DETERMINING THE DELAY FACTORS FOR RECONSTRUCTED MEGA-PROJECT'S PHASES AND THE ASSOCIATED CHALLENGES

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FACULTY OF ENGINEERING
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KUALA LUMPUR

2021

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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

**FACULTY OF CIVIL ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR**

2021

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Basem Adnan Al Khatib

Matric No: KVA170037, 17043396/1

Name of Degree: Doctor of Philosophy

Title of Thesis:

DETERMINING THE DELAY FACTORS FOR RECONSTRUCTED MEGA-PROJECT'S PHASES AND THE ASSOCIATED CHALLENGES

Field of Study: Construction Technology & Management
(Civil Engineering)

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DETERMINING THE DELAY FACTORS FOR RECONSTRUCTED MEGA-PROJECT'S PHASES AND THE ASSOCIATED CHALLENGES

ABSTRACT

In recent decades, the construction industry has developed rapidly. Delays in construction projects are a common phenomenon throughout industry. It was and remains one of the most important challenges negatively affecting not only this industry but also the economy. Many studies were conducted to identify the delay factors in new construction projects in different regions, but very few have focused on finding an explanation for the delay causes in reconstruction projects. The study aims to conduct a comprehensive analysis of the delay factors in mega reconstruction projects which took place recently in the Middle East, namely Mataf Expansion Project in Mecca, Saudi Arabia. This project consists of two main parts, nonhistorical and historical and it clarifies the difficulties facing this type of reconstruction projects, which combine demolition and construction works at the same time while the project is under operation. In order to achieve the study goal, twenty-nine interviews were held with the experts working on the project to identify the delay factors and ninety-three questionnaires were distributed by hand to sort them. The results showed that these factors could be divided into three groups: the first one is related to the demolition phase and the second is related to construction phase, while the last is related to overall reconstruction duration. In addition, it has been observed that the materials challenges are considered the major delay factor in the historical building of this project. The questionnaire results were analyzed and delay factors were sorted in a descending order according to the relative importance index (RII). The three main factors affecting the overall reconstruction project duration were site conditions and constraints, electrical and mechanical rerouting works, and design constructability and modification. Finally, recommendations were provided to bridge or reduce the negative impacts of the delay factors in future reconstruction projects.

Keywords: reconstruction projects; delay factors; relative importance index; demolition; Middle East; materials challenges

MENGENAL PASTI FAKTOR-FAKTOR BAGI PENANGGUHAN PEMBINAAN SEMULA PROJEK-PROJEK MEGA BERFASA DAN CABARAN-CABARANNYA

ABSTRAK

Dalam beberapa dekad ini, industri pembinaan telah berkembang dengan pesat. Penangguhan-penangguhan dalam projek-projek pembinaan adalah suatu fenomena yang normal melalui industri. Perkara ini sudah dan tetap menjadi salah satu cabaran penting yang memberi kesan negatif, bukan hanya kepada industri in, bahkan juga kepada ekonomi. Terdapat banyak kajian dijalankan bagi mengenal pasti faktor-faktor penangguhan dalam projek-projek pembinaan baharu di beberapa tempat yang berbeza, namun sangat sedikit kajian yang memfokuskan kepada kajian mengenai penjelasan bagi punca-punca penangguhan dalam projek-projek pembinaan. Oleh itu, kajian ini bertujuan untuk mengadakan analisis yang komprehensif terhadap faktor-faktor penangguhan projek-projek mega yang baru-baru ini berpusat di Timur Tengah dengan nama “Perluasan Projek Mataf“di Mekah, Arab Saudi. Projek ini terdiri daripada dua komponen penting; tempat tiada sejarah dan tempat bersejarah, dan komponen tersebut menjelaskan cabaran-cabaran yang dihadapi bagi jenis projek-projek pembinaan semula ini, di mana menggabungkan kerja-kerja perobohan dan pembinaan pada masa yang sama walhal projek itu masih dalam operasi penyelenggaraan. Bagi mencapai objektif kajian, sebanyak 29 temu bual bersama dengan pakar-pakar pelaksana projek dijalankan bagi mengenal pasti faktor-faktor penangguhan dan sebanyak 93 soal selidik diagihkan secara bersemuka untuk memperolehi data. Hasil kajian menunjukkan bahawa faktor-faktor ini boleh dibahagikan kepada 3 kumpulan; kumpulan pertama ialah faktor yang berkaitan dengan fasa perobohan, kumpulan kedua ialah faktor yang berkaitan dengan fasa pembinaan, manakala kumpulan yang terakhir pula ialah faktor yang berkaitan dengan keseluruhan tempoh pembinaan semula. Tambahan pula, perkara ini dapat dilihat di mana kekurangan bahan turut menjadi faktor terbesar bagi penangguhan dalam sejarah pembinaan projek ini. Hasil soal selidik telah dianalisis dan faktor-faktor penangguhan dibahagi mengikut turutan menurun berdasarkan indeks hubung kait kepentingan (RII). Ketiga-tiga faktor utama yang memberi kesan kepada keseluruhan tempoh projek pembinaan semula tersebut ialah keadaan tapak pembinaan dan had-hadnya, pemasangan elektrik, kerja-kerja pengubahsuaian mekanikal, reka bentuk buatan dan ubah suai. Kesimpulannya, cadangan-cadangan telah dikemukakan bagi menghubungkan atau mengurangkan kesan negatif bagi faktor-faktor penangguhan untuk projek-projek pembinaan semula akan datang.

Kata kunci: projek-projek pembinaan semula, faktor-faktor penangguhan, indeks hubung kait kepentingan; perobohan, Timur Tengah, kekurangan bahan

ACKNOWLEDGEMENTS

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RII	:	Relative Importance Index
RII_2	:	Relative Importance Index using 2-Point Likert scale
RII_4	:	Relative Importance Index using 4-Point Likert scale
W	:	Weight given to each delay factor by the respondent
A	:	Highest weight
N		Overall number of respondents
n_1	:	Number of respondents who strongly agree
n_2	:	Number of respondents who agree
n_3	:	Number of respondents who disagree
n_4	:	Number of respondents who strongly disagree
HSE		Health, Safety and Environment

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Background

Delays in the construction industry are very common and significant problems that should be further investigated. This problem affects not only the construction sector but also the growth of the economy and the sustainable development of nations (Bal et al., 2013; Morakinyo et al., 2015). Time overrun (delay) is the difference between the actual period for project completion and the estimated one (Chan, 2001). Another way to describe a project delay is by defining it as the time overrun against the contract period (Assaf & Al-Hejji, 2006). In addition, the time required to complete the project will be readjusted to be longer and as a result, it will definitely lead to negative impacts on both the project duration and relationship between project parties.

Besides, the total cost of the project will increase for both the client and contractor (Ahmed et al., 2003). In fact, accessing the project budgeted cost and its variance at the project completion due to the delay factors is extremely difficult. Moreover, it is usually confidential and not allowed especially in a project like Mataf Expansion Project which is our case study.

The delay factors and their impacts on the construction projects differ greatly from one country to another. These differences are derived from the work environment, technology, and other constraints (Fugar & Agyakwah-Baah, 2010; Shebob et al., 2012). An example of work environment is the availability of construction materials, especially the ones used in historical projects which causes a delay and that what happened in the reconstruction of Mataf Expansion Project.

In fact, there are major differences between the building structure of historical and nonhistorical buildings. The building structure of the historical parts in Mataf Expansion Project consists of foundations, columns, arches and domes made of ancient stones, while the components of nonhistorical ones are foundations ,columns, beams and slabs made of reinforcement concrete.

Size is considered one of the significant points used in defining megaprojects (Erol et al., 2018). Consequently, Mataf Expansion is a mega reconstruction project which has an overall area of about 210,000 square meters.

1.2 Problem Statement

In general, there are many aims for reconstruction building projects, such as increasing the buildings capacity, improve and update various electrical and mechanical systems, safety and stability reasons, achieving commercial aims and sustainability purposes particularly for the historical buildings. Sometimes the reconstructions for historical buildings is very important due to the damage of these buildings over time, which usually caused by weather conditions, erosion, natural disasters like earthquakes, volcanoes, floods, or because of disputes and wars especially in the Middle East Area.

In fact, the problem statement for this study can be summarized in the following points:

- All the previous aims for reconstruction projects will not be achieved on time if the reconstruction work is delayed. As a result of the delay, a considerable number of problems may arise between the main parties of the project (contractor, owner, and consultant) and might turn out to be an essential challenge that needs to be solved.
- The pressing need for reconstruction of many buildings especially the historical ones which are partially damaged over time, that usually caused by weather conditions, erosion, natural disasters like earthquakes, volcanoes, floods, or because of disputes and wars especially in the Middle East Area.
- Many studies have been conducted to identify the delay factors related to new construction projects, but few studies have focused on the factors related to

reconstruction projects, which are under operation and service, particularly the historical projects.

1.3 Research Objectives

Reconstruction projects became pretty significant and a necessity nowadays. Because of their importance and the lack of studies associated with them, this study aimed to conduct a comprehensive analysis of reconstruction projects delay factors through the following:

(a) Identifying the delay factors: This includes determining all the factors that have negative impact on the reconstruction project duration.

(b) Defining the materials-related challenges in historical projects: This includes determining the material challenges during reconstruction works.

(c) Ranking the delay factors of reconstruction projects: This includes sorting the delay factors according to their negative effects on the project duration.

These objectives were chosen in order to avoid or reduce the potential problems and their negative effects in future reconstruction projects. Furthermore, this would provide a better study and plan for this type of projects. Figure 1.1 shows a project life cycle which demonstrates a framework of reconstruction projects where the delay factors might be taken into consideration for a better study.

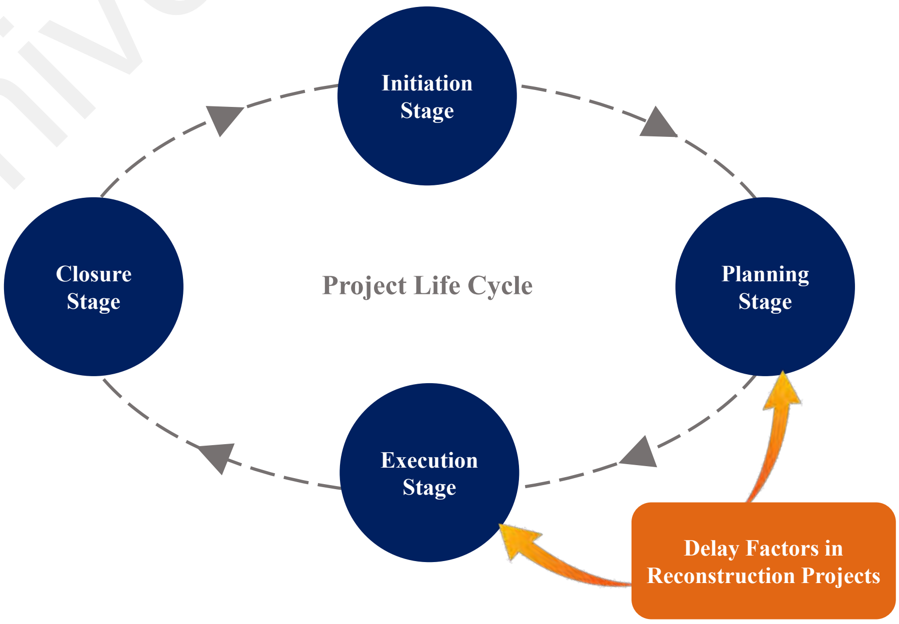

Figure 1.1: Shows a project life cycle where the reconstruction delay factors might be taken into account for a better study

1.4 Research Novelty and Significance

The main objective of this study is to determine the delay factors for reconstructed mega-projects. Although a lot of researchers' studies were carried out to define delay factors related to new construction projects in different countries all over the world, very few studies concentrated on the delay factors related to reconstruction projects, which were under operation and service, especially the historical ones. In addition, this study investigated the delay factors in one of mega reconstruction projects which is Mataf Expansion Project in Mecca Saudi Arabia. Moreover, it focused on reconstruction delay factors of historical and nonhistorical projects and highlighted the material challenges in the historical ones. In fact, this project was under operation during the study, which imposed new conditions and constrains on it and led to divide the work into phases. As a result, a group of delay factors appeared in these reconstructed mega-project's phases, which are not reported in the previous studies.

1.5 Scope of Work

This study was conducted on a mega reconstruction project, which includes historical and nonhistorical parts that were under operation during the execution period. It was carried out on a group of experts working on the project location and focused on the delay problem through identifying the delay factors. Moreover, the study was performed during the execution stage of this project life cycle, so all the delay results affected the project duration. In addition, it aimed to identify the delay factors and their effect on the project duration only. During the study, there wasn't any force majeure affected the project duration, therefore all the collected delay factors were related to reconstruction works and affected the reconstruction project duration.

1.6 Thesis layout

The thesis consists of five chapters according to the conventional format. The first chapter focuses on background, problem statement, research novelty and significance, scope of work and research layout.

The second chapter concentrates on literature review where the delay factors related to construction and reconstructions studies were discussed.

The third chapter focuses on research methodology and it contains a case study used in the research, where data was collected and discussed concerning delay factors and historical material challenges.

The fourth chapter focuses on the results and discussion, where the collected data analyzed and discussed.

The fifth and last chapter contains the study conclusion and recommendations.

CHAPTER 2: LITERATURE REVIEW

Many studies were conducted to identify delay factors in construction projects in different countries, but very few have concentrated on finding an explanation for delay factors in reconstruction projects. This study showed the delay factors in construction and reconstruction projects as follows:

2.1 Delay Factors for Construction Projects

According to the recent research during the last three decades in the construction industry, the most significant delay factors were studied, reviewed and collected in different countries all over the world concerning construction projects. The results indicated that, there was a clear overlap in the delay factors between the previous studies. The number of delay factors mentioned in these studies is 45 factors, which are detailed in Table 2.1. Column 1 shows the factor number, while column 2 shows a delay factor description, whereas column 3 shows the references to each delay factor. The last column in Table 2.1, which is titled Delay Factor Index, shows the number of the previous studies that highlighted common delay factors.

In fact, the 45 factors have been arranged in Table 2.1 according to the delay factor index from the most frequent factor to the least frequent one, as shown in the last column in the table. This index displays the similarity in the delay factors, although the studies were conducted in different countries with dissimilar purposes and the delay factors were as follows:

2.1.1 Financial Problems and Difficulties of the Contractor and Owner

Most of the previous studies mentioned in Table 2.1 indicated that the financial problems and difficulties of the contractor and owner was the most critical factor, according to the delay factor index, and it was the most frequent one that occurred in 37 out of the 48 studies. An example of a latest study Yap et al. (2021) which emphasized that financial problems of contractors factor was one of the most significant factors in Malaysian construction projects. Moreover, Bounthipphasert et al. (2020) insisted that all the construction financial issues in Laos country played the most important role in the projects delay. Besides, Alsuliman (2019) confirmed that the financial problems factor was the most remarkable one in delaying the construction projects in Saudi Arabia. In addition to the mentioned studies, there were 34 studies reported that the financial problems factor was a major cause for construction projects delay as shown in Table 2.1. In fact, the financial factor is very critical in all construction projects, because the project might be stopped totally, partially or might be in slow progress if the project cash flow is not secured from both of the owners and contractors. For example, construction work in the project might be highly affected if the salaries for direct and indirect manpower are not paid on time, the required materials are unavailable, and many other financial issues that might occur with the suppliers and subcontractors.

2.1.2 Shortage of Skilled Workers

It was noticeable that, the second most frequent factor in Table 2.1 was shortage of skilled workers, with a delay factor index equal to 18. Al-Emad et al. (2017) affirmed that shortage of skilled workers factor was of a great significance in delaying construction projects in Mecca, Saudi Arabia. In addition to that, Jarkas and Haupt (2015) studied the delay factors in Qatar construction projects from contractors' point of views and demonstrated that this factor was one of the critical factors in construction projects delay. Moreover, Gündüz et al. (2013) studied the time overrun factor in Turkish construction projects and reported that inexperienced workers factor was one of the crucial factors causing delay in construction projects. Besides, the mentioned studies, there were 15 studies reported that the shortage of skilled workers factor was one of the major causes of construction projects delay as shown in Table 2.1. Actually, the majority of studies carried out in the Arabian Gulf countries showed that the shortage of skilled workers was a main delay factor in construction projects (Faridi & El-Sayegh, 2006). That was due to the fact that, these countries usually depend on foreign workers in the execution of works and any shortage of workers directly affects the construction progress especially qualified ones. Indeed, the availability of skilled manpower means high workers efficiency with speed in the execution of works which often leads to avoiding reworks and any defective works.

2.1.3 Improper Planning and Scheduling

The third considerable delay factor that most studies focused on was improper planning and scheduling in Table 2.1 with a delay factor index equal to 15. Sweis (2013) insisted on the significance of good planning for construction projects. His study showed that poor planning and scheduling factor was one of the major factors that often delayed Jordanian construction projects. Aziz (2013) also investigated delay factors in the Egyptian construction projects in an attempt to reduce the negative impacts of the delay phenomenon. He concluded that inadequate project planning and scheduling was one of the important delay factors. Furthermore, Ameh and Osegbo (2011) confirmed the negative impact of this factor on the construction projects delay in Nigeria. In addition to the mentioned studies, there were 12 studies reported that improper planning and scheduling factor was one of the main causes of construction projects delay as shown in Table 2.1. In fact, perfect planning reflects a good study of all project aspects, such as project conditions, duration, safety, quality, and construction methods. As a result, this would reduce the construction problems during the execution phase.

2.1.4 Change Orders

The fourth significant delay factor that many studies concentrated on was change orders in Table 2.1 with a delay factor index equal to 14. Mydin et al. (2014) determined the reasons of delays in Malaysian construction projects. According to the study results, one of the delay causes was variations orders. Alinaitwe et al. (2013) also studied the delay causes in Uganda's construction projects. The study findings showed that there were changes in the work scope, and this factor negatively affected the construction projects duration. Moreover, Chan and Kumaraswamy (1997) affirmed that the same factor delayed construction projects in Hong Kong. Besides the mentioned studies, there were 11 studies reported that change orders factor was one of the considerable reasons for construction projects delay as shown in Table 2.1. In fact, this factor usually affects negatively the construction duration through adding more scope to the project, modifying the construction work and long procedures for change orders approval by the consultant and owner.

2.1.5 Poor Site Management and Supervision

It was noticeable that, the fifth factor in Table 2.1 was poor site management and supervision, with a delay factor index equal to 13. Gardezi et al. (2014) studied the delay causes that led to time extension in Pakistani construction projects. He demonstrated that one of the delay factors that negatively affected the construction projects was inefficient site management. Moreover Fallahnejad (2013) found in his study that this factor negatively affected the projects in Iran. Abd El-Razek et al. (2008) also indicated that poor site management and supervision factor was a critical factor that delayed the construction projects in Egypt. In addition to the mentioned studies, there were 10 studies reported that poor site management and supervision factor was one of the significant reasons for construction projects delay as shown in Table 2.1. Actually, without proper site management many problems might appear such as, bad site arrangement, rework, poor efficiency for direct manpower, demotivated project team and chaos at the project site. Consequently, there would be a delay in the construction projects.

