Rework in Construction Projects and Impact of BIM on Rework Causes

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ABSTRACT

Most projects suffer from construction overruns. Hence, making them strive to improve project performance. Several studies have assessed causes that might lead to overruns in construction; rework has been considered a prime cause of overruns in the construction industry. Thus, one of the goals of this study is identifying causes of the rework in construction projects, having been conducted by a systematic literature review that has identified 31 causes of rework. The 31 causes were identified, refined into 24, and categorized into 5 groups. This study must specify a particular country as a case to study. The Saudi Arabian Construction industry is highly active., this study shall measure the existence and impact of rework on construction projects while being supported by a questionnaire according to the Likert scale ranking. Total of 74 participants returned the questionnaire, after which Cronbach's Alpha reliability test was conducted to ensure validity.

Furthermore, the total importance index methodology was adopted to determine the rank of each cause, the ranks of the rework reasons in this study were compared to earlier studies in other nations to demonstrate a variation in prioritization of the rework causes. Finally, this study measured the manageability of rework causes through BIM. A comparative study between those who utilized BIM as an auxiliary tool with those who did not were conducted to evaluate whether BIM adoption decreases the occurrence of rework. The F.I was adopted to rank the rework causes in this comparative study.

Based on this study's results, stakeholders in the construction sector should consider the critical causes of rework and plan accordingly in the preliminary stages of the project. Additionally, based on the comparative study of the impact of BIM utilization, Stakeholders in the construction field can decide whether BIM will be practical in mitigating the occurrence of rework.

Keywords: Construction, Overruns, Rework, Frequency index, Total importance index, BIM, Building information modeling.

ÖZ

Genelde çoğu proje inşaat maliyeti aşımlarından muzdariptir. Bu nedenle, zaman ve maliyet açısından proje performansını iyileştirmeye çalışmak için bir kaç çalışma yapılarak inşaat maliyetlerindeki aşımlara yol açabilecek nedenleri bulmuş ve değerlendirmiştir; Yeniden üretim, inşaat sektöründeki maliyet aşımlarının başlıca nedeniydi. Bu nedenle, bu çalışmanın amaçlarından biri, inşaat projelerinde yeniden üretim nedenlerinin belirlenmesidir. Bu çalışma, yeniden üretim sorununun otuz bir nedenini belirleyen sistematik bir literatür taraması gerçekleştirdi. Devamında, otuz bir neden yirmi dört nedene indirgendi ve beş grupta kategorize edildi. Bu Çalışmada, yeniden üretim nedenlerini değerlendirmek için, bir vaka olarak belirli bir ülkenin seçilmesi uygun görüldü. Suudi Arabistan İnşaat sektörünün, özellikle petrol ve gaz sektöründe çok aktif olduğu aşikardır. Suudi Arabistan inşaat endüstrisinin değerlendirilmesi yoluyla, bu çalışma, yeniden üretimin petrol ve gaz sektörün inşaat projelerindeki varlığını ve etkisini ölçecektir. Bu çalışma, Likert ölçeği sıralamasına göre bir anket ile desteklenmektedir. Toplam yetmiş dört katılımcı anketi geri gönderdi ve ardından geçerliliği sağlamak için Cronbach's Alpha güvenilirlik testi yapıldı.

Ayrıca, her nedenin sırasını belirlemek için toplam önem indeks metodolojisi kabul edildi. Ek olarak, bu çalışmada puanlanan yeniden üretim nedenleri diğer ülkelerdeki önceki çalışmaların bulgularıyla karşılaştırıldı, ve yeniden üretimin önceliklendirilmesinde, kültürel, politik, coğrafi ve ekonomik farklılıkların etkileri gösterilmeye çalışıldı. Son olarak, çalışma, BIM'le yeniden üretim nedenlerinin yönetilebilirliğini ölçmüştür. Çalışmanın temel hedeflerinden birini karşılamak için; Suudi Arabistan'daki BIM'in yardımcı bir araç olup olmadığını değerlendirmek için

yapılanlarla yaptığı kişilerle bir yardımcı araç olarak BIM'yi kullananlar arasında bir karşılaştırmalı bir çalışma, yeniden işleme oluşumunun olasılığını azaltır. Bu karşılaştırmalı çalışmada yeniden işleme nedenlerini sıralamak için frekans endeksi kabul edildi.

