Requirement by Supplier</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

Group 6: Others

31. What is the Level of Importance of <u>Extreme Weather Conditions Damaging Completed Works</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

32. What is the Level of Importance of <u>Unforeseen Incidents Damaging Site</u>

<u>and/or Completed Works</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

33. What is the Level of Importance of <u>Poor Subcontractors Performance Causing Damages to Others Work</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

34. What is the Level of Importance of <u>Theft & Vandalism</u> in Generating Construction Wastes?

☐ Not Important at all

☐ Slightly Important

☐ Moderately Important

☐ Very Important

☐ Extremely Important

35. What is the Level of Importance of <u>Design</u> in Generating Construction Wastes?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
◯	◯	◯	◯	◯

36. What is the Level of Importance of Logistics in Generating Construction Wastes?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
○	○	○	○	○

37. What is the Level of Importance of Execution in Generating Construction Wastes?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
○	○	○	○	○

38. What is the Level of Importance of Management in Generating Construction Wastes?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
○	○	○	○	○

39. What is the Level of Importance of Procurement in Generating Construction Wastes?

Not at all important	Slightly important	Moderately important	Very important	Extremely important
○	○	○	○	○

End of This Survey, THANK YOU…