2.1.6 Delay and Shortage of Materials

The sixth considerable delay factor that several studies focused on was delay and shortage of materials in Table 2.1 with a delay factor index equal to 12. Enshassi et al. (2009) studied the delay factors in Gaza Sector in Palestine. He pointed out that materials shortage was one of the important factors that delayed the construction projects. Le-Hoai et al. (2008) also insisted that unavailability of materials was a main delay factor in Vietnamese construction projects. Moreover, Aibinu and Odeyinka (2006) demonstrated that late delivery of ordered materials was a major factor that affected negatively the construction projects period in Nigeria. Besides the mentioned studies, there were 9 studies reported that shortage of materials factor was one of the considerable reasons for construction projects delay as shown in Table 2.1.In fact, problems and delays might occur, because of shortage of materials due to many reasons such as, providing wrong material estimation, damages during handling materials, poor inventory management system, rework and price changing of raw materials etc. As a result, lack of materials has a negative impact on the construction projects duration.

2.1.7 Poor Communication and Coordination between Construction Parties

The seventh important delay factor that many studies mentioned was poor communication and coordination between construction parties in Table 2.1 with a delay factor index equal to 11. Doloi et al. (2012) showed that lack of communication and coordination factor was one of the main factors that negatively affected Indian construction projects. Furthermore, Khoshgoftar et al. (2010) indicated that poor communication between parties was the key reason for projects delay in Iran. Lo et al. (2006) also found that the previous factor was a significant cause for delay in construction works in Hong Kong. In addition to the mentioned studies, there were 8 studies reported that poor communication and coordination between construction parties factor was one of the significant reasons for construction projects delay as shown in Table 2.1. It is obvious that, good communication and coordination between project parties, who are usually the contractor, consultant and client, leads to project success. As a result of this good relation, all project issues and problems related to this factor might be solved in the project.

2.1.8 Design Changes and Modification

It was noticeable that, the eighth factor in Table 2.1 was design changes and modification with a delay factor index equal to 10. Kazaz et al. (2012) showed that one of the most significant delay factors in Turkish construction projects was design changes. Al Jurf and Beheiry (2012) studied the delay factors in Qatar construction projects. His study demonstrated that design modification was an important factor that caused projects delay. Kaming et al. (1997) found in his study that the previous factor also negatively affected Indonesian construction projects period. Besides the mentioned studies, there were 7 studies reported that design changes and modification factor was one of the considerable reasons for construction projects delay as shown in Table 2.1. In fact, changes and modification might occur in construction works. However, it could lead to many negative effects such as rework, disruption and dispute between project parties. Consequently, this factor might cause a delay in construction projects.

2.1.9 Lack of Qualified and Experienced Personnel

The ninth important delay factor that many studies mentioned was lack of qualified and experienced personnel in Table 2.1 with a delay factor index equal to 9. Gidado and Niazai (2012) studied the delay factors in Afghanistan's construction industry and found that poor qualification of the contractor’s staff was one of the delay factors that negatively affected construction projects duration. Moreover, Al-Kharashi and Skitmore (2009) pointed out that lack of experienced personnel caused a delay in construction projects in Saudi Arabia. Furthermore, Enshassi et al. (2009) mentioned that unavailability of experienced personnel factor delayed the Palestinian construction projects. In addition to the mentioned studies, there were 6 studies reported that lack of qualified and experienced personnel factor was one of the important causes of construction projects delay as shown in Table 2.1. Actually, having well trained and qualified staff usually leads to accuracy, quality and speed in running construction projects successfully.

2.1.10 Subcontractors' Incompetency

The tenth delay factor that many studies referred to was subcontractors' incompetency in Table 2.1 with a delay factor index equal to 8. Alsuliman (2019) demonstrated that the subcontractors' incompetency delayed Saudi Arabia construction projects. Gündüz et al. (2013) also found that the same factor affected negatively Turkish construction projects. Moreover, Ameh and Osegbo (2011) showed that unreliable subcontractors factor delayed Nigerian construction projects. Besides the mentioned studies, there were 5 studies reported that subcontractors' incompetency factor was one of delay reasons for construction projects as shown in Table 2.1. In fact, subcontractors' incompetency might lead to many issues, such as defective works, low level of performance, reworks, wasted time and a delay in construction projects.

The above ten delay factors were the most frequent factors mentioned in the previous studies. However, there were other delay factors that were reported in some studies as shown in Table 2.1 which were: poor labor productivity, bid award for lowest price, lack of contractor experience, poor contract management, slow decision making from owner, unrealistic project duration, difficulties in obtaining work permits, poor contractor management, price escalation, design errors, construction mistakes and defective works, design delays, poor qualification of consultants, shortage of equipment, the type of contract, unforeseen ground conditions, weather conditions, political insecurity and instability, construction methods, discrepancies between drawings and specifications, escalation of material prices, poor site conditions, delay in site delivery, inaccurate estimating, inadequate tools and equipment, preparation and approval of shop drawings, incomplete documents, delay in performing inspection and testing, excessive bureaucracy in project–owner organization, frequent interruptions from public (local people, pressure groups, etc.), lack of clarity in project scope, land expropriation, segmentation of the West Bank, sources of information and works in conflict with existing utilities.

2.2 Delay factors for Reconstruction Projects

A few studies were developed in order to determine delay factors in reconstruction projects. In The United States, Krizek et al. (1996) mentioned that many reconstruction projects were more difficult and complicated to be executed than new construction ones due to constraints and conditions of the existing buildings. According to their study, one of the most delay factors in reconstruction projects was poor coordination between all contract parties. In fact, this factor was one of delay factors in construction projects as reported by Al-Emad et al. (2017) in their study in Saudi Arabia and other studies as shown in Table 2.1. However, Krizek et al. (1996) demonstrated that changing the designer was one of the delay factors in reconstruction projects, while it was not the case in the previous studies related to construction projects.

Pavlovskis et al. (2017) also investigated the problems in reconstruction projects in Lithuania. He found that one of the critical factors causing delay was unqualified project staff. Actually, this factor was one of delay factors in construction projects as mentioned by Sweis (2013) study in Jordan and other studies as shown in Table 2.1. Although, poor documentation was one of the delay factors in reconstruction projects according to Pavlovskis et al. (2017), it was not a delay factor in construction projects in the previous studies.

In addition, Chang et al. (2011) identified delay factors affecting post disaster reconstruction projects in China. The result showed that poor project scheduling, lack of personnel experience, unqualified contractors and political instability were some main reasons for reconstruction projects delay. In fact, these factors were similar to the ones related to construction projects delay in the previous studies as shown in Table 2.1.

Table 2.1: Summary of delay factors in the previous studies

No.	Delay Factor	Reference	Delay Factor Index
1	Financial problems and difficulties of contractor & owner	Yap et al. (2021); Bounthipphasert et al. (2020); Alsuliman (2019); Al-Emad et al. (2017); Jarkas and Haupt (2015); Mydin et al. (2014); Memon et al. (2014); Gardezi et al. (2014); Mahamid (2016); Sweis (2013); Mahamid (2013b); Gündüz et al. (2013); Aziz (2013); Alinaitwe et al. (2013); Mahamid (2013a); Kazaz et al. (2012); Doloi et al. (2012); Fallahnejad (2013); Gidado and Niazai (2012); Al Jurf and Beheiry (2012); Ameh and Osegbo (2011); Khoshgoftar et al. (2010); Enshassi et al. (2009); Al-Kharashi and Skitmore (2009); Abd El-Razek et al. (2008); Le-Hoai et al. (2008); Sweis et al. (2008); Toor and Ogunlana (2008); Sambasivan and Soon (2007); Alaghbari et al. (2007); Faridi and El-Sayegh (2006); Abdul-Rahman et al. (2006); Aibinu and Odeyinka (2006); Lo et al. (2006); Acharya et al. (2006); Frimpong et al. (2003); Al-Khalil and Al-Ghafly (1999)	37
2	Shortage of skilled workers	Al-Emad et al. (2017); Jarkas and Haupt (2015); Memon et al. (2014); Sweis (2013); Gündüz et al. (2013); Aziz (2013); Gidado and Niazai (2012); Enshassi et al. (2009); Abd El-Razek et al. (2008); Sweis et al. (2008); Faridi and El-Sayegh (2006); Aibinu and Odeyinka (2006); Al-Khalil and Al-Ghafly (1999); Mezher and Tawil (1998); Chan and Kumaraswamy (1997); Kaming et al. (1997); Ogunlana et al. (1996); Assaf et al. (1995)	18

Table 2.1: Summary of delay factors in the previous studies (continued)

No.	Delay Factor	Reference	Delay Factor Index
3	Improper planning and scheduling	Al-Emad et al. (2017); Mahamid (2016); Sweis (2013); Gündüz et al. (2013); Aziz (2013); Al Jurf and Beheiry (2012); Ameh and Osegbo (2011); Al-Kharashi and Skitmore (2009); Abd El-Razek et al. (2008); Sweis et al. (2008); Toor and Ogunlana (2008); Faridi and El-Sayegh (2006); Chan and Kumaraswamy (1997); Ogunlana et al. (1996); Mansfield et al. (1994)	15
4	Change orders	Alsuliman (2019); Mahamid (2016); Jarkas and Haupt (2015); Mydin et al. (2014); Sweis (2013); Gündüz et al. (2013); Aziz (2013); Alinaitwe et al. (2013); Al-Kharashi and Skitmore (2009); Sambasivan and Soon (2007); Faridi and El-Sayegh (2006); Al-Khalil and Al-Ghafly (1999); Chan and Kumaraswamy (1997); Arditi and Gutierrez (1991)	14
5	Poor site management and supervision	Mydin et al. (2014); Memon et al. (2014); Gardezi et al. (2014); Mahamid (2013b); Gündüz et al. (2013); Aziz (2013); Fallahnejad (2013); Ameh and Osegbo (2011); Enshassi et al. (2009); Abd El-Razek et al. (2008); Sweis et al. (2008); Mansfield et al. (1994); Arditi and Gutierrez (1991)	13
6	Delay & shortages of materials	Jarkas and Haupt (2015); Aziz (2013); Gündüz et al. (2013); Doloi et al. (2012); Al Jurf and Beheiry (2012); Enshassi et al. (2009); Abd El-Razek et al. (2008); Sweis et al. (2008); Toor and Ogunlana (2008); Alaghbari et al. (2007); Lo et al. (2006); Mezher and Tawil (1998)	12
7	Poor communication and coordination between construction parties	Al-Emad et al. (2017); Mydin et al. (2014); Mahamid (2016); Mahamid (2013b); Gündüz et al. (2013); Mahamid (2013a); Ameh and Osegbo (2011); Enshassi et al. (2009); Abd El-Razek et al. (2008); Le-Hoai et al. (2008); Sambasivan and Soon (2007)	11
8	Design changes & modification	Gardezi et al. (2014); Gündüz et al. (2013); Aziz (2013); Kazaz et al. (2012); Gidado and Niazai (2012); Al Jurf and Beheiry (2012); Khoshgoftar et al. (2010); Enshassi et al. (2009); Aibinu and Odeyinka (2006); Ogunlana et al. (1996)	10
9	Lack of qualified and experienced personnel	Alsuliman (2019); Sweis (2013); Alinaitwe et al. (2013); Fallahnejad (2013); Alaghbari et al. (2007); Al-Khalil and Al-Ghafly (1999); Mezher and Tawil (1998); Kaming et al. (1997); Dlakwa and Culpin (1990)	9

Table 2.1: Summary of delay factors in the previous studies (continued)

10	Subcontractors' incompetency	Alsuliman (2019); Memon et al. (2014) Gündüz et al. (2013); Al Jurf and Beheiry (2012); Ameh and Osegbo (2011); Abd El-Razek et al. (2008); Toor and Ogunlana (2008); Aibinu and Odeyinka (2006);	8
11	Poor labor productivity	Al-Emad et al. (2017); Mahamid (2016); Mahamid (2013b); Aziz (2013); Sweis et al. (2008); Aibinu and Odeyinka (2006); Ogunlana et al. (1996)	7
12	Bid award for lowest price	Mahamid (2013b); Aziz (2013); Mahamid (2013a); Doloi et al. (2012); Sambasivan and Soon (2007); Faridi and El-Sayegh (2006)	6
13	Lack of contractor experience	Mydin et al. (2014); Mahamid (2016); Sweis (2013); Gündüz et al. (2013); Abd El-Razek et al. (2008); Sambasivan and Soon (2007)	6
14	Poor contract management	Al-Emad et al. (2017); Mydin et al. (2014); Ameh and Osegbo (2011); Khoshgoftar et al. (2010); Enshassi et al. (2009); Lo et al. (2006)	6
15	Slow decision making from owner	Jarkas and Haupt (2015); Sweis (2013); Gündüz et al. (2013); Sweis et al. (2008); Aibinu and Odeyinka (2006); Arditi and Gutierrez (1991)	6
16	Unrealistic project duration	Gardezi et al. (2014); Mahamid (2016); Doloi et al. (2012); Sambasivan and Soon (2007); Faridi and El-Sayegh (2006); Arditi et al. (1985)	6
17	Difficulties in obtaining work permits	Gardezi et al. (2014); Doloi et al. (2012); Enshassi et al. (2009); Sweis et al. (2008); Faridi and El-Sayegh (2006)	5
18	Poor contractor management	Enshassi et al. (2009); Alaghbari et al. (2007); Abdul-Rahman et al. (2006); (Chan & Kumaraswamy, 1997); (Mansfield et al., 1994)	5
19	Price escalation	Gardezi et al. (2014); Enshassi et al. (2009); Toor and Ogunlana (2008); Lo et al. (2006); Frimpong et al. (2003)	5
20	Design errors	Jarkas and Haupt (2015); Toor and Ogunlana (2008); Aibinu and Odeyinka (2006); Arditi et al. (1985)	4
21	Construction mistakes and defective works	Mydin et al. (2014); Mahamid (2016); Mahamid (2013b); Abd El-Razek et al. (2008)	4

Table 2.1: Summary of delay factors in the previous studies (continued)

No.	Delay Factor	Reference	Delay Factor Index
22	Design delays	Al-Emad et al. (2017); Gündüz et al. (2013); Al-Khalil and Al-Ghafly (1999); Chan and Kumaraswamy (1997)	4
23	Poor qualification of consultants	Jarkas and Haupt (2015); Sweis (2013); Aziz (2013); Sambasivan and Soon (2007)	4
24	Shortage of equipment	Aziz (2013); Mahamid (2013a); Abd El-Razek et al. (2008); Mezher and Tawil (1998)	4
25	The type of contract	Aziz (2013); Abdul-Rahman et al. (2006); Acharya et al. (2006); Mansfield et al. (1994)	4
26	Unforeseen ground conditions	Gündüz et al. (2013); Sambasivan and Soon (2007); Faridi and El-Sayegh (2006); Arditi and Gutierrez (1991)	4
27	Weather conditions	Mydin et al. (2014); Sweis (2013); Sambasivan and Soon (2007); Acharya et al. (2006)	4
28	Political insecurity and instability	Gardezi et al. (2014); Alinaitwe et al. (2013); Mahamid (2013a); Fallahnejad (2013)	4
29	Construction methods	Ameh and Osegbo (2011); Enshassi et al. (2009); Acharya et al. (2006)	3
30	Discrepancies between drawings and specifications	Jarkas and Haupt (2015); Gardezi et al. (2014); Sweis (2013)	3
31	Escalation of material prices	Alaghbari et al. (2007); Frimpong et al. (2003); Mezher and Tawil (1998)	3
32	Poor site conditions	Mydin et al. (2014); Enshassi et al. (2009); Arditi et al. (1985)	3
33	Delay in site delivery	Gündüz et al. (2013); Arditi et al. (1985)	2
34	Inaccurate estimating	Gidado and Niazai (2012); Lo et al. (2006)	2

Table 2.1: Summary of delay factors in the previous studies (continued)

No.	Delay Factor	Reference	Delay Factor Index
35	Inadequate tools and equipment	Al Jurf and Beheiry (2012); Toor and Ogunlana (2008)	2
36	Preparation and approval of shop drawings	Sweis et al. (2008); Aibinu and Odeyinka (2006)	2
37	Incomplete documents	Mydin et al. (2014)	1
38	Delay in performing inspection and testing	Gündüz et al. (2013)	1
39	Excessive bureaucracy in project–owner organization	Aibinu and Odeyinka (2006)	1
40	Frequent interruptions from public (local people, pressure groups, etc.)	Arditi et al. (1985)	1
41	Lack of clarity in project scope	Mansfield et al. (1994)	1
42	Land expropriation	Doloi et al. (2012)	1
43	Segmentation of the West Bank	Mahamid (2013a)	1
44	Sources of information	Acharya et al. (2006)	1
45	Works in conflict with existing utilities	Sambasivan and Soon (2007)	1

2.3 Summary of Reconstruction Studies and Research gaps

Table 2.2 shows a summary of reconstruction studies and research gaps. It displays the year of the study, the author and where the study has done, in addition to the main objectives, findings and the research gaps.

Table 2.2: Chronological summary of reconstruction studies and research gaps

<table>
<tr><th>Year</th><th>Author/ Country</th><th>Objectives</th><th>Findings</th><th>Research gaps</th></tr>
<tr><td>1996</td><td>Krizek et al. / The United States</td><td>Identifying delay factors affecting reconstruction projects</td><td>- More need for active management and close coordination between all contract parties
- Clear contract documents without any conflicts
-Providing a strong basis to solve all issues and changes during construction period
- Changing the designer during the project period</td><td rowspan="3">- Carried on normal not mega projects

- Conducted on nonhistorical projects

- Performed on projects not under operation and service

- Carried on some reconstruction projects post disasters</td></tr>
<tr><td>2011</td><td>Chang et al. / China</td><td>Identifying the significant factors affecting post-disaster reconstruction projects</td><td>- Poor project scheduling
- Lack of personnel experience
- Unqualified contractors
- political instability</td></tr>
<tr><td>2017</td><td>Pavlovskis et al. / Lithuania</td><td>Problems facing the implementation of reconstruction projects</td><td>- Unqualified project staff
- Poor documentation
- Long procedure period for purchasing required materials</td></tr>
</table>

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

Figure 3.1 shows a research flow chart for the whole study.