Bu çalışma sonuçlarına dayanarak, Suudi Arabistanlı paydaşlar ve petrol ve gaz sektöründeki uygulayıcılar, yeniden üretimin kritik nedenlerini, projenin ilk aşamalarına hesaba katmalı ve planlamalı sağlanabilir. Ayrıca, BIM kullanımının etkisinin karşılaştırmalı çalışmasına dayanarak, Suudi Arabistanlı paydaşları ve petrol ve gaz alanındaki uygulayıcılar, BIM'nin yeniden üretimin oluşumunu hafifletmede faydalı olup olmayacağına karar verebilirler.

Anahtar Kelimeler: İnşaat, Taşmalar, Yeniden İşleme, Frekans indeksi, Toplam önem indeksi, BIM, Bina bilgi modellemesi.

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BIM	Building Information Modeling
KMO	Kaiser-Meyer-Olkin
PCA	Principal Component Analysis Technique
PIC	Productivity and Innovation Credit
RFID	Radio Frequency Identification Device

Chapter 1

INTRODUCTION

1.1 Background

The construction industry is an essential source of income for countries, contributing significantly to the growth of economies; having been comprised of different sectors, such as building, infrastructure, and industrial buildings (Alrashed et al., 2014; Assaf et al., 1995; Love, Edwards, et al., 2016; Ogunbiyi, 2014; Sarhan et al., 2017). The cost overruns that occur during the construction project can jeopardize the project's success, and client satisfaction can lead to extreme financial burdens. It may lead to economic depression in the countries (Derakhshanalavijeh & Teixeira, 2017). Several studies in the field of construction management tried to enhance the knowledge of construction cost overruns in several types of projects such as roads, buildings, and bridges (Abdul-Malak et al., 2002; Ahiaga-Dagbui & Smith, 2014; Annamalaisami & Kuppuswamy, 2019; Assaf et al., 1995; Cheng, 2014; Dlakwa & Culpin, 1990; Flyvbjerg et al., 2004; Huo et al., 2018; Kaliba et al., 2009; Koushki et al., 2005; Larsen et al., 2016; Love et al., 2014; Mansfield et al., 1994; Odeck, 2004; Olaniran et al., 2015; Rosenfeld, 2014; Williams & Gong, 2014). These previous studies demonstrated and assessed the cost overruns according to project type and countries. Other studies such as those assessed construction overruns and demonstrated some factors which stated that one of the leading causes of cost overruns was rework.

Rework affects construction projects' cost, duration, and quality (Gunduz et al., 2013; Hwang et al., 2009; Love et al., 2010; Shibani & Arumugam, 2015). It has been considered a fundamental cause responsible for cost overruns in construction projects. Rework-related direct spending accounts for approximately 5% of overall construction expenses. (Hwang et al., 2009; Hwang et al., 2019; Love & Edwards, 2005; Love et al., 2018; Mills et al., 2009). Thus, the causing factor of rework should be determined and assessed to avoid any occurrence of time or cost overruns (Fayek et al., 2004; Hwang et al., 2009; Ye et al., 2015).

Process management comprises identifying significant factors and potential risk that causes rework identified by project managers during the planning phase (Dahanayake et al., 2016; Yap et al., 2016). Therefore, many studies aimed to identify and assess the reason for rework in different countries and construction sectors (Al-Janabi et al., 2020; Eze & Idiake, 2018; Forcada et al., 2017; Forcada et al., 2014; Hwang et al., 2009; Josephson et al., 2002; Love & Sing, 2013; Mahamid, 2016, 2017, 2020; Trach et al., 2021). Therefore, this study will demonstrate and assess the cause of rework in the construction industry. As a case study, Saudi Arabia is known for investing billions of dollars in construction projects. Moreover, the Saudi Arabian construction industry is known for its poor project performance with highly prolonged overruns (Alrashed et al., 2014; Assaf et al., 1995).

Construction projects in Saudi Arabia have grown drastically over the past two decades (Ogunbiyi, 2014), spending more than $US 120 billion a year (Alrashed et al., 2014). Currently, the Kingdom's construction industry encompasses fifteen percent of its workforce and consumes more than fourteen percent of the country's energy Accordingly, multiple companies in Saudi Arabia seek sustainability in their construction projects, leading to the investment in BIM implementation in construction projects. However, a survey of construction industries operating in the Middle East, including the United Arab Emirates (UAE), Saudi Arabia, Qatar, Oman, Bahrain, Kuwait, and Jordan 2011 showed that BIM usage is around twenty-five percent. Although BIM's importance is well understood, the survey also noted that it might be hampered by a lack of skilled staff and training. This effort needs to be supported by industry leaders by providing adequate expert guidance (Almuntaser et al., 2018). As a result, this Saudi Arabia research study will seek to examine the impact of using BIM on rework in building projects.