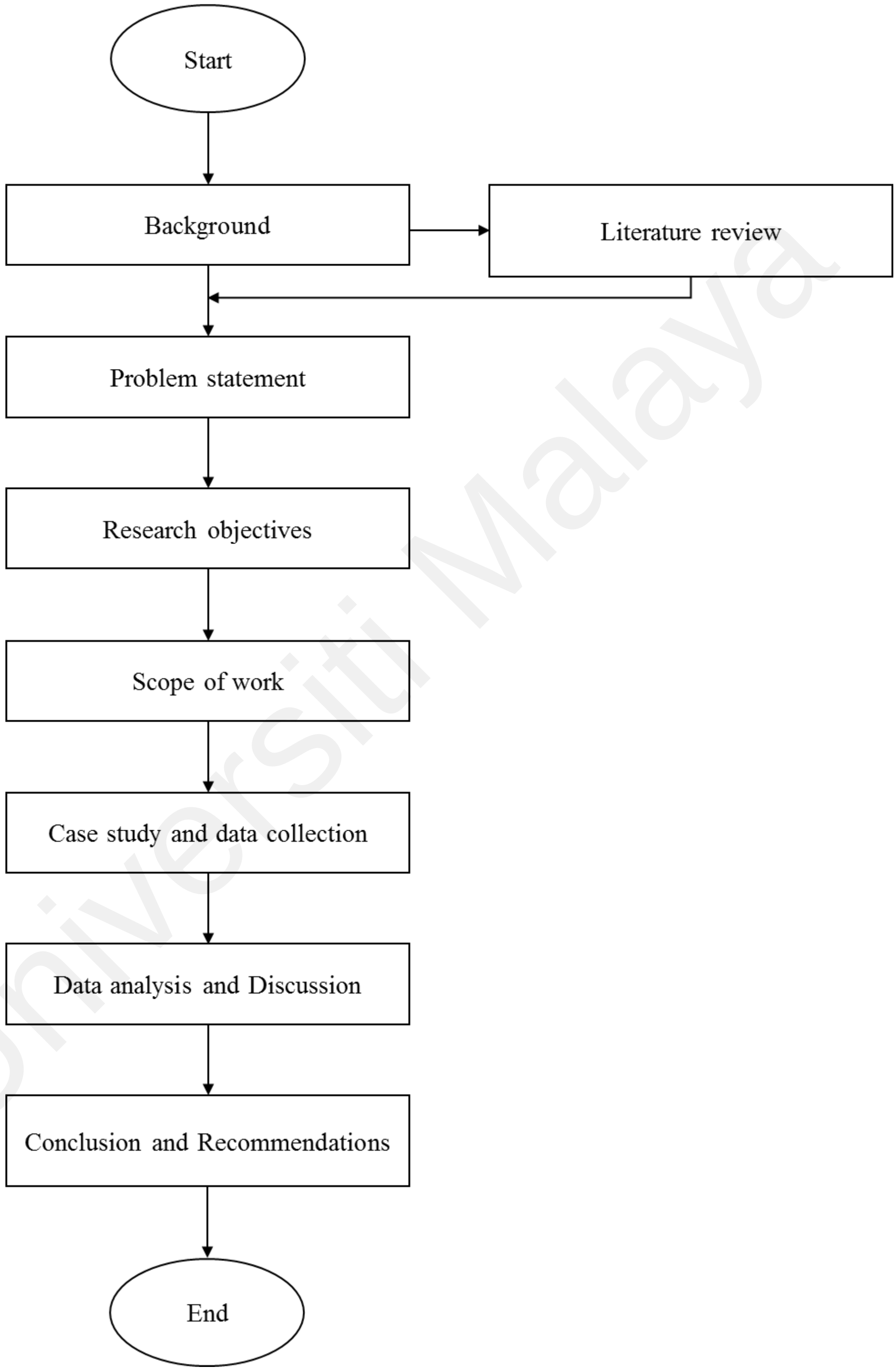

Figure 3.1: Research flow chart

The study was carried out on Mataf Expansion project, which is one of the mega reconstruction projects carried out recently in the Middle East in Mecca Saudi Arabia as shown in Figure 3.1.

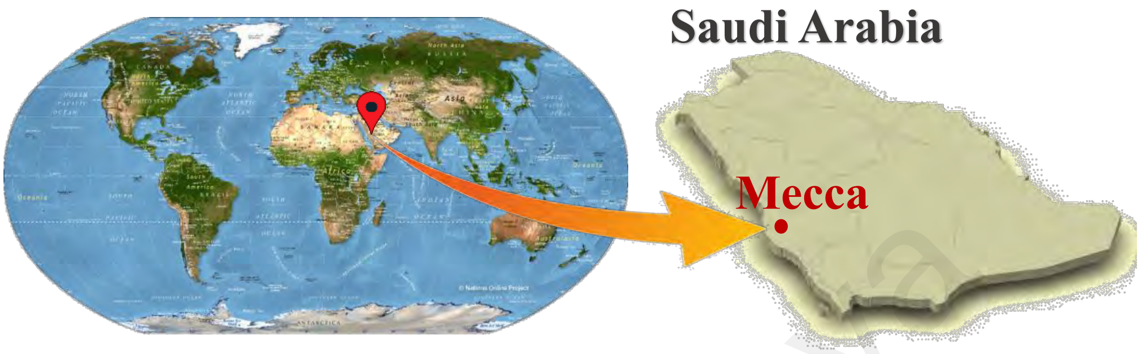

Figure 3.2: Mataf Expansion Project location

Mataf Expansion project is an example and a case study of mega reconstruction projects of great importance shown in Figure 3.2. It clarifies the difficulties and obstacles facing this type of reconstruction projects, which combines demolition and construction works at the same time while the project is under operation. Appendix A shows the ground floor plan of Mataf Expansion project before and after reconstruction works.

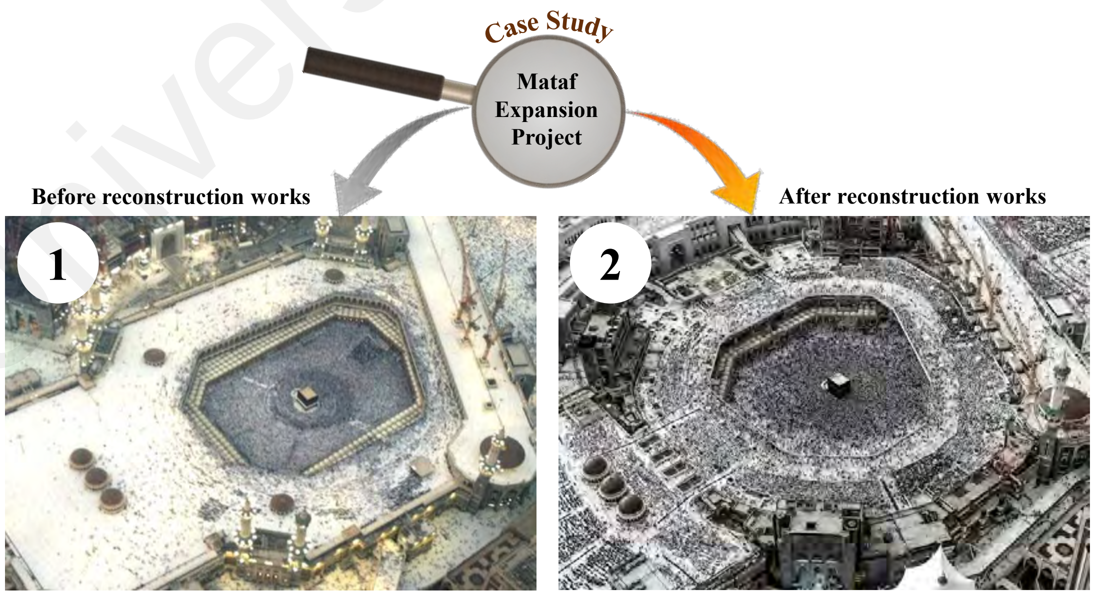

Figure 3.3: Image 1 shows Mataf Expansion Project before reconstruction works, while image 2 shows it after reconstruction works

This project consists of two main parts, nonhistorical and historical, as shown in Figure 3.3. It is a very important and crowded place and receives millions of visitors each year and should be at least partially opened during the whole year. For these reasons, the reconstruction works in this project were divided into three major phases, as shown in Figure 3.3.

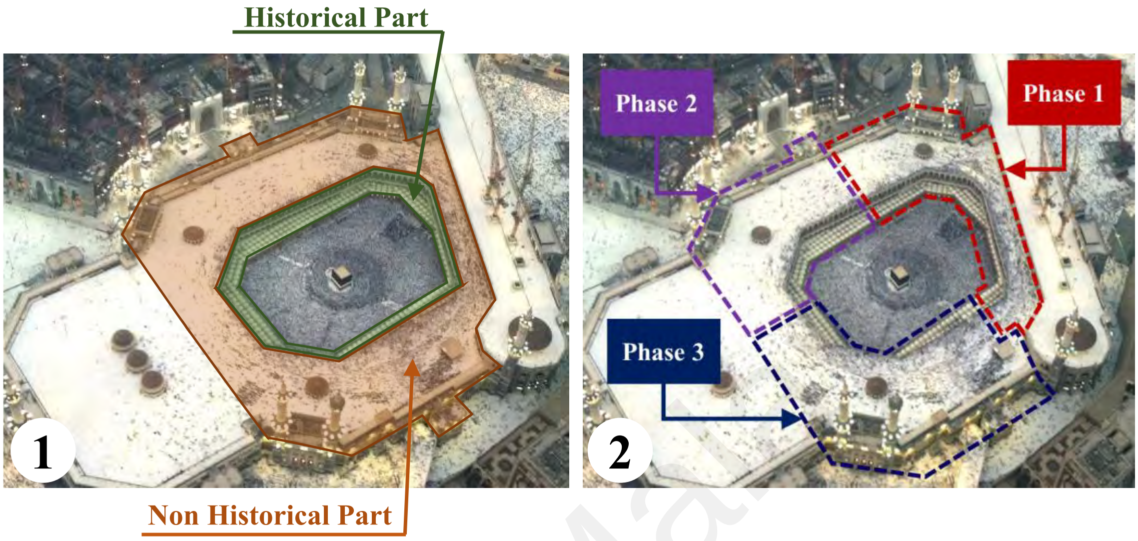

Figure 3.4: Image 1 shows Mataf Expansion Project main parts with the historical part shown in green and the nonhistorical one shown in orange, and Image 2 shows the three main phases for reconstruction work

During the mobilization and preparation stage and before starting the actual works at Mataf Expansion project, workshop and storage locations were selected. These locations were around 16 kilo meters away from Mataf Expansion project location as shown in Figure 3.4. In fact, many preparation works had been done in the workshop area to serve the project. Two demolition mockups were built for this project in the workshop area, one for the historical part and the other for the nonhistorical one, as shown in Figure 3.5. In addition, there were two construction mockups, one for the historical part and the other for the nonhistorical one, as shown in Figure 3.6. The aim of these four mockups was to determine the best demolition and construction methods that could be used in the project before starting the actual work on the site.

Figure 3.5: Map shows the location and the distance between Mataf Expansion Project and the workshop area

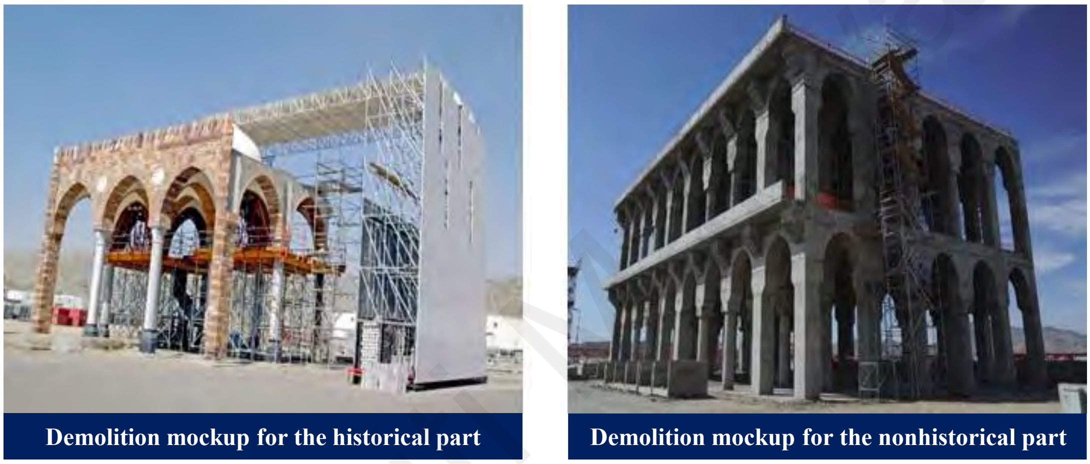

Figure 3.6: Demolition mockup for the historical and nonhistorical parts in the workshop area

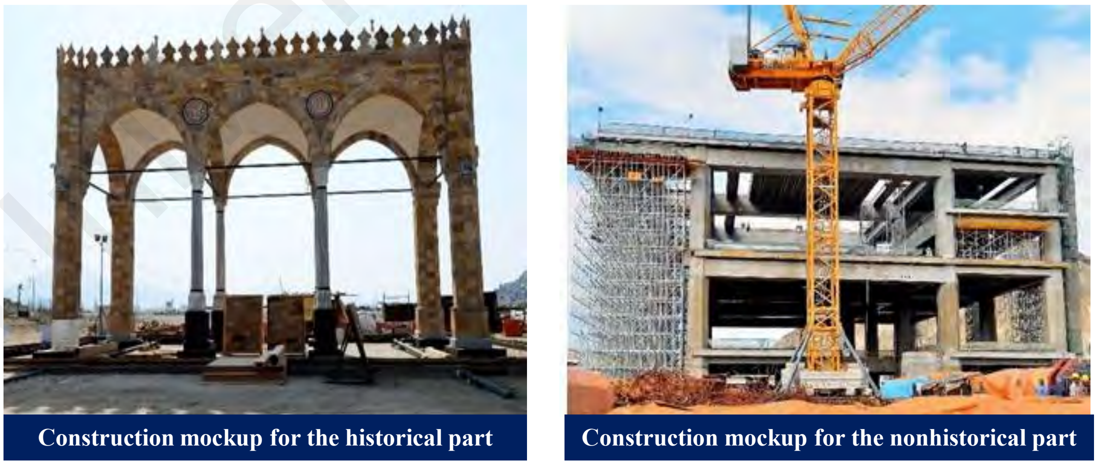

Figure 3.7: Construction mockup for the historical and nonhistorical parts in the workshop area

3.2 Case Study and Data Collection

Figure 3.7 shows the study methodology and flowchart which identify mega reconstruction delay factors.

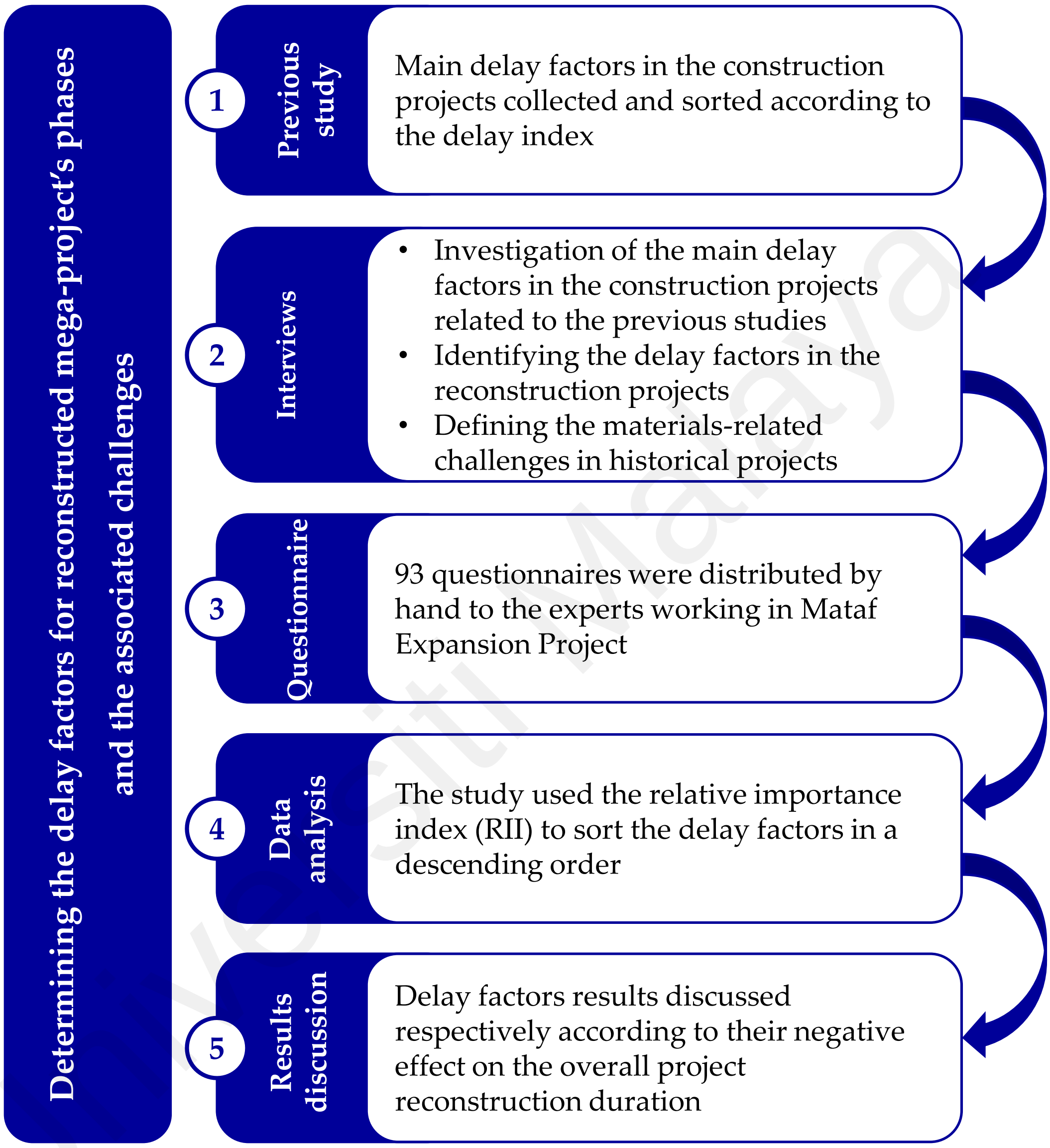

Figure 3.8: Study methodology and framework

3.2.1 Interviews with the Experts Working in Mataf Expansion Project

The summarized factors causing delay were determined through previous studies and shown in Table 2.1 reflected in a graphical shape as shown in Figure 3.8 which demonstrated the delay factors with the delay factor index value. This figure formed the basis of the dialogues during the interviews that were held with the experts working in Mataf expansion project in Mecca, Saudi Arabia.

Fourteen interviews were conducted with the experts working in the Project form different levels of seniority. The seniority level included two project managers, two construction managers, two planning engineers, six site engineers, and two technical engineers. In addition, the experience of all the experts was at least eight years in the construction industry. The main objective of these interview sessions was to identify the delay factors in the reconstruction projects regardless of these factors ranking. Furthermore, the sample size “14 interviewees” in such a qualitative research method, which depends on the interviews in order to collect the required data and information, can be identified through saturation. That means, any additional interviews that do not produce new data or information could be omitted from the analysis (Guest et al., 2006). Actually, this issue was carried out by 2 additional interview sessions with 2 different senior site engineers in order to confirm the outcomes of the 14 interview sessions.

During the interview sessions, the delay factors that have been acquired from the previous studies were investigated by briefing the experts the factors presented in Figure 3.8. Subsequently, the delay factors in the reconstruction project were collected and discussed.

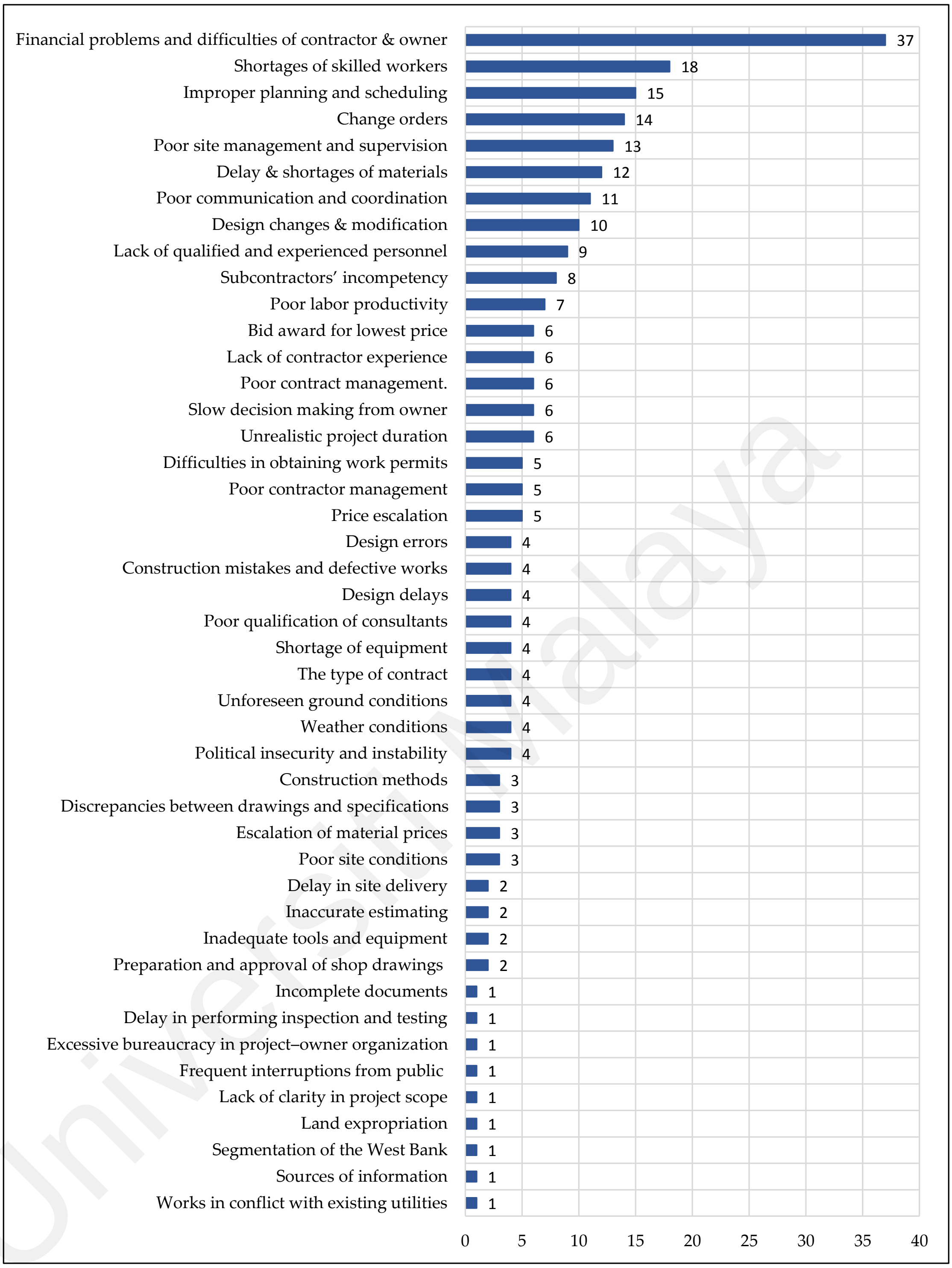

Figure 3.9: Delay factors index

It is clear in Figure 3.8 that this delay factors arrangement plays an important and positive role in breaking the barrier that is usually common in the interview sessions. In fact, there are always limits on the researchers when asking the experts being interviewed questions and recording the answers, due to the time constrains of the experts interviewed. In some cases, the expert might respond quickly to the researcher's questions without paying the required attention to the question, especially when the expert is unable to catch easily the purpose of the research during the interview or to perceive the desired benefits from this research. Therefore, it has been decided to prepare to the experts all the tables and figures to keep visualizing all the required data and information and to provide the proper feedback. The interview questions and format were designed in a proper way in order to cover the previous study factors and to identify the reconstruction delay factors as shown in Appendix B. The main questions were:

First question: "Do you think, as an expert in this project that these factors cause delay in this reconstruction project?"

Second question: "Are there any further factors that cause delays and you think they are important to add?"

During the interviews the experts demonstrated that each project phase in Mataf Expansion Project was divided into two stages. The first stage was the demolition and dismantling while the second was the construction stage. The experts' answers showed that there were delay factors related to the demolition and dismantling stage and other ones related to the construction stage.

3.2.1.1 Demolition and Dismantling Stage

In order to avoid possible delays in the demolition and dismantling stage, two demolition mockups for the historical and nonhistorical parts were built in the workshop area to study the methods, tools and the suitable equipment for this stage, which would be implemented at the site during demolition works. In fact, the experts mentioned five factors, which led to a delay in the demolition and dismantling stage.

Actually, the first delay factor that was mentioned was the rerouting works for all electrical and mechanical utilities. For safety purposes, the demolition area in the first phase of the project was surrounded by a temporary fence and isolated from the other phases of the project. However, the demolition works did not start in some areas in phase one and did not finish in other areas until the completion of rerouting works for electrical and mechanical services. Moreover, alternative routes were provided to ensure the continuity of these services in the rest phases of the project.

In fact, there was a need to delay the demolition of a few parts within the demolition area, because it was the only access for visitors from outside the demolition area until the establishment of new alternative safe access. Although the work in the project was divided into phases, the working team was unable to completely separate the first phase from the remaining phases of the project, because of the need for safe paths in the demolition area to allow visitors to move between the project areas. Accordingly, the safe paths were considered an indispensable and logistical necessity and it was a major reason for the demolition delay as the experts mentioned during the interviews.

Moreover, there was a delay factor related to dismantling historical elements. This factor appeared because of the overlap between the historical and nonhistorical parts in some project areas. As a result of this overlap, the demolition phase in these areas was delayed until the dismantling of the historical elements. These elements were very sensitive and required special protection procedures before starting the dismantling work, to keep them in proper condition in order to use them in gain in the reconstruction phase due to the limitations of not having similar building materials nowadays.

Furthermore, there was a need for back propping works. In fact, the demolition work in the project did not start until the completion of the required back propping works in all the floors. However, the continuity of the operation work in the project during the demolitions and the presence of safe accesses in the demolition area required the implementation of extra propping works, which led to the delay in the demolition work in some of the project areas.

3.2.1.2 Construction Stage

During the interviews, the experts mentioned nine factors causing a delay in the construction stage, such as the design constructability and modification factor. The project was designed to allow an additional number of floors to be added in the future, and the spaces between the columns were large to facilitate the movement of visitors. These things made the design difficult to implement and affected negatively the project duration in addition to the design modifications during the project execution works.

One more delay factor mentioned was the site conditions and constraints, which imposed a set of restrictions on the project. This factor was a common factor between the demolition and construction stages. In fact, this factor affected the execution time negatively, as there was difficulty in handling the required materials and in the movement of the equipment due to the narrow entrances, exits, and corridors connected to the construction site.

Another delay factor was mentioned during the interview sessions was providing a safe access for the visitors in order to move between the project areas safely. In fact, this factor was a common factor in both demolition and construction stages. Moreover, the experts highlighted during the interview session that all the construction works in this safe access area had to be completely stopped to assure safety for Mataf project visitors until providing an alternative safe access.

Furthermore, there was conflict between the execution of some parts of the project and the alternative temporary projects. In fact, some parts of the project were delayed, because of their conflict with the temporary projects being executed to reduce the pressure on visitors. This was evident in the Temporary Mataf project, which was temporarily executed during the project period to reduce the pressure on visitors, and that led to a delay in some parts of the project until the dismantling of the Temporary Mataf.

Moreover, the historical elements test period factor was affected by the required tests related to the historical elements dismantled during the demolition. A series of tests was carried out on the historical elements, that were dismantled from the project during the demolition phase and the appropriate ones were subsequently sorted to be used in the construction phase. These tests and the repairing works required a period of time, which led to a delay in the start of these works at the project site.

On the other hand, one of the main reasons for the delay in the construction of historical parts was due to the difficulty in providing alternative materials similar to the historical elements and obtaining the approvals required from the consultants of the project before starting these works at the site.

Furthermore, in some areas of the project, there was an overlap in the works between the historical parts and nonhistorical ones and this led to the delay in the historical parts until the completion of the execution of nonhistorical parts. That was due to the safety requirements and the difficulty in the execution of all these works together.

Besides, the workforce productivity rate decreased due to the design difficulty and the hot weather conditions, in addition to the stoppage of works at the site during prayer times which caused a construction delay.

In addition, the safety requirements factor imposed a number of conditions on the project including leaving a buffer zone between the demolition and construction works. In fact, construction works in this zone could not be started until the demolition was completely done. This led to delays in the construction works in areas adjacent the demolition areas.

3.2.2 Interviews with the Experts Working in the Historical Part of Mataf Expansion Project

Table 3.1 shows the summary of challenges related to the construction materials and their negative effect on the project duration, as discussed in the previous studies. In addition, Table 3.1 shows many reasons behind these challenges. The main objective of this table was to draw the attention of the experts interviewed to the significance of this subject. It was also a motivation for them to mention the challenges that they faced related to the materials during the reconstruction of the historical part of Mataf Expansion project. This historical part called Old Riwaq, which is one of the most important historical projects that recently reconstructed in the Middle East. It is characterized by its historical value.

Table 3.1: Material related challenges with associated reasons

No.	Challenge	Main Reason	Reference
1	Shortage of material	Providing wrong estimation. Damages during handling materials and poor inventory management system. Delay in payments and financial problems. Construction defective and mistakes. Scope of works changes. Late identification of the type of materials needed	Jarkas and Haupt (2015); Aziz (2013); Le-Hoai et al. (2008); Sambasivan and Soon (2007); Enshassi et al. (2009); Ogunlana et al. (1996); Indhu and Ajai (2014); Durdyev et al. (2017); Alaghbari et al. (2007); Ibironke et al. (2013); Kaming et al. (1997); Mansfield et al. (1994); Haseeb et al. (2011); Doloi et al. (2012); Sayed et al. (2017); Fugar and Agyakwah-Baah (2010); Gunduz and AbuHassan (2016); Tumi et al. (2009)
2	Late delivery of materials	Delay in payments and financial problems. Delay in procurement of materials. Customs clearance for imported material. Slowness in decision making.	Jarkas and Haupt (2015); Durdyev et al. (2017); Alaghbari et al. (2007); Ibironke et al. (2013); Gündüz et al. (2013); Ameh and Osegbo (2011); Faridi and El-Sayegh (2006); Aibinu and Odeyinka (2006); Arditi et al. (1985); Majid and McCaffer (1998); Koushki and Kartam (2004); Gebrehiwet and Luo (2017); Salama et al. (2008); Alhajri and Alshibani (2018)

Table 3.1: Material related challenges with associated reasons (continued)

No.	Challenge	Main Reason	Reference
3	Fluctuations and Escalation of material price	Change in the cost of raw materials. Changes in market conditions and Shortage of supplies. Instability in local currencies exchange rates and increasing of Inflation rates. The additional cost of transport and import duties. Rising labor or production costs in the supply chain.	Enshassi et al. (2009); Mansfield et al. (1994); Fugar and Agyakwah-Baah (2010); Gebrehiwet and Luo (2017); Frimpong et al. (2003); Dlakwa and Culpin (1990); Owolabi et al. (2014); Koshe and Jha (2016)
4	long duration of materials procurement	Delay in finalizing material take of list, as well as materials shop drawings. Contractor delay in submission the technical requirement for the consultant's approval. Delay in consultant's reviewing and approval. Spending long time in supplier price negotiation and financial problems.	Assaf and Al-Hejji (2006); Salama et al. (2008); Frimpong et al. (2003); Pavlovskis et al. (2017)
5	Changes of material	Design Changes Scope of works Changes The lead time of material delivery Late initiation of value engineering process	Indhu and Ajai (2014); Kazaz et al. (2012)

Table 3.1: Material related challenges with associated reasons (continued)

No.	Challenge	Main Reason	Reference
6	Poor quality of materials	Selecting poor source of materials. Lack of quality control and assurance systems. Bad shipping and storage handling. Cheap construction materials. Lack of materials test and inspection.	Enshassi et al. (2009); Gebrehiwet and Luo (2017)
7	Imported materials	Delays in placing purchase orders for imported materials. Long period of delivery. Custom clearance procedures. Seasons such as festivals, vacations, winters etc.	Fallahnejad (2013)

Fifteen interviews were carried out with the experts working in Old Riwaq project in different levels in the organization chart of this historical project, with some of them working in the day shift and others in the night shift. The interviewees included one project manager, one construction manager, two planning and scheduling engineers, two senior site engineers, five site engineers, and four engineers working in the technical office as technical engineers. All experts interviewed in this project had at least six years of experience in the construction industry. The main target of these interview sessions was to highlight the materials-related challenges of historical reconstruction project which negatively affected the project duration. Moreover, the sample size "15 interviewees" in such a qualitative research method that depends on the interviews in order to collect the required data and other information, can be identified through saturation. This means that any further interview sessions that do not produce new data or information might be omitted from the study (Guest et al., 2006). In fact, this issue was achieved by two additional interview sessions with a construction manager and project manager who worked in the night shift, in order to confirm the results of the 15 interview sessions.

Old Riwaq project was visited several times in order to choose suitable times for the experts to be interviewed. In fact, the objective of this step is for the expert to feel comfortable during the interview and to have enough time to mention all the challenges they faced during work on the project. In order to secure suitable interview times, questions were prepared to facilitate the registration of all the information mentioned by the experts as shown in appendix B.

In the first interview, the materials-related challenges were discussed with Old Riwaq project manager. During this interview, the project manager explained that the materials-related challenges in this type of historical projects were distinct from other construction projects. He stated that working on historical reconstruction projects was divided into a series of stages and each stage encountered a range of challenges that were different from the other stages. During the interview, the project manager indicated that working on Old Riwaq project could be divided into two main stages; the first stage was the documentation and dismantling of the historical building, while the second was the workshop stage.

The challenges mentioned by the project manager related to the previous two stages were collected and discussed. He also recommended two questions to be asked to the engineers working in the project during the interviews and giving them an opportunity to mention the challenges that faced them during the execution work. These questions were:

First question: "In your view as an expert working on this project, what are the materials-related challenges associated with the documentation and dismantling of the historical building?"

Second question: "What are the materials-related challenges associated with the workshop stage?"

In fact, this first interview with the project manager was very important and resulted in the preparation of a new working paper which included the two previous questions as the basis for the rest of the interviews with the experts working in the project.

The second interview was conducted with the construction manager where the new working paper was discussed containing the two questions proposed by the project manager in order to identify the challenges of the project materials.

The construction manager mentioned a number of challenges that characterized each stage in the project, where they were collected and discussed.

In fact, as an expert working on the project, the construction manager suggested a third question to be added to the working paper concerning the new designs and mockup stage. He pointed out that this stage could be separated from the workshop stage and considered as the third stage of the project, where it was characterized by a special set of challenges. The construction manager noted that adding a specific question related to this stage would make it easier for the experts to be interviewed later to mention the materials-related challenges encountered during the execution works in a clearer and more detailed way.

In fact, the second interview with the construction manager resulted in the final form of the new working paper which included a third question in addition to the previous two questions.

Third question: “What are the materials-related challenges associated with the new designs and mockup stage?

During the interviews, the experts mentioned that the work in the historical part which is called Old Riwaq project was divided into three main phases. Figure 3.9 shows the location of Old Riwaq and Figures 3.10 and 3.11 show Old Riwaq phases. That was because of the special location and the great importance of the project, which prevented it being closed completely.

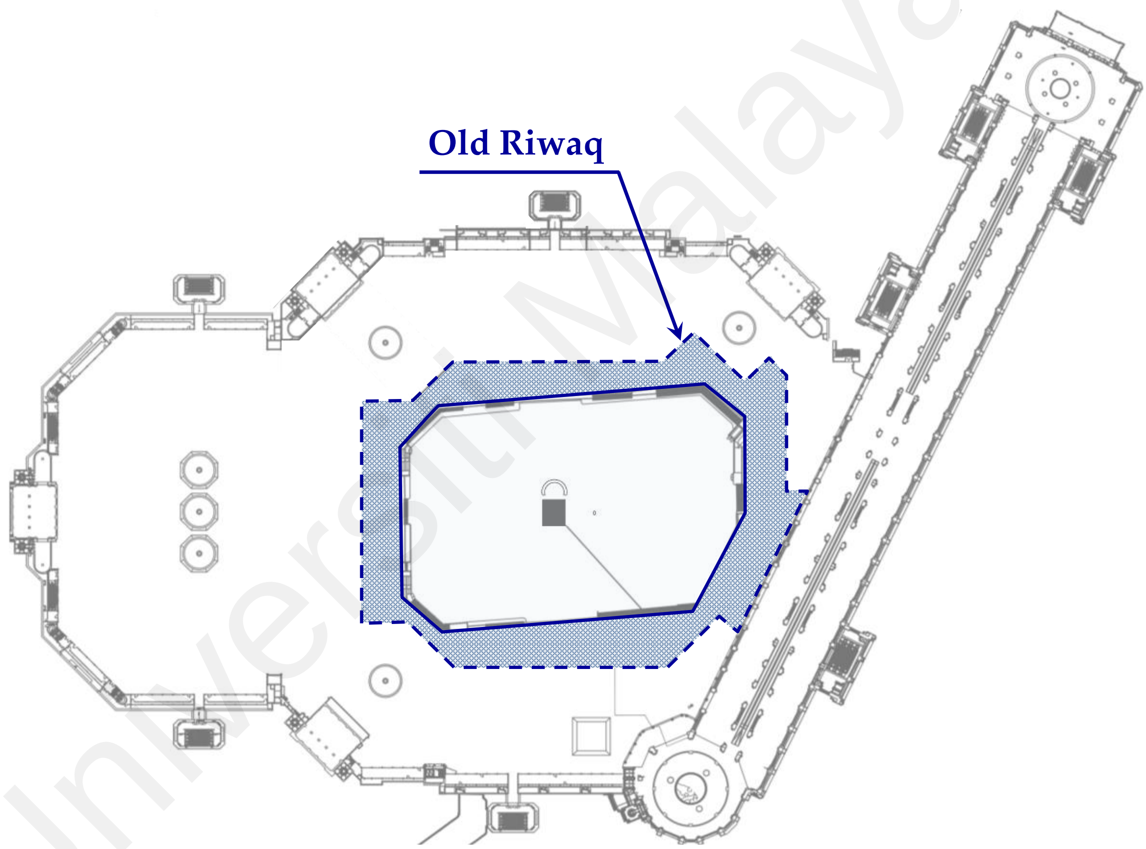

Figure 3.10: The location of the historical part which is called Old Riwaq project