1.2 Problem Statement

The causes of rework and their impacts on project cost and time have been studied in several recent research studies (Al-Janabi et al., 2020; Eze & Idiake, 2018; Forcada et al., 2017; Forcada et al., 2014; Hwang et al., 2009; Josephson et al., 2002; Love & Sing, 2013; Mahamid, 2016, 2017, 2020; Trach et al., 2021). However, there seems to be a lack of knowledge regarding the causes of rework in some countries. For instance, Ye et al. (2014) claimed "*there is a lack of knowledge regarding rework causes in developing countries.*" Moreover, love 2018 stated that "*little progress has been made to reduce its occurrence and adverse consequences*" (Love et al., 2018). Therefore, this study seeks to assess and determine the existence of rework in construction projects in Saudi Arabia. As aforementioned, Saudi Arabia is known for investing vast amounts in construction. Preliminary research showed that many construction projects face a lot of reworks which causes overruns; therefore, this study will measure the manageability of rework through the BIM. As (Al-Yami & Sanni-Anibire, 2019) stated in their research on the adoption of BIM in the Saudi Arabian construction, "The findings showed a widespread lack of BIM knowledge. Thus, it is obvious that, when compared with the global trends, there is a huge research gap in the development, adoption, and implementation of BIM in Saudi Arabia". This study will analyze the influence of BIM on rework in building projects in this regard.

Finally, most of the studies failed to identify the rework causes in Saudi Arabia and rank them. Furthermore, the researchers failed to differentiate between these two groups established within the study: projects with and without BIM. Therefore, within this study, the differentiation between projects shall clarify the benefits of BIM utilization and bridge the gaps from previous studies.

1.3 Research Questions

With respect to the issues aforementioned, the following research questions will be addressed in distinct stages of this study:

1) What are the causes that significantly affect construction rework?
2) How would rework causes be prioritized in terms of their probability of occurrence and their impact on time and cost?
3) How would the adoption of BIM affect the occurrence probability of rework?

1.4 Research Aim and Objectives

Any construction project's success relies on overcoming delays and cost overruns and gaining the client's satisfaction. However, numerous unplanned reworks in any project could deteriorate the reputation of construction companies. This dissertation mainly measures the rework probability of occurrence, effect on duration and cost through the construction projects; twenty-four rework parameters have been determined from the previous studies. Shreds of evidence will prove the existence of rework within the construction projects while discussing its manageability using BIM.

In this respect, objectives of the study are clarified:

1. To identify rework causes occurred in construction projects.
2. To categorize the rework causes with respect to group related distinct.
3. To determine the impact of these rework causes in construction industry with respect to cost and time, from respondents' point of view.
4. To rank the rework causes based on their frequency index and total importance index.
5. To measure the manageability of rework causes through BIM.

1.5 Research Contributions and Novelty

The method used in this study was the best technique to assess the cause for rework in Saudi Arabia. This study collected the data using a quantitative survey conducted and distributed to Saudi Arabian stakeholders in the construction sector. The collection of data by the questionnaire supported the study in demonstrating knowledge of the motive of rework from an expert perspective. In addition, this study assessed BIM utilization in the Saudi Arabian construction industry by implementing a comparative study between two sets of projects to evaluate the adoption of BIM. The risk assessment will emulate an even more realistic depiction. Although the findings of this case study are intriguing, there is room for improvement in future investigations. For example, future studies may consider converging solutions to the causes of rework in the construction industry and alternative methods of downsizing the impact of overruns. Moreover, this study allows for an inquisition into their various ranking methods and how they influence causes rankings and assist in implementing strategies to accomplish a more effective BIM.

1.6 Guide to Thesis

The study is structured in following chapters:

Chapter 2 “**Literature Review**” introduces the previous studies on construction rework assessment, it’s impact on construction projects and prioritization.

Chapter 3 “**Research Methodology**” shows the methods utilized in this study. For instance, it explains the reliability, descriptive and statistical tests adopted to analyze the data collected.