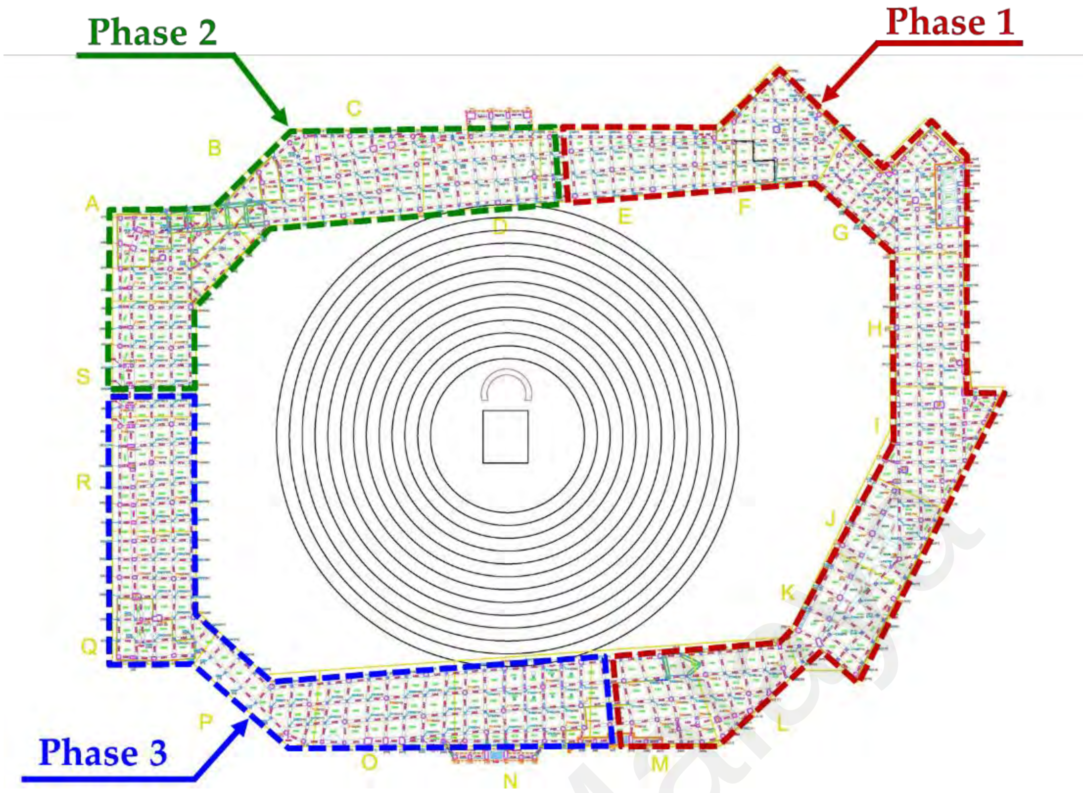

Figure 3.11: Main reconstruction phases of Old Riwaq project

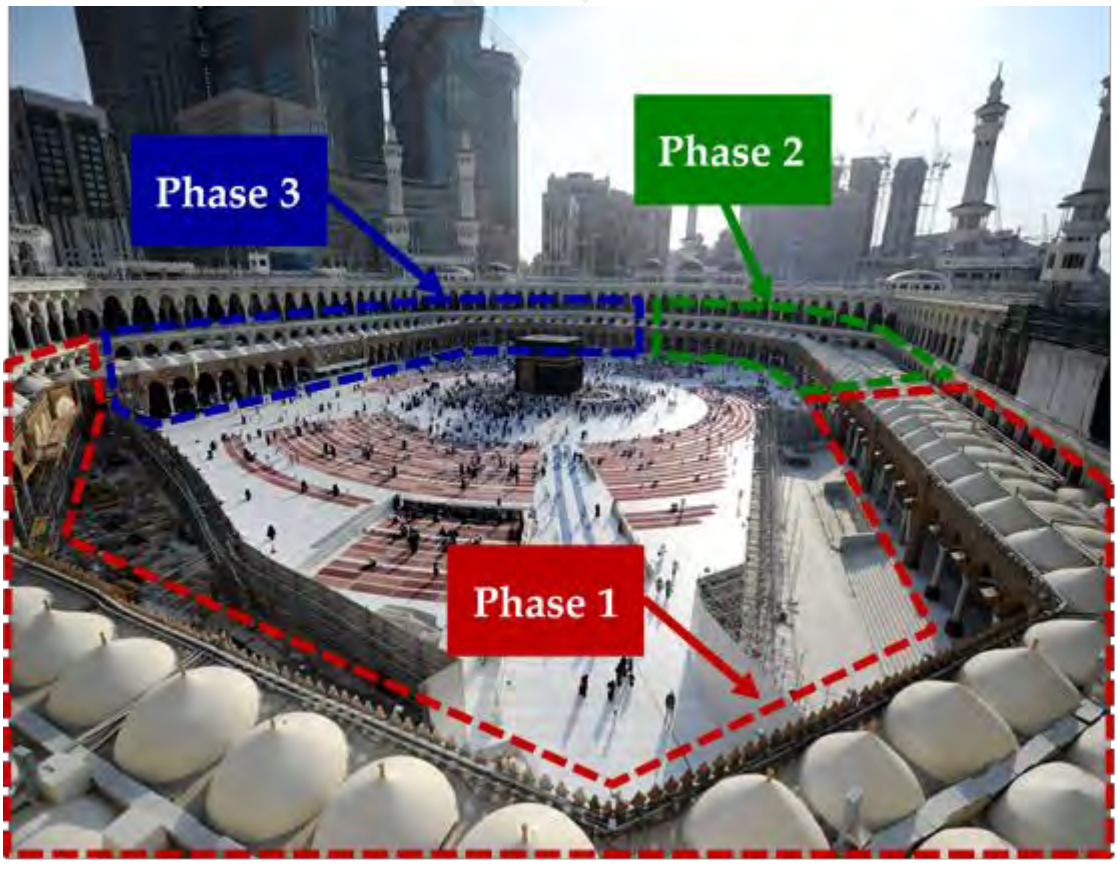

Figure 3.12: Image shows phases of the Old Riwaq project

In each phase of Old Riwaq project the results of the interviews indicated the existence of several different challenges that followed the reconstruction stages. These stages were the same in each phase as the follows:

3.2.2.1 Materials-related challenges in documentation and dismantling stage

3.2.2.2 Materials-related challenges in workshop stage

3.2.2.3 Materials-related challenges in new designs and mockup stage

3.2.2.1 Materials-Related Challenges in Documentation and Dismantling Stage

The first step in this historical project was the documentation work, as the experts mentioned in the interviews. Actually, before starting the dismantling procedures for the building, it was necessary to do the surveying works using modern surveying instruments and expert surveyors specialized in this type of historical projects, in addition to different types of photography with high quality and resolution. In fact, the aim of this work is to prepare an accurate as-built drawing that shows the location of each element in the historical building, alongside the photos, which play a fundamental role in the historic documentation of the project. The shape and the condition of each element in the building were also documented, because of the great historical value of the project. The experts pointed out that they could not start the dismantling works in any phase until the completion of the documentation works, which affected the reconstruction time of Old Riwaq project.

The second challenge in this stage was numbering the historical elements, dismantling works, protecting, packaging and transportation in special wooden boxes to the workshop area. In fact, this is considered a very important step in order to maintain the sustainability and the style of the historical elements. Figures (3.12- 3.15) show some of these works related to the historical columns which were divided into three parts: the capital, the body and the base. These parts were numbered, dismantled, protected, and packaged.

Figures (3.16- 3.19) show the numbering works for the historical stones, the dismantling works for the domes, the facade stones, and the dismantling works for the arches. All the historical stones were protected, packed and transported to the workshop area. The experts mentioned that the previous works required special and manual dismantling tools. In spite of the availability of skilled laborers, however these works required a long period that negatively affected the project duration.

Figure 3.13: Numbering the column body

Figure 3.14: Numbering the column capital

Figure 3.15: Protecting and packing the column

Figure 3.16: Column dismantling

Figure 3.17: Numbering the historical stones

Figure 3.18: Domes dismantling

Figure 3.19: Facade stones dismantling

Figure 3.20: Arches stones dismantling

3.2.2.2 Materials-Related Challenges in Workshop Stage

After transferring the historical elements to the workshop area, the next stage works started by unpacking, sorting and arranging the different elements as Figures (3.20-3.23) show the unpacking and sorting works for the stones and the columns.

Moreover, many tables were prepared showing the total number of similar historical items. Table 3.2 displays the summary of the historical items belonging to the first phase of the project after the completion of sorting and arranging works within the workshop area.

Figure 3.21: Unpacking works

Figure 3.22: Unpacking and sorting works

Figure 3.23: Sorting works of the stones

Figure 3.24: Sorting of the stones and Columns

Table 3.2: Inventories of dismantled items (1st Phase)

Elements	**Item**
Marble column	88
Capital	92
Base	70
Profile stone	50
Arch stone	1491
Finial	48
Keystone of arches	15
Shemasi pillar stone	678
Egyptian gate	112
Cornices	461
Muqarnas	82
Parapet stone	215
Rosette	45
Script	17

The historical items were carefully tested by using special equipment in order to identify their stability and conditions. After that, they were re-documented by using many tables that show the measurements and photos as well as the status of each item. Using the previous tables, the design consultant had selected the items that would be reconstructed again in the project location. Actually, this selection was made according to the aesthetical and historical value of each item as well as the structural applicability and sustainability.

The experts mentioned that the selected items were treated through a series of activities according to the item condition. The first activity was the cleaning works which divided into two steps. The first step was the surface cleaning by using soft brushes and small spatulas, while the second one was the deep cleaning by using the chemical materials in order to remove the grease and oil stains, as well as cleaning the joints and spaces as shown in Figures 3.24 and 3.25.

Figure 3.25: Surface cleaning of a column base

Figure 3.26: Deep cleaning of a column body

Actually, all the old previous treatments that were made for the historical elements all over the years were removed and replaced by the latest treatments, which simulates the historical element shape. In fact, the previous procedures are called imitations. The experts pointed out that the previous works were very important in order to know the amount of damage in the historical items.

The final step in this stage was the restoration work, which depended on the amount of damage for each item. In fact, the restoration works were divided into two main types. The first type is related to surface damages and cracks. This type was restored by using special chemical substances that were mixed with a powder similar to the nature of the historical item. The results were a mortar similar to the historical item with high sustainability used to restore the surface damages and the cracks. However, the second type of the restoration is related to the joining two pieces or more of the historical item together by using chemical substances in addition to special steel anchors if necessary.

Actually, sometimes the joining pieces could be from the same historical item, as shown in Figures (3.26- 3.29).

Figure 3.27: Chemical substances applied

Figure 3.28: Steel anchors utilized

Figure 3.29: Stone pieces joined

Figure 3.30: Stone shape after restoration

However, sometimes for restoration works a new piece of the same nature of the historical item could be joined as shown in Figures (3.30- 3.31).

Figure 3.31: Chemical substances and anchors applied

Figure 3.32: Marble column after restoration

The previous steps were considered as a big challenge, because it was very difficult to maintain the historical item totally to become as the original one when it was installed for the first time. That was especially, when a new piece was added to the damaged original historical item during the restoration procedures. However, the restored item might simulate the form of the original one in a high percentage, while the structure stability had to be one hundred percent similar for safety and sustainability purposes. In fact, restoration of the historical items negatively affected the Old Riwaq reconstruction duration.

3.2.2.3 Materials-Related in New Design and Mockup Stage

The design showed the historical restoration materials and other similar materials that should be used in the reconstruction works. However, the final shape, location and connection between these materials were subject to a mockup being made in order to display these details and avoid any clashes in the integrated design before starting the reconstruction works at project site.

Actually, the design team faced many challenges while preparing the new design for this historical project, as the experts mentioned during the interviews. The first challenge was related to the new form of the project which had to simulate the previous one through the preservation of spirit and the ancient shape of the old building which had been dismantled from the project site. The second challenge was related to the project level. Indeed, the old project was built on different levels, however the new historical building had to be constructed on one level, the lowest level in the project. This design would facilitate the movement and the flow of the visitors easily. In addition to, the safety and sustainability challenge was a very important one for the new historical building. In fact, this challenge added many constraints on the new structure design.

Moreover, the new design approval from all the related parties before proceeding with the reconstruction works at site, was subject to the building of a mockup showing all the details related to the structure, mechanical, plumbing and electrical design. In fact, the execution of the mockup was the final outcome of all the above mentioned stages and challenges, as mentioned by the experts in the project. It was also the penultimate step preceding the reconstruction of Old Riwaq at the project site. In addition, during the interviews many purposes for the mockup were mentioned such as: testing the best and fastest methods for the reconstruction works, especially the formwork systems and the required equipment, testing the design constructability and conflicts, showing the shape of the restoration elements after the installation works and the final integration form of the project, testing the sustainability and the safety requirement for the new reconstruction building and obtaining approvals from the consultant and other entities in order to start the actual reconstruction works at site. Figures (3.32-3.34) show the three-dimensional model for the new design and the new historical building mockup.

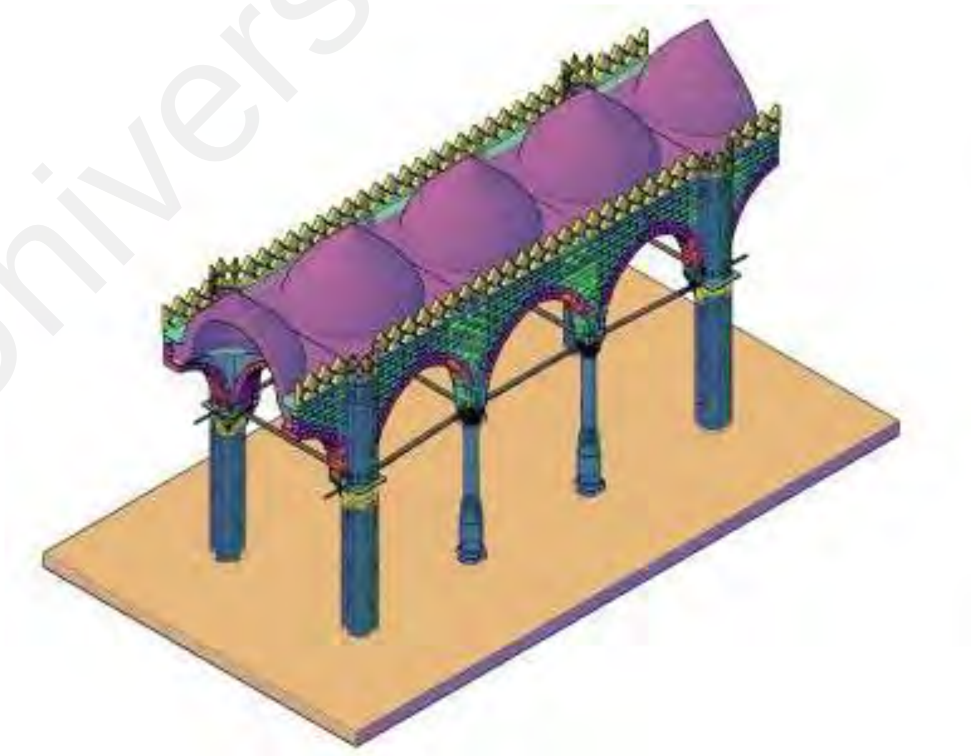

Figure 3.33: 3D modeling for the new design

Figure 3.34: New historical building mockup

Figure 3.35: Mockups for column pedestals stone cladding

Actually, the experts pointed out that the previous works related to the new design and mockup requirements were a big challenge in terms of time, and affected negatively Old Riwaq project duration.

3.2.3 Questionnaire Distributing to the Experts Working in Mataf Expansion Project

In this study, a questionnaire was prepared based on the project delay factors resulting from the experts' interviews. In fact, the goal of the questionnaire was to collect experts' opinions on the importance of delay factors affecting reconstruction work. In order to achieve this target, the questionnaire was divided into three parts. The first part was related to factors affecting demolition and dismantling phase. The second one was related to factors affecting construction phase. The third and final one was related to overall delay factors and their impact on the overall project duration as shown in Appendix C. A four-point Likert scale was adopted in the questionnaire, where 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree, in order to rank the delay factors significance and effects on project duration.

The site was visited many times and appointments were set up with the experts working on the project in order to fill out the questionnaire after informing them about this study goals. Some of these appointments were in the morning, while the others were in the evening. All the appointments were set up according to the experts' working conditions and free time to fill in the questionnaire as accurately as possible and in a way that reflects the reality of the project work. Before distributing the questionnaire to the experts, it was discussed with two construction managers to check that the delay factors were described clearly. In fact, these two interviews had an important role in the study as some points in the questionnaire were modified based on their recommendations. In addition, they advised us to distribute the questionnaire to experts who had worked for more than a year and could evaluate the delay factors significance according to their experience in this project. It should be mentioned here that the experts who responded to the questionnaire were professional engineers with various specialties and different levels in the project organizational chart. Table 3.3 shows the 93 respondents to the questionnaire and their position in terms of their level, job title, number within the group, and the percentage to the total number of respondents. In fact, all the respondents had a background about the project progress and conditions due to their direct work on the project location, which helped to obtain confident responses.

The respondents of the questionnaire were three groups, the first group was 11 managers with different job titles, and the percentage of respondents at the manager level was 11.8% of the total number of respondents. The second group was the senior level; the number of seniors was 22 and the percentage of respondents at the senior level was 23.7% of the total number of respondents. While the last group was the junior engineers with the highest number of respondents equal to 60 and the percentage of respondents at the junior engineers' level was 64.5% of the total number of respondents. In fact, about 35% of the respondents were from both managerial and senior levels together. This large percentage positively reflected the high level of confidence in the achieved delay factors and their evaluation. This was because of the differences in the experts' experience, in addition to their awareness of the project, and the real details of the delay factors which were discussed in the weekly progress meetings.

Table 3.3: Expert/Respondent's information

Expert/Respondent's Level	Job Title	Total Number	Total Percentage
Manager	Project manager, construction manager, technical manager, project control manager, logistics manager, planning manager, quality manager, safety manager, workshop manager	11	11.8%
Senior	Senior planning engineer, senior quality engineer, Senior site engineer (structural, electrical, mechanical and architectural), senior technical engineer (structural, electrical, mechanical and architectural), senior safety engineer	22	23.7%
Junior Engineer	Planning engineer, quality engineer, site engineer (structural, electrical, mechanical and architectural), technical engineer (structural, electrical, mechanical and architectural)	60	64.5%
Overall respondents		93	100%

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Data Analysis

The questionnaire data was analyzed by filling three tables that showed the number of the respondents in each questionnaire category who strongly agree, agree, disagree and strongly disagree. Table 4.1 presents the number of respondents who answered the factors related to the demolition and dismantling phase. Table 4.2 presents the number of respondents who answered the factors related to the construction phase. Table 4.3 presents the number of respondents who answered the factors related to the overall project reconstruction duration.

Table 4.1: Number of respondents who answered the factors related to the demolition and dismantling phase

No.	Delay Factor	Respondents Number				Total
		Strongly Agree	Agree	Disagree	Strongly Disagree	
1	Rerouting works for all electrical and mechanical utilities	77	16	0	0	93
2	Providing alternative safe access	62	31	0	0	93
3	Site conditions and constraints	79	14	0	0	93
4	The historical elements dismantling	54	32	7	0	93
5	The back propping and supporting works	27	34	21	11	93

Table 4.2: Number of respondents who answered the factors related to the construction phase

No.	Delay Factor	Respondents Number				Total
		Strongly Agree	Agree	Disagree	Strongly Disagree	
1	The design constructability and modification	71	22	0	0	93
2	Providing alternative safe access	50	29	12	2	93
3	Site conditions and constraints	76	17	0	0	93
4	The conflict between temporary projects and construction works	61	20	8	4	93
5	The historical elements test period	69	17	5	2	93
6	The alternative materials for the historical elements	40	28	16	9	93
7	The overlap between the execution of historical and nonhistorical parts	38	28	17	10	93
8	Workforce productivity rate	58	20	11	4	93
9	Delays in the construction work adjacent to the demolition area	21	31	23	18	93

Table 4.3: Number of respondents who answered the factors related to the overall project reconstruction duration

No.	Delay Factor	Respondents Number				Total
		Strongly Agree	Agree	Disagree	Strongly Disagree	
1	Rerouting works for all electrical and mechanical utilities	71	22	0	0	93
2	The historical elements dismantling	51	33	9	0	93
3	The back propping and supporting works	26	34	21	12	93
4	The design constructability and modification	69	24	0	0	93
5	Providing alternative safe access	59	21	12	1	93
6	Site conditions and constraints	75	18	0	0	93
7	The conflict between temporary projects and construction works	58	20	11	4	93
8	The historical elements test period	51	30	9	3	93
9	The alternative materials for the historical elements	35	30	19	9	93
10	The overlap between the execution of historical and nonhistorical parts	37	28	18	10	93
11	Workforce productivity rate	51	26	12	4	93
12	Delays in the construction work adjacent to the demolition area	20	30	25	18	93

To analyze the responses that are available in the above Tables (4.1-4.3), we will use a statistical measure, called, the relative importance index (RII). The RII is a percentage that describes the importance of the factor under consideration. It ranges between zero, corresponding to the least importance, to one, corresponding to the highest importance.

In this study, two methods are used to calculate the RII which are the 4-point and 2-point Likert scaling methods. The 4-ponit scaling method gives the exact relative importance percentage. However, it is affected by the responses that might not be very accurate. So it might be useful to combine the agreeing and disagreeing categories to achieve more simplicity. The later approach is what we referred to as the 2-point Likert scaling method, which is typically used to measure Agreement. After that, the results of the two approaches are used to analyze and have better understanding of the data, as follows:

5.1.1 RII_4 using 4-point Likert Scale

5.1.2 RII_2 using 2-point Likert Scale

5.1.3 Analysis results

4.1.1 RII_4 Using 4-Point Likert Scale

The relative importance index RII is the most proper and familiar method for sorting the delay factors in the previous studies such as Morakinyo et al. (2015), Jarkas and Haupt (2015), Al Jurf and Beheiry (2012), Abd El-Razek et al. (2008), Faridi and El-Sayegh (2006), Chan and Kumaraswamy (1997), Doloi et al. (2012), Sambasivan and Soon (2007), Assaf et al. (1995) and Kazaz et al. (2012). As a result, this study used the RII_4 to define the comparative ranking of the delay factors which is given by the following formula:

$$\text{RII}_4 = \frac{\sum w}{A*N} = \frac{4n_1+3n_2+2n_3+1n_4}{4*N} \quad (4.1)$$

Where the symbols indicate:

W: Weight given to each delay factor by the respondent within the range

(4, 3, 2, 1), multiplying by the number of respondents (n_1,n_2,n_3,n_4) for each factor;

n_1: Number of respondents who strongly agree;

n_2: Number of respondents who agree;

n_3: Number of respondents who disagree;

n_4: Number of respondents who strongly disagree;

A: Highest weight (in this study: 4);

N: Overall number of respondents (in this study: 93).

According to the RII_4 results, the delay factors were sorted in a descending ranking. The highest RII_4 value refers to the factor that causes the maximum delay, while the lowest RII_4 value refers to the factor that causes the least delay. By using the previous formula, the questionnaire analysis results were organized into three tables. Table 4.4 presents the delay factors that negatively affected the demolition and dismantling phase duration. Table 4.5 presents the delay factors that negatively affected the construction phase duration. Table 4.6 presents the delay factors that negatively affected the overall project reconstruction duration.

Table 4.4: Delay factor analysis results for the demolition and dismantling phase according to the RII_4

No.	Delay Factor	Percentage of Respondents Number				RII_4	Rank
		Strongly Agree	Agree	Disagree	Strongly Disagree		
1	Rerouting works for all electrical and mechanical utilities	82.8%	17.2%	0.0%	0.0%	0.957	2
2	Providing alternative safe access	66.7%	33.3%	0.0%	0.0%	0.917	3
3	Site conditions and constraints	84.9%	15.1%	0.0%	0.0%	0.962	1
4	The historical elements dismantling	58.1%	34.4%	7.5%	0.0%	0.876	4
5	The back propping and supporting works	29.0%	36.6%	22.6%	11.8%	0.707	5

Table 4.5: Delay factor analysis results for the construction phase according to RII_4

No.	Delay Factor	Percentage of Respondents Number				RII_4	Rank
		Strongly Agree	Agree	Disagree	Strongly Disagree		
1	The design constructability and modification	76.3%	23.7%	0.0%	0.0%	0.941	2
2	Providing alternative safe access	53.8%	31.2%	12.9%	2.2%	0.841	6
3	Site conditions and constraints	81.7%	18.3%	0.0%	0.0%	0.954	1
4	The conflict between temporary projects and construction works	65.6%	21.5%	8.6%	4.3%	0.871	4
5	The historical elements test period	74.2%	18.3%	5.4%	2.2%	0.911	3
6	The alternative materials for the historical elements	43.0%	30.1%	17.2%	9.7%	0.766	7
7	The overlap between the execution of historical and nonhistorical parts	40.9%	30.1%	18.3%	10.8%	0.753	8
8	Workforce productivity rate	62.4%	21.5%	11.8%	4.3%	0.855	5
9	Delays in the construction work adjacent to the demolition area	22.6%	33.3%	24.7%	19.4%	0.648	9

Table 4.6: Delay factor analysis results for the overall reconstruction project according to the RII_4

No.	Delay Factor	Percentage of Respondents Number				RII_4	Rank
		Strongly Agree	Agree	Disagree	Strongly Disagree		
1	Rerouting works for all electrical and mechanical utilities	76.3%	23.7%	0.0%	0.0%	0.941	2
2	The historical elements dismantling	54.8%	35.5%	9.7%	0.0%	0.863	5
3	The back propping and supporting works	28.0%	36.6%	22.6%	12.9%	0.699	11
4	The design constructability and modification	74.2%	25.8%	0.0%	0.0%	0.935	3
5	Providing alternative safe access	63.4%	22.6%	12.9%	1.1%	0.871	4
6	Site conditions and constraints	80.6%	19.4%	0.0%	0.0%	0.952	1
7	The conflict between temporary projects and construction works	62.4%	21.5%	11.8%	4.3%	0.855	6
8	The historical elements test period	54.8%	32.3%	9.7%	3.2%	0.847	7
9	The alternative materials for the historical elements	37.6%	32.3%	20.4%	9.7%	0.745	10
10	The overlap between the execution of historical and nonhistorical parts	39.8%	30.1%	19.4%	10.8%	0.747	9
11	Workforce productivity rate	54.8%	28.0%	12.9%	4.3%	0.833	8
12	Delays in the construction work adjacent to the demolition area	21.5%	32.3%	26.9%	19.4%	0.640	12

4.1.2 RII_2 Using 2-Point Likert Scale

The 2-point Likert scaling method combines the strongly agree and the agree data in one category, as well as the disagree and the strongly disagree data in one category. This would give more realistic figures that would help in making a better decision on the percentage of agreement and disagreement with the effect of a certain delay factor.

In fact, the degree of agreement is very rigid with weights of 4 or 3 for strongly agree or agree categories, respectively, still the respondents in both categories agree. Similarly, the disagreement with weights of 2 or 1 for disagree or strongly disagree categories, respectively, and still the respondents in both categories disagree. It might be useful to combine the agreeing categories in one category and the disagreeing categories in one category. We would get, in this case, sort of a binary decision responses (agree or disagree), where analyzing them in this way gives a different perspective to the problem. The RII_2 of 2-point Likert scale is given by the following formula:

$$RII_2 = \frac{1(n_1+n_2)+0(n_3+n_4)}{N} \tag{4.2}$$

Where the symbols indicate:

1: weight was given to each delay factor by the respondents' agreements;

0: weight was given to each delay factor by the respondents' disagreements;

n_1: number of respondents who strongly agree;

n_2: number of respondents who agree;

n_3: number of respondents who disagree;

n_4: number of respondents who strongly disagree;

N: overall number of respondents (in this study: 93).

According to the RII_2 results, the delay factors were sorted in a descending ranking. The highest RII_2 value refers to the factor that shows more agreement, while the lowest RII_2 value refers to the factor that shows less disagreement. By using RII_2 formula, the questionnaire analysis results were organized into three tables. Table 4.7 presents the delay factors that negatively affected the demolition and dismantling phase duration. Table 4.8 presents the delay factors that negatively affected the construction phase duration. Table 4.9 presents the delay factors that negatively affected the overall project reconstruction duration.

Table 4.7: Delay factor analysis results for the demolition and dismantling phase according to the RII_2

No.	**Delay Factor**	**Respondents Number**		**Percentage of Respondents Number**		**RII_2**	**Rank**
		Agree	**Disagree**	**Agree**	**Disagree**		
1	Rerouting works for all electrical and mechanical utilities	93	0	100.0%	0.0%	1.000	1
2	Providing alternative safe access	93	0	100.0%	0.0%	1.000	1
3	Site conditions and constraints	93	0	100.0%	0.0%	1.000	1
4	The historical elements dismantling	86	7	92.5%	7.5%	0.925	2
5	The back propping and supporting works	61	32	65.6%	34.4%	0.656	3

Table 4.8: Delay factor analysis results for the construction phase according to RII_2

No.	Delay Factor	Respondents Number		Percentage of Respondents Number		RII_2	Rank
		Agree	Disagree	Agree	Disagree		
1	The design constructability and modification	93	0	100.0%	0.0%	1.000	1
2	Providing alternative safe access	79	14	84.9%	15.1%	0.849	4
3	Site conditions and constraints	93	0	100.0%	0.0%	1.000	1
4	The conflict between temporary projects and construction works	81	12	87.1%	12.9%	0.871	3
5	The historical elements test period	86	7	92.5%	7.5%	0.925	2
6	The alternative materials for the historical elements	68	25	73.1%	26.9%	0.731	6
7	The overlap between the execution of historical and nonhistorical parts	66	27	71.0%	29.0%	0.710	7
8	Workforce productivity rate	78	15	83.9%	16.1%	0.839	5
9	Delays in the construction work adjacent to the demolition area	52	41	55.9%	44.1%	0.559	8

Table 4.9: Delay factor analysis results for the overall reconstruction project according to the RII_2

No.	Delay Factor	Respondents Number		Percentage of Respondents Number		RII_2	Rank
		Agree	Disagree	Agree	Disagree		
1	Rerouting works for all electrical and mechanical utilities	93	0	100.0%	0.0%	1.000	1
2	The historical elements dismantling	84	9	90.3%	9.7%	0.903	2
3	The back propping and supporting works	60	33	64.5%	35.5%	0.645	8
4	The design constructability and modification	93	0	100.0%	0.0%	1.000	1
5	Providing alternative safe access	80	13	86.0%	14.0%	0.860	4
6	Site conditions and constraints	93	0	100.0%	0.0%	1.000	1
7	The conflict between temporary projects and construction works	78	15	83.9%	16.1%	0.839	5
8	The historical elements test period	81	12	87.1%	12.9%	0.871	3
9	The alternative materials for the historical elements	65	28	69.9%	30.1%	0.699	7
10	The overlap between the execution of historical and nonhistorical parts	65	28	69.9%	30.1%	0.699	7
11	Workforce productivity rate	77	16	82.8%	17.2%	0.828	6
12	Delays in the construction work adjacent to the demolition area	50	43	53.8%	46.2%	0.538	9

4.1.3 Analysis Results

The analysis results show high matching in the delay factors ranking results according to 4-point and 2-point Likert scaling methods. Tables (4.10-4.13) and Figures (4.1-4.3) demonstrate these results.

Table 4.10: The analysis results of RII_4 and RII_2 that affect the demolition and dismantling phase

No.	Delay Factor	RII_4 Analysis Results		RII_2 Analysis Results	
		Value	Rank	Value	Rank
1	Rerouting works for all electrical and mechanical utilities	0.957	2	1.000	1
2	Providing alternative safe access	0.917	3	1.000	1
3	Site conditions and constraints	0.962	1	1.000	1
4	The historical elements dismantling	0.876	4	0.925	2
5	The back propping and supporting works	0.707	5	0.656	3

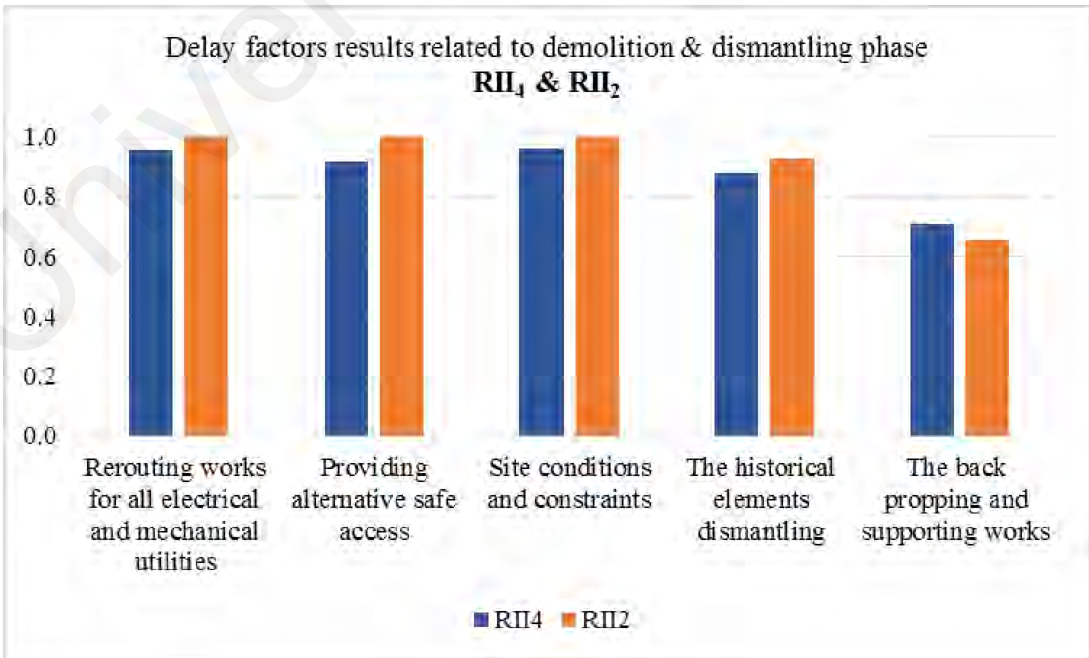

Figure 4.1: Graphical representation of RII_4 and RII_2 that affect the demolition and dismantling phase

Table 4.11: The analysis results of RII_4 and RII_2 that affect the construction phase

No.	Delay Factor	RII_4 Analysis Results		RII_2 Analysis Results	
		Value	Rank	Value	Rank
1	The design constructability and modification	0.941	2	1.000	1
2	Providing alternative safe access	0.841	6	0.849	4
3	Site conditions and constraints	0.954	1	1.000	1
4	Overlap between temporary projects and construction works	0.871	4	0.871	3
5	Historical elements test period	0.911	3	0.925	2
6	Alternative materials for the historical elements	0.766	7	0.731	6
7	Overlap between the historical and nonhistorical parts	0.753	8	0.710	7
8	Workforce productivity rate	0.855	5	0.839	5
9	Delays in the building works next to the demolition area	0.648	9	0.559	8

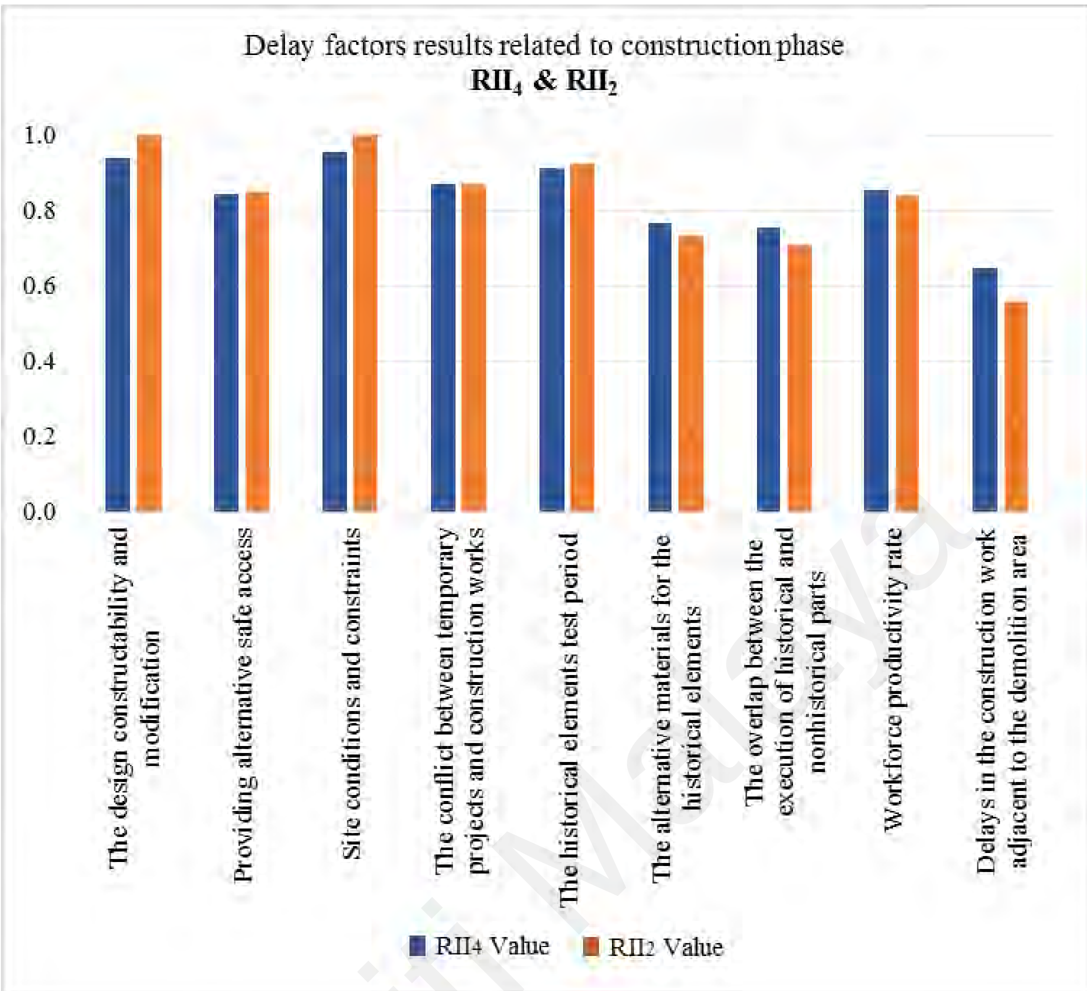

Figure 4.2: Graphical representation of RII_4 and RII_2 that affect the construction phase