Chapter 4 “**Result and discussion**” present and discusses the results obtained from implemented approaches showed in the research methodology that were performed.

Chapter 5 “**Conclusion**” conclude this study and provide recommendation for future research.

Chapter 2

LITERATURE REVIEW

2.1 Construction Overruns

Construction industries in countries are a potent source of income due to the workforce's integrity and energy within construction projects. However, the success of construction projects depends on execution within the estimated time, budget, and quality targets (Sambasivan & Soon, 2007). Therefore, construction overruns are a challenge for any project to achieve success. Therefore, many studies attempted to determine the reason for construction overruns (Abdul-Malak et al., 2002; Ahiaga-Dagbui & Smith, 2014; Annamalaisami & Kuppuswamy, 2019; Assaf et al., 1995; Cheng, 2014; Dlakwa & Culpin, 1990; Flyvbjerg et al., 2004; Huo et al., 2018; Kaliba et al., 2009; Koushki et al., 2005; Larsen et al., 2016; Love et al., 2014; Mansfield et al., 1994; Odeck, 2004; Olaniran et al., 2015; Rosenfeld, 2014; Williams & Gong, 2014). According to the aforementioned studies, rework is the leading cause of construction overruns. For instance (Love et al., 2014) stated that recent empirical studies have shown that rework is a significant cause of construction overruns.

2.2 Construction Rework

Rework is identified as redoing process of the work done to satisfy unique requirements (Khalesi et al., 2020; Ye et al., 2015); however, it does vary accordingly within studies, making it a replaceable output occurring due to the mistakes done in the construction stage (Josephson et al., 2002). Table 2.1 shows some of the definitions established through the previous studies.

Table 2.1: Definitions of Rework in Previous Studies

Definition	**Reference**
Rework emerges because of change, exclusion, or blunder that starts from the plan prepare or during construction	(Love, Edwards, et al., 2016; Sarhan et al., 2017)
Re-doing work that was not done correctly the first time can have negative effects on project and organizational performance, such as safety, cost and schedule, and profitability.	(Hwang et al., 2009; Hwang et al., 2019; Li & Taylor, 2014; Love et al., 2018; Mills et al., 2009)
The verb rework is to revise or rework anything. A variety of rework definitions have been disseminated in the literature in the context of construction, all of which revolve around the themes of quality (i.e., compliance) and change/deviation.	(Hwang et al., 2009; Hwang et al., 2019; Love et al., 2018; Mills et al., 2009)
Rework is described using terms such as error, fault, defect, quality failure, quality deviation, non-conformance, and snag.	(Hwang et al., 2009; Hwang et al., 2019; Li & Taylor, 2014; Love et al., 2018; Mills et al., 2009)
Rework is defined as "a component of a project that was previously deemed trash or useless but is now a part of the building process."	(Forcada et al., 2017; Oyewobi et al., 2011)
Rework is the wasteful effort of redoing a procedure or activity that was implemented poorly the first time around.	(Almuntaser et al., 2018; Forcada et al., 2017; Oyewobi et al., 2011)

Furthermore, to understand the process of rework see figure 2.1, this figure shows the concept of rework according to (Love et al., 2020).

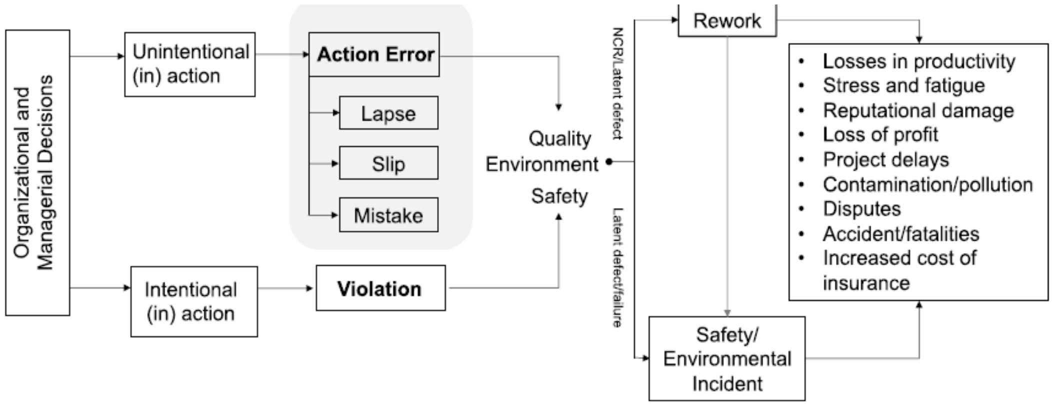

Figure 2.1: Conceptualizing the Etiology of Rework (Love et al., 2020)

Design flaws, omissions, and alterations were responsible for approximately fifty percent of overall rework and total rework expenditures (Love, Ackermann, et al., 2016). There are many other reasons which can increase the rework amount, such as lack of inspection, poorly trained labor, and lack of experience of some managers (Hwang et al., 2019).