Table 4.12: The analysis results of RII_4 and RII_2 that affect the overall reconstruction project

No.	Delay Factor	RII_4 Analysis Results		RII_2 Analysis Results	
		Value	Rank	Value	Rank
1	Rerouting works for all electrical and mechanical utilities	0.941	2	1.000	1
2	The historical elements dismantling	0.863	5	0.903	2
3	The back propping and supporting works	0.699	11	0.645	8
4	The design constructability and modification	0.935	3	1.000	1
5	Providing alternative safe access	0.871	4	0.860	4
6	Site conditions and constraints	0.952	1	1.000	1
7	The conflict between temporary projects and construction works	0.855	6	0.839	5
8	The historical elements test period	0.847	7	0.871	3
9	The alternative materials for the historical elements	0.745	10	0.699	7
10	The overlap between the execution of historical and nonhistorical parts	0.747	9	0.699	7
11	Workforce productivity rate	0.833	8	0.828	6
12	Delays in the construction work adjacent to the demolition area	0.640	12	0.538	9

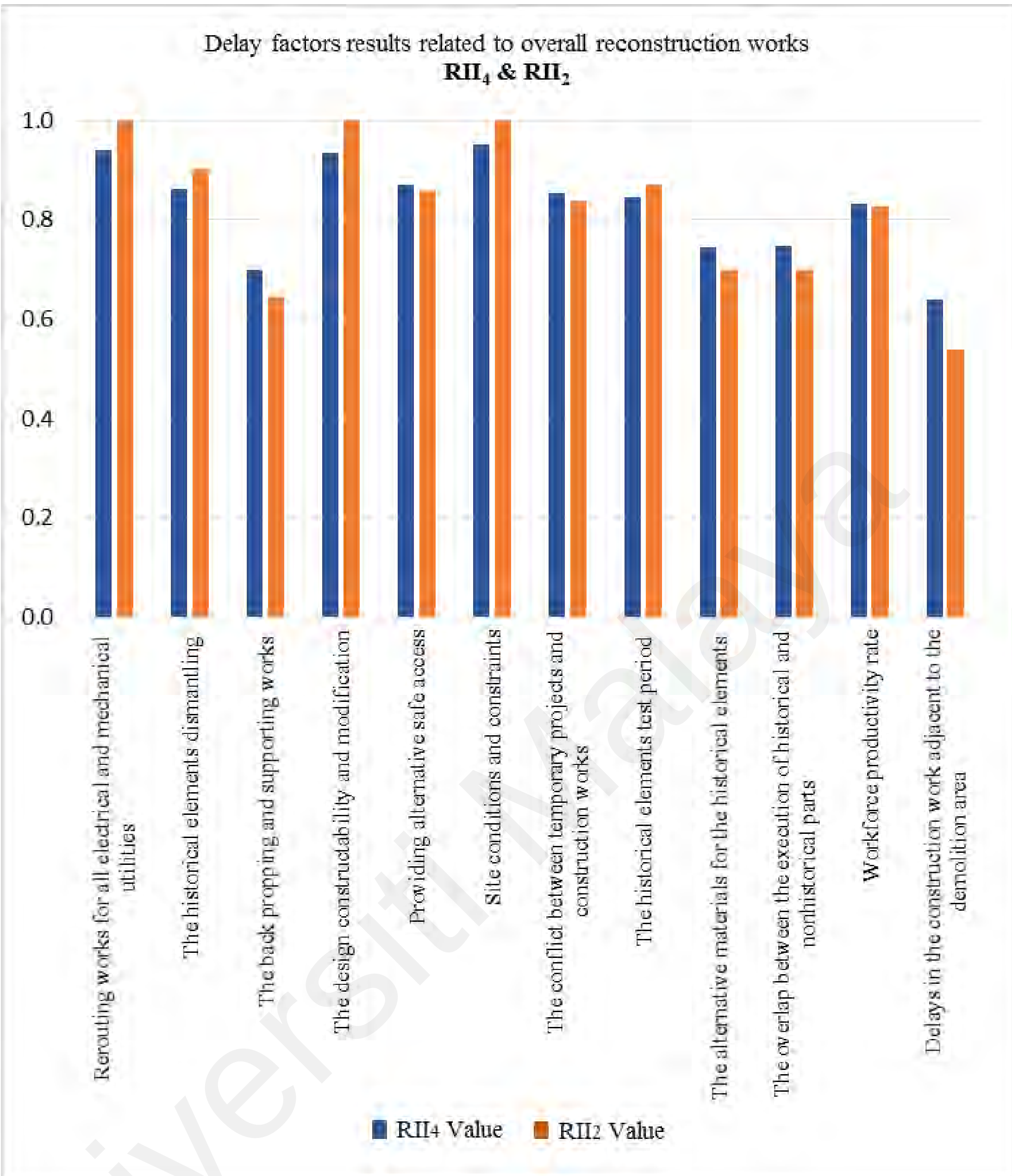

Figure 4.3: Graphical representation of RII_4 and RII_2 that affect the overall reconstruction project

4.2 Discussion

The data analysis results demonstrate great correspondence in the delay factors ranking results according to the RII_4 and RII_2.

The first factor, which is site conditions and constraints came first in terms of its impact on the overall project duration according to Table 4.12, where ($RII_4 = 0.952$, Rank = 1) and ($RII_2 = 1$, Rank = 1). It also came first with respect to the effect on the demolition and dismantling phase duration according to Table 4.10 ($RII_4 = 0.962$, Rank = 1) and

(RII_2 = 1, Rank = 1) and with respect to the impact on the construction phase duration according to Table 4.11 (RII_4 = 0.954, Rank = 1) and (RII_2 = 1, Rank = 1). There was a big difference between the site conditions during demolition and construction mockups, which were built in special workshop, and site conditions during work on the project. This difference resulted from a set of points. Firstly, the mockups could be easily accessed and worked on from all sides, whereas the project site is not easily accessible, so work is restricted to specific aspects, as shown in Figures (4.4 - 4.5).

Figure 4.4: Demolition mockup for accessibility

Figure 4.5: The project site itself, showing it is not easily accessible

Secondly, there are no restrictions on the equipment size used for demolition and construction within the workshop area, where demolition and construction mockups were built due to the availability of wide tracks and entrances. However, this is not the case on the actual project site, where there are restrictions on large equipment due to the narrow tracks. This means that equipment, demolition debris, and building materials are often transported using tower cranes, as shown in Figures (4.6-4.7).

Figure 4.6: Large (in the bottom red circle) and small (in the top red circle) machinery at the demolition mockup

Figure 4.7: Small machinery (shown in the red circles) at the project site

Thirdly, the mockup area is completely closed off to visitors, which allows work to continue without interruptions or special safety requirements. Fourthly, demolition work started immediately on the mockup without the need for any mobilization or preliminary work. Unlike the project site, where demolition work did not start until the following works, which are historical documentation, dismantling and packaging holdings, and building fences that mimic the project shape are done as it is shown in Figures (4.8-4.9)

Figure 4.8: Dismantling and packaging holdings

Figure 4.9: Temporary fences mimic the project shape

Fifthly, cutting the roof slabs for the mockup roof began directly. However, in the project site the slabs demolition and cutting could not start until the marble and roofing system materials were removed from the roof, as shown in Figure 4.10.

Figure 4.10: Marble and roofing system material removal

Sixthly, the demolition and construction works in the mockups did not require work permits, unlike work on the project. These previously mentioned points made the site conditions and constraints the most important factor affecting the demolition phase duration and the construction phase duration, and consequently the overall project duration.

Rerouting works for all electrical and mechanical utilities factor ranked second in terms of influence on the overall project duration, according to Table 4.12 (RII_4 = 0.941, Rank = 2) and (RII_2 = 1, Rank = 1), and it came second in relation to its impact on the demolition and dismantling phase duration, according to Table 4.10 (RII_4 = 0.957, Rank = 2) and (RII_2 = 1, Rank = 1). There was a consensus on this factor, because all the electrical and mechanical services and systems were operating in integrated systems and continuous loops. For these systems to continue working properly and safely in the rest of the project phases without any disruption, these services had to be transformed and alternative routes found. This ensures that the services work properly and with the required efficiency. In fact, the transfer of electromechanical services is not limited to diverting the routes of these utilities, but also includes rebuilding new service rooms outside the demolition areas and equipping them with all the required equipment and control systems. These rooms are tested and operated temporarily in order to ensure their effectiveness and performance, before handing them over to the authorized entities to obtain permission for removing the old rooms, as shown in Figure 4.11. Service transfer takes time and delays the demolition work and, as a result, the project as a whole.

Figure 4.11: Rerouting work for an electrical service room

The design constructability and modification factor came third in terms of the impact on the overall project duration, according to Table 4.12 (RII_4 = 0.935, Rank = 3 and (RII_2 = 1, Rank = 1), and second in terms of the impact on the construction phase duration, according to Table 4.11 (RII_4 = 0.941, Rank = 2) and (RII_2 = 1, Rank = 1). The most important criterion was large spaces between the columns in order to permit people to move easily among the project zones, and the possibility of expanding the project vertically without the need for any demolition work. These were major reasons behind the project design difficulty. For example, the steel reinforcement of the raft foundation made it particularly hard to execute the necessary work as shown in Figure 4.12. In fact, design difficulties and modifications during the building work delayed the construction phase, and this delay negatively affected the overall project duration.

Figure 4.12: Steel reinforcement density in the raft foundation

Providing alternative safe access factor came fourth in terms of its impact on the overall project duration, according to Table 4.12 (RII_4 = 0.871, Rank = 4) and (RII_2 = 0.860, Rank = 4), and ranked third in terms of impact on the demolition and dismantling phase duration according to Table 4.10 (RII_4 = 0.917, Rank = 3) and (RII_2 = 1, Rank = 1). It ranked sixth in terms of the effect on the construction phase duration, according to Table 4.11 (RII_4 = 0.841, Rank = 6) and (RII_2 = 0.849, Rank = 4). In fact, to ensure that visitors move safely between the different project areas, in addition to inside and outside the project, it was necessary to leave passageways within the demolition and construction areas that allow easy and safe movement. These safe accesses were an area where work was not permitted. This is evident in Figure (4.13-4.15), where Figure 4.13 and Figure 4.14 show the completion of the demolition work within the first phase area, except for the safe passageway part, which remains suspended until an alternative safe access is secured within the construction area, and Figure 4.15 shows the demolition work in the safe access part which has been resumed after providing an alternative safe access for the visitors within the construction area. In addition, these safe passageways have divided one work area into two completely separate areas, and this imposed additional restrictions on the equipment and the laborers' movement between the work areas, as shown in Figure (4.13-4.15). The creation of safe access within the demolition and construction areas delays the work and, as a result, negatively affects the overall project duration.

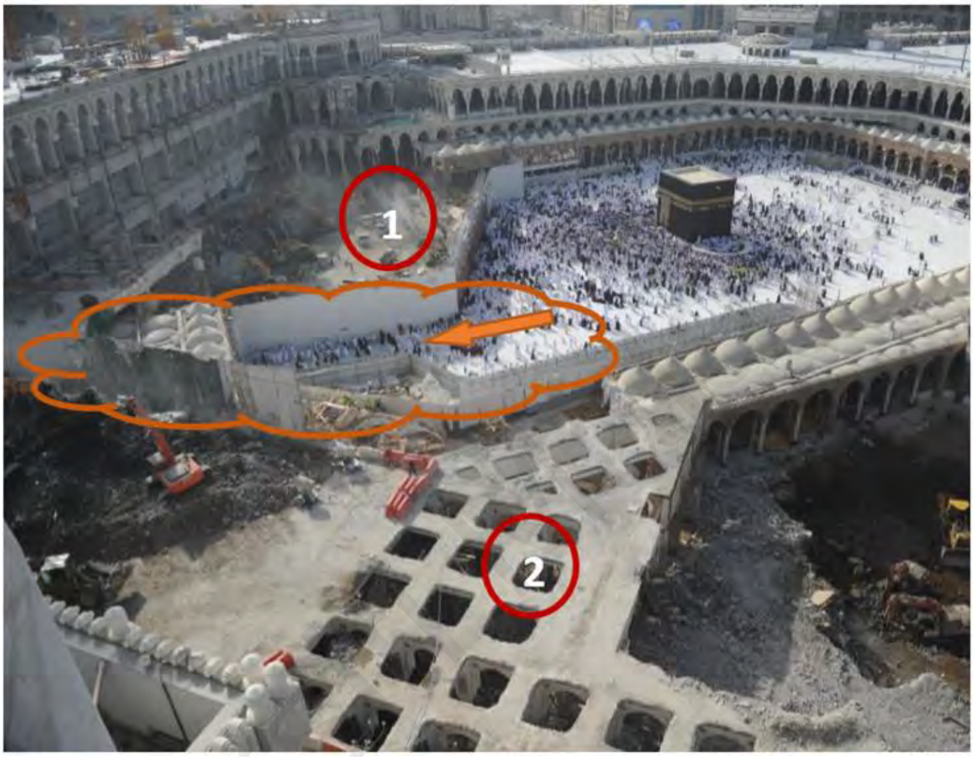

Figure 4.13: The clouded area in early stage of the project, showing the safe path for people which divided phase one of demolition area into two parts (1 & 2)

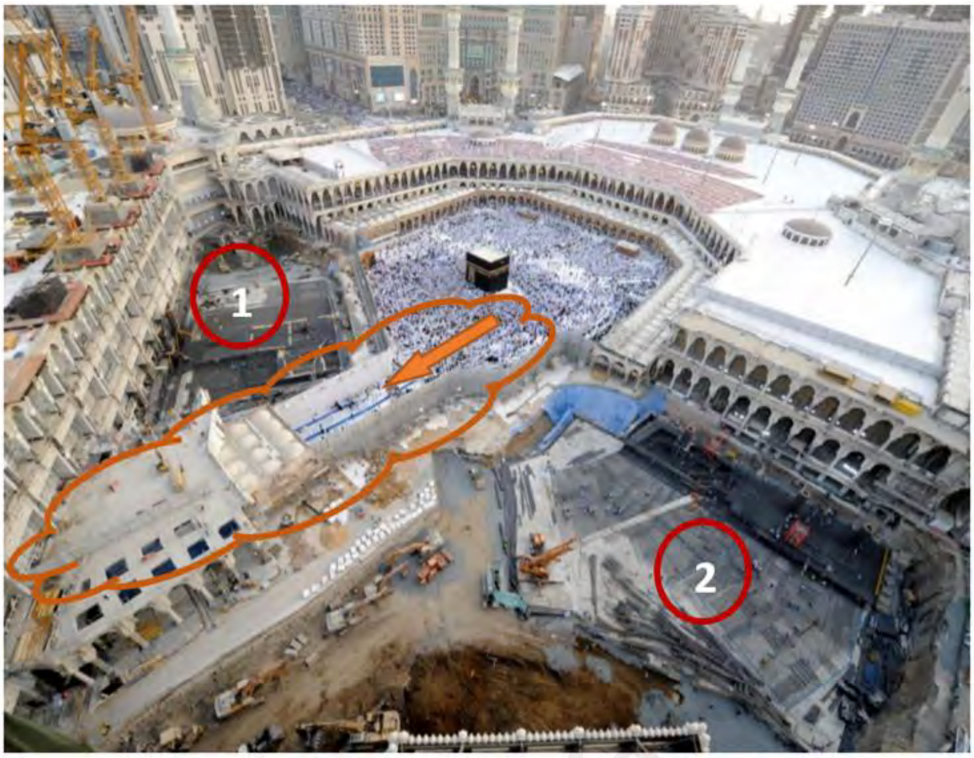

Figure 4.14: The clouded area shows the safe path for people, which could not be demolished, while the construction works started in parts (1 & 2)

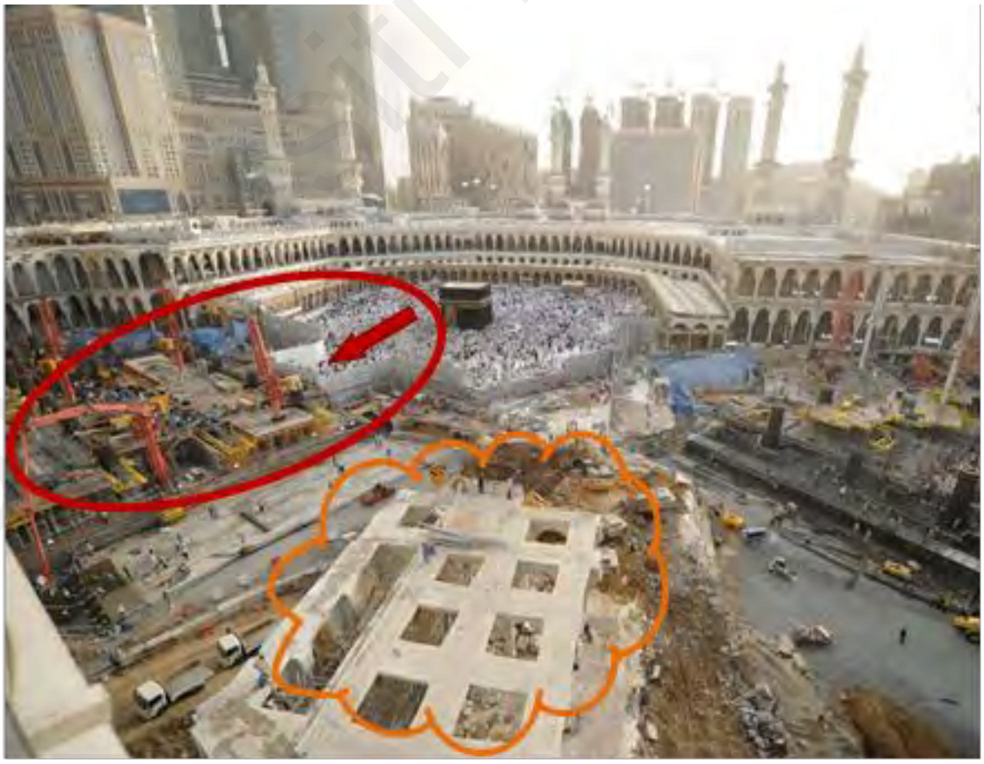

Figure 4.15: The orange clouded area is the last demolition stage, while the red arrow shows the visitors new safe access which is built under the construction area shown in the red shape

The historical elements dismantling factor came in fifth place in terms of the impact on the overall project duration, according to Table 4.12 ($RII_4 = 0.863$, Rank = 5) and ($RII_2 = 0.903$, Rank = 2), and was ranked fourth in terms of impact on the demolition and dismantling phase duration, according to Table 4.10 ($RII_4 = 0.876$, Rank = 4) and ($RII_2 = 0.925$, Rank = 2). The negative impact of this factor on the project duration resulted from two main matters. The first is related to the historical building itself, while the second is due to the relationship between the historical and nonhistorical buildings in terms of the overlap between them. In fact, the first negative impact related to the historical building is the result of the procedures that must be taken into account before starting to remove any historical element. These procedures are explained before in the first stage of materials challenges of the historical part. These actions are important to preserve the historical elements in order to use them again during the reconstruction phase, and that takes time which negatively affects the project duration. However, in overlapping areas all demolition work in the nonhistorical section adjacent to the historical one had to be stopped until the removal of all the historical elements was completed, in order to ensure the safety of the historical elements, as shown in Figure 4.16 This delay negatively affected the overall project duration.