Several studies have attempted to identify numerous solutions to the rework problem by identifying several aspects and potential risks and discussing them throughout the project planning stage (Hwang et al., 2019) while also attempting to calculate the direct costs associated with rework in construction and engineering projects, or its components project (Dahanayake et al., 2016; Fayek et al., 2004; Yap et al., 2016).

Past investigations were focused on identifying the factors that influence the effect of rework in construction projects; as it is academically crucial for project managers to identify factors such as financial and time risks in the project that could lead to rework; making them find the appropriate solutions and draw scenarios to prevent the amount of rework in the project. Stakeholders in construction projects, classify rework. Owner-related issues, procurement-related difficulties, design-related, contractor-related, and external issues have been identified in the literature as critical sources of rework.

2.3 Causes of Construction Rework

The goal is to discover the elements that cause rework. Many of the causes that lead to rework are stated in Table 2.2.

Table 2.2: Construction Rework Causes in the Previous Studies

No.	Causes of Construction Rework	References
1	Less Communication Between the Architect and The Design Engineers	(Arain & Pheng, 2006; Eze et al., 2018; Forcada et al., 2017; Forcada et al., 2014; Hwang et al., 2019; Ye et al., 2015)
2	Lack 0f Experience and Knowledge in the Project Design	
3	Lack of Experience in Construction Knowledge and Performance	
4	Time and Money Bad Use in The Project	
5	Financial Barriers	
6	Inadequate Client Participation in The Project	
7	Give Less Importance and Low Funding for Preparing Contract Documents	

8	Clients Design Changes	(Arain & Pheng, 2006; Forcada et al., 2017; Hwang et al., 2019; Ye et al., 2015)
9	Not Completed Design	
10	Removing Items from Contract Documents	
11	Less Coordination for Design	
12	Contractor Unplanned Changes Through the Construction Process	
13	Finding Errors in Contract Documents	(Hwang et al., 2019; Ye et al., 2015) (Arain & Pheng, 2006; Hwang et al., 2019; Ye et al., 2015)
14	Not Giving Enough Time for Preparing Contract Documents	
15	Put A Deadline to Finish the Certain Activity	
16	Un Clear Contract Preparing Brief from The Consultant	
17	Lack Of Needed Skills to Complete Certain Task	
19	Changes Done by The Regulatory Managers	
20	Inefficient Use of The Quality Management	
21	Economic Change That Requires Design Change	
22	Social Change That Requires Design Change	
23	Legal Change That Requires Design Change	

24	Inefficient Use of The Valid Technologies	
25	Setting Out Errors	
26	Unsuitable Training and Lack of Experience	
27	Less Coordination Between the Project Resources	
28	Un Able to Do Some Parts of Construction Process	
29	Inefficient Use of The Quality Management	
30	Poor Planning	(Hwang et al., 2019; Ye et al., 2015)
31	Less Use of Protection Factor in Construction Process	
32	Lack Of Safety	
33	Excessive Over time	
34	Do Not Follow the Standards and Specifications	
35	Excessive Employee Turnover	
36	Lack Of Supervisors	
37	Defective Workmanship	
38	Improper Foreman or Supervisors	
39	Carelessness During the Work Which Causes Damage	
40	Vague Instructions Given to Labors	
41	Unplanned Site Conditions Which Can Change the Work Procedures	

42	Information Given Is Not Completed or Not Adequate	
43	Breakdown In Site Machines	
44	Weather Conditions Causes Some Damage	
45	Natural Disasters Causes Damage	
46	Material or Equipment Replacement During the Construction	
47	Poor Communication between the client and the end user	
48	Delay in providing Site Facilities (e.g., Water, electricity, etc.…)	
49	Active Rework to Improve Quality	
50	Lack of Use of advanced Mechanical Equipment	(Hwang et al., 2019; Ye et al., 2015)
51	Poor Site Conditions	
52	Conflict between suppliers and construction team	
53	Accidents and errors occurring during transportation	
54	In sufficient Check of the goods imported to the site	

After determining the rework cause, these causes should be categorized into related distinct groups, to enhance the assessment and present accurate results.