Figure 4.16: The red cloud in image 1 shows overlap between the historical and nonhistorical parts, and image 2 shows dismantling of historical columns located under the nonhistorical parts

The conflict between temporary projects and construction works factor came in sixth place in terms of the impact on the overall project duration, according to Table 4.12 (RII_4 = 0.855, Rank = 6) and (RII_2 = 0.839, Rank = 5), while it came fourth in terms of its influence on the construction phase duration, according to Table 4.11 (RII_4 = 0.871, Rank = 4) and (RII_2 = 0.871, Rank = 3). The project was divided into three main phases so that the site did not have to be closed off entirely. With the start of work in the first phase, the space available to visitors decreased, which required the execution of some temporary projects in order to reduce crowding and ensure safe movement. An example is the temporary Mataf project shown in Figure 4.17. Despite the positive role that this project played in serving visitors and facilitating their safe movement, some of Mataf temporary passageways were located within the construction area, which delayed the construction work and negatively affected the overall project duration.

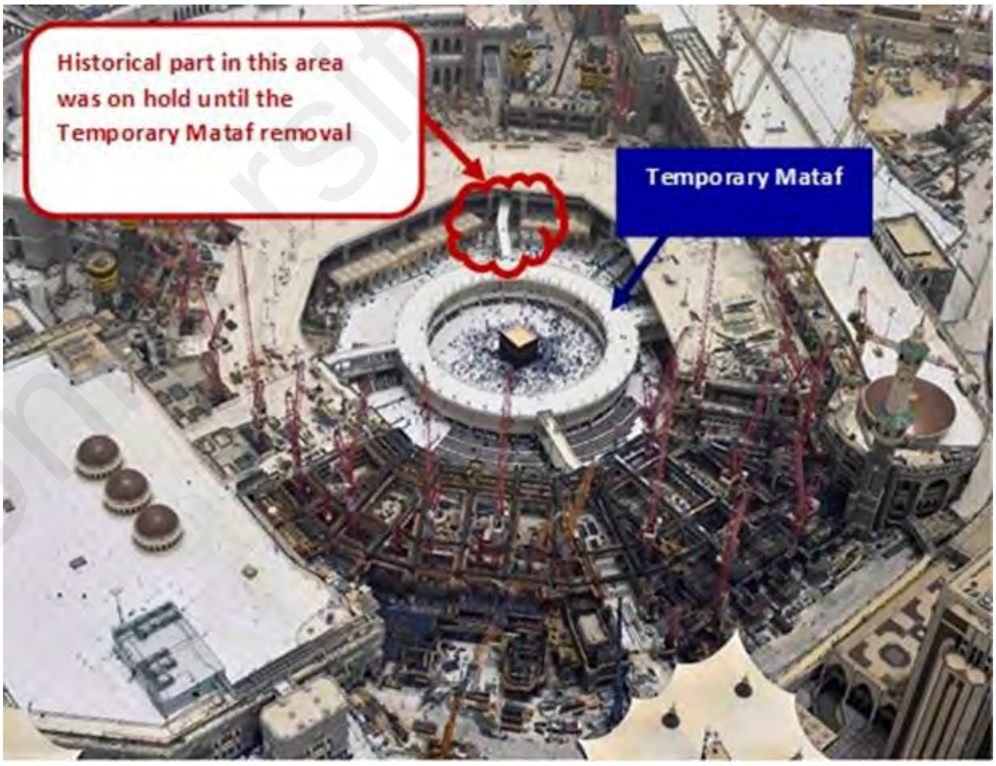

Figure 4.17: Temporary Mataf project

The historical elements test period factor came in seventh place in terms of its impact on the overall project duration, according to Table 4.12 (RII_4 = 0.847, Rank = 7) and (RII_2 = 0.871, Rank = 3), while it came third in terms of its influence on the construction phase duration, according to Table 4.11 (RII_4 = 0.911, Rank = 3) and (RII_2 = 0.925, Rank = 2). This factor and its impact explained before in the second stage of materials challenges of the historical part. These challenges delayed the historical building reconstruction, and negatively impacted the overall project duration.

Workforce productivity rate factor came in eighth place in terms of its impact on the overall project duration, according to Table 4.12 (RII_4 = 0.833, Rank = 8) and (RII_2 = 0.828, Rank = 6), while it came fifth in terms of its impact on the construction phase duration, according to Table 4.11 (RII_4 = 0.855, Rank = 5) and (RII_2 = 0.839, Rank = 5). The laborers' productivity rate decreased due to the difficulty of transporting materials and equipment maneuvering at the site. In addition, the design difficulty, hot weather, and stopping work during prayer times caused delay, which negatively affected the overall project duration.

The overlap between the execution of historical and nonhistorical parts factor came in ninth place in terms of its impact on the overall project duration, according to Table 4.12 (RII_4 = 0.747, Rank = 9) and (RII_2 = 0.699, Rank = 7), while it ranked eighth in terms of its effect on the construction phase duration, according to Table 4.11 (RII_4 = 0.753, Rank = 8) and (RII_2 = 0.710, Rank = 7). According to the Health, Safety and Environmental (HSE) requirements of the project, construction work stopped on the historical parts overlapping with the nonhistorical ones until the construction of the nonhistorical parts was completed. This matter delayed the construction work in the historical building and this delay reflected negatively on the overall project duration.

The alternative materials for the historical elements factor came in tenth place in terms of its impact on the overall project duration, according to Table 4.12 (RII_4 = 0.745, Rank = 10) and (RII_2 = 0.699, Rank = 7), while it came seventh in terms of influencing the construction phase duration, according to Table 4.11 (RII_4 = 0.766, Rank = 7) and (RII_2 = 0.731, Rank = 6). One of the most important factors that delayed the construction work in the historical part was the need to get new materials similar to the historical elements and obtain approval from the supervising authorities. In fact, this factor and its impact explained before in the third stage of materials challenges of the historical part. These challenges delayed the start of the historical building construction works, which impacted negatively on the overall project duration.

The back propping and supporting works factor came in eleventh place in terms of its impact on the overall time project duration, which is the penultimate stage, according to Table 4.12 (RII_4 = 0.699, Rank = 11) and (RII_2 = 0.645, Rank = 8), while it came in fifth place in terms of its impact on the demolition phase duration according to Table 4.10 (RII_4 = 0.707, Rank = 5) and (RII_2 = 0.656, Rank = 3). Before starting demolition work in any area of the project, necessary supporting work had to be completed based on the approved demolition plan. In fact, the project required additional propping-up, due to the fact that construction was in operation and visitors' safe access had to be ensured, in addition to the large floor height, as shown in Figure 4.18. The propping-up required additional time, which affected the demolition phase duration. As a result, it affected the overall project duration.

Figure 4.18: Back propping and supporting works

Delays in the construction work adjacent to the demolition area factor came in twelfth in terms of the impact on the overall project duration, according to Table 4.12 (RII_4 = 0.640, Rank = 12) and (RII_2 = 0.538, Rank = 9), while it ranked ninth in terms of the impact on the construction phase duration according to Table 4.11 (RII_4 = 0.648, Rank = 9) and (RII_2 = 0.559, Rank = 8). In fact, according to the Health, Safety and Environmental (HSE) requirements, an interval zone between the demolition and construction work had to be left to avoid any possible accidents. Construction work in this zone was not permitted until the demolition work was totally completed in the vicinity. This delayed the start of construction work in the areas adjacent to the demolition zones, which negatively affected the construction work duration and thus the overall project duration.

It is evident from the above discussion, that there are twelve factors affecting the reconstruction project duration negatively. Besides, providing alternative safe access and site conditions and constraints are shared factors between demolition and dismantling phase and the construction phase, In fact, among the twelve delay factors affecting the reconstruction projects, there are three shared factors with previous studies related to the construction projects and they are: design constructability and modification, workforce productivity rate, and site conditions and constraints. As for the nine remaining delay factors, they are unique to reconstruction projects and they are different from the previous studies.

CHAPTER 5: CONCLUSION

Several studies have highlighted and discussed construction projects delay factors in many countries in order to avoid or at least mitigate the negative effects of such factors on the construction industry. However, these studies are still limited to reconstruction projects that are classified into two main phases, namely a demolition phase and a construction phase, which remain under operation during the project execution period. A case study was conducted on Mataf Expansion Project in Mecca, Saudi Arabia, which is considered one of the most important mega reconstruction projects recently conducted in the Middle East. This project consists of two main parts, nonhistorical and historical, and it clarifies the difficulties facing this type of mega reconstruction projects.

This study aimed to conduct a comprehensive analysis of mega reconstruction projects delay factors, which has recently become widespread. In fact, there is a need for reconstruction projects. For example, some buildings need to expand and develop their electromechanical systems in order to match nowadays needs. Reconstruction also takes place in old buildings of a historical and cultural heritage which are unsafe. Furthermore, reconstruction takes place in buildings affected by natural disasters such as earthquakes or damaged by conflicts.

Twenty-nine interviews were conducted with project experts of different levels of seniority to identify the delay factors in this type of mega-projects and their negative impact on the project duration.

5.1 Conclusion

The interviews results showed that the delay factors could be divided into two groups. The first one is associated with the demolition and dismantling phase which are five factors: rerouting works for all electrical and mechanical utilities, providing alternative safe access, site conditions and constraints, historical elements dismantling and the back propping and supporting works. The second one is associated with construction works which are nine factors: the design constructability and modification, providing alternative safe access, site conditions and constraints, the overlap between temporary projects and construction works, the historical elements test period, the alternative materials for the historical elements, the overlap between the execution of historical and nonhistorical parts, workforce productivity rate and delays in the construction work adjacent to the demolition area.

It is clear by reviewing the previous fourteen factors that there are common ones between demolition and dismantling phase and the construction phase, which are providing alternative safe access and site conditions and constraints. After deleting the two repetitive shared factors, there are twelve delay factors affecting negatively the mega reconstruction projects.

In addition, it had been observed that the materials challenges during the reconstruction were considered the major delay factor in the historical building of this project. In fact, historical projects are based mainly on the sustainability of the historical item that formed the construction materials. The results of the interviews indicated that the work in the historical project was divided into several stages. At each stage, the experts mentioned several materials challenges as follows:

The first stage was the documentation and dismantling of the historical building. During this stage, the major challenges were:

(i) Surveying and photography works as well as the preparation of an accurate as-built drawings.

(ii) Numbering of the historical elements, dismantling works, packaging and transportation.

The second stage was the workshop stage. The challenges that emerged during this stage were:

(i) Sorting, testing and arranging the historical elements.

(ii) Cleaning the historical items and removing the imitations.

(iii) Restoration of historical elements using different methods and applying special substances.

The third stage was the new designs and mockup stage. The challenges that showed during this stage were:

(i) Design requirements.

(ii) Building a mockup showing the final shape of the new historical building.

(iii) The speed of obtaining the required consultant and other entities approvals.

Afterwards, a questionnaire was prepared divided into three parts. The first part was related to the five factors affecting the demolition and dismantling duration, and the second was related to the nine factors affecting the construction duration. While the last one was related to the twelve factors, after deleting the repeated ones, which affected the overall reconstruction duration. In fact, the questionnaire was done in order to sort the delay factors affecting the project duration.

Ninety-three questionnaires were distributed by hand to experts working on the project. Then, the questionnaires results were analyzed and the delay factors were sorted in a descending order according to the relative importance index (RII). They were as follows:

The delay factors that negatively affected the demolition phase duration:

(1) Site conditions and constraints.

(2) Rerouting works factor for electrical and mechanical utilities.

(3) Providing alternative safe access.

(4) Historical element dismantling.

(5) Back propping and supporting works.

The delay factors that negatively affected the construction phase duration:

(1) Site conditions and constraints.

(2) Design constructability and modification.

(3) Historical elements test period.

(4) Overlap between temporary projects and construction works

(5) Workforce productivity rate.

(6) Providing alternative safe access.

(7) Alternative materials for the historical elements.

(8) Overlap between the historical and nonhistorical parts.

(9) Delays in the building works next to the demolition area.

Due to the overlap between the demolition phase and the construction phase, in addition to the existence of some common factors between these two phases, the final list of delay factors that negatively affected the overall project reconstruction duration was:

(1) Site conditions and constraints.

(2) Rerouting works factor for electrical and mechanical utilities.

(3) Design constructability and modification.

(4) Providing alternative safe access.

(5) Historical element dismantling.

(6) Overlap between temporary projects and construction works

(7) Historical elements test period.

(8) Workforce productivity rate.

(9) Overlap between the historical and nonhistorical parts.

(10) Alternative materials for the historical elements.

(11) Back propping and supporting works.

(12) Delays in the building works next to the demolition area.

To conclude, it might be necessary to take into account the above delay factors in future reconstruction projects. As a result, that might make reconstruction project plans more applicable and avoid or at least mitigate the negative effects on the project duration Figure 5.1.

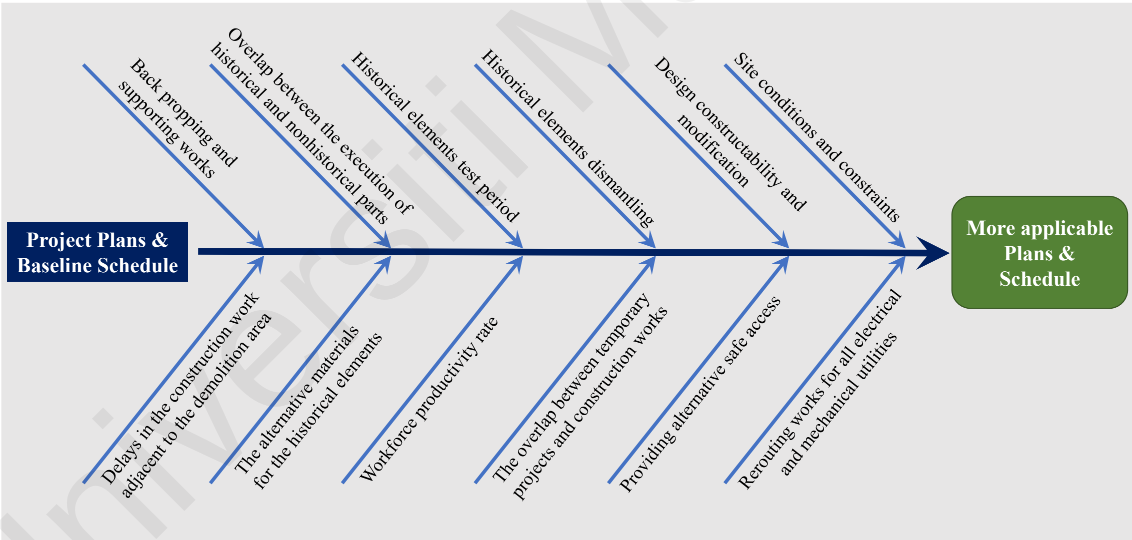

Figure 5.1: shows how a project plan and baseline schedule might be more applicable if the reconstruction delay factors are taken into consideration

5.2 Recommendations

The study results shed light on the delay factors in the mega reconstruction projects, and this was clear by classifying these factors according to their negative effect on the project duration. The research recommendations were based on three main points:

- The lessons learned from the first project phase, which were applied to the second and third project phase.
- The suggestions and ideas mentioned by the experts during the interviews, which were documented with great interest.
- The researchers' vision resulting from their study to Mataf Expansion Project in addition to the conducted literature review on the previous studies.

In fact, these recommendations are considered as a bridge that can help to overcome the delay factors and their negative effects on reconstruction projects or they can at least mitigate the negative impact of these factors. The study recommendations can be divided as the following:

5.2.1 Recommendation Related to Material Challenges of the Historical Building

In fact, the previous material challenges of the historical building were evident during the work in the first phase of the project, as experts agreed during the interviews. Actually, the expert team was able to mitigate some negative effects of these challenges and overcome many of them within the remaining project phases through new plans that took into account all the challenges that emerged in the first phase of the project. The new plans were reflected on the execution methodology and included a series of corrective actions, which were as follows:

- Completing the documentation works, surveying and photographing of the remaining project phases during the construction of first phase of the project. This resulted in shortening the time required of remaining phases and accelerating the start of the dismantling works within the second and third phase of the project.
- Modifying the execution methods by developing the scaffolding, back propping and formwork systems, which accelerated the installation of these

systems and facilitated the movement of workers as well as the transfer of historical elements.

- Dividing the workshop into many areas and providing these areas with specialized teams, as follows:
    - Specialized teams in surface cleaning of historical elements.
    - Deep cleaning teams.
    - Specialized teams in the restoration of columns (bases, column bodies and crowns).
    - Specialized teams working with stones restoration based on their different types.

  These specialized teams resulted in shortening the working time within the workshop area and transforming them into production lines.

The study also recommends several points as follows:

- The previous materials challenges should be studied carefully during the planning phase of similar projects.
- Materials challenges should be examined in order to estimate a proper project period.

5.2.2 Recommendation Related to the Overall Delay Factors in the Reconstruction Projects

There are a set of procedures involved in the project which formed the basis for managing the delay factors and mitigating its negative effects and avoiding its repetition in later project phases. These procedures are as follows:

- Preparing daily reports which describe the accomplished work in the morning and evening shifts in detail.

- Comparing the performed work on the site daily with the planned one and determining the variance and execution problems.
- Updating the construction schedule and determining the variance according to the baseline schedule.
- Periodical accurate delay analysis and determining the delay period caused by each factor.
- Work plans modification and increasing the equipment and workforce according to the updated plans.
- Emphasizing the coordination between the various managements and the project sections.
- Accelerating the design completion and preparing the shop and coordination drawings.
- Using modern technology and equipment in the project, which allows the acceleration of work.

We strongly advise studying the site location and conditions for the reconstruction projects and implementing an accurate and detailed system for planning, monitoring, and contorting before starting the work on site. We also recommend more research on various kinds of reconstruction projects, whether they are in operation during the reconstruction period or not, to identify all the delay factors that might negatively affect the project duration. As a result, these factors would form a database for experts to better plan a project before starting work on site. In fact, the relative importance index (RII) analysis method, which was employed in this study, showed a strong possibility to provide an accurate ranking procedure. In addition, it can facilitate this type of study and form a platform for sorting delay factors according to their effect on reconstruction project duration.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

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