2.4 Categorization of Construction Rework Causes

The categorization of the causes must occur so the researchers can identify and study the impact properly. Rework can be categorized according to the author opinions. For example, Table 2.3 will show the previous studies and the authors' categorization of the rework causes.

Table 2.3: Categorization of Rework Causes

	1	2	3	4	5	6	7	8	9	10
Article Title	*Analyzing Causes for Reworks in Construction Projects in China*	*Analysis of rework risk triggers in the Nigerian construction industry*	*Effect of BIM on Rework in Construction Projects in Singapore: Status Quo, Magnitude, Impact, and Strategies*	*Analysis of direct rework costs in Ukrainian construction*	*Reworks causes and related costs in construction: case of Parand mass housing project in Iran*	*Rework in Malaysian building construction: impacts, causes and potential solutions*	*Illustrative Benchmarking Rework and Rework Costs in Swedish Construction Industry*	*Effect of change orders on rework in highway projects in Palestine*	*Factors Causing Rework and Their Impact on Projects' Performance in Egypt*	*Rework in building construction: principal culprits and underlying causes*
No. Of Causes	39	47	32	20	8	18	40	39	87	36
No. Of Categorization	10	3	8	4	5	5	5	3	10	4
Categorization	Contractor field management	Client Related Issues	Owner Change	Poor Coordination	Material improper delivery	Poor Coordination	Construction	Client design errors	Client Related factors	Client
	External Environment	Contractor Related Issues	Design Error	Errors and omissions in construction stage	Unclear Project Management	Procurement methods	Client	Contractor design errors	Contractor & Sub-contractor related factors	Designer
	Contract Management	Consultant Related Issuers	Design Change	Errors and omissions in design stage	Poor Sub-contractor Management	Insufficient time for Design Stage	Occupier	Consultant design errors	Contract Management related factors	Contractor
	Subcontractor Management		Contractor Error	loss in documents	Poor Constructability	Poor Documentation	Manufacturer		Design related factors	Exogenous
	Design Management		Contractor Change		Poor Supervision	Misunderstanding the Design	Others/ Unknown		Supervisory related factors	
	Project Communication Management		Vendor Error		executive Operation				Constructions related factors	
	Project Plan Changes		Vendor Changes		Standard Failure				Site related factors	
	Changes for Quality Improvements		Transportation Error		Poor Contracting				labor related factors	
	Client Management								Material and Equipment related factors	
	Project Process/Scope management								External related factors	

2.5 Evaluation of Rework Causes in Construction Projects

It is vital to analyze the rework causes. Thus, this section will highlight the evaluation of rework causes in the previous studies.

Analysis was conducted to check the reliability and validity of collected data, which concluded that there are different methods of data analysis:

- Content Validity
- Statistical Validity
- Reliability Analysis

2.5.1 Content Validity

According to (Enshassi et al., 2017), content validity was formed through analyzing a group consisting of 10 professionals with a minimum of 10 years of experience in the field, and each participant was requested to give their perspective on each item based on the rating the index of content validity; according to which some of the factors were changed and modified based on the expert's comments.

(Hwang et al., 2019) evaluated the content validity through two diverse sources of information to cross-analyze collected data, ensuring that it is valid and reliable. The study conducted different methods by using face-to-face interviews with experts related to the construction industry and ensuring that each participant has an experience of 10 years or more in the field. Participants were chosen from distinct categories in the construction industry; developers, designers, contractors, and consultants to determine the impact of utilizing the BIM in the construction industry on mitigating the rework impact on the project performance.

In agreement with a research (Balouchi et al., 2019), testing was made by extracting the needed data using forms filled out on-site. First, validity was checked using a checklist controlled by quality control staff, followed by asking some experts to give their opinion on the forms and modify some of the problems within the questionnaire.

(Love, Ackermann, et al., 2016) tested the content validity by forming a triangulation basis of data collection to overcome bias and validity problems (Patton, 1990). The triangular basis comprises unstructured interviews, archived sources such as lessons learned, notes from workshops and project reports, and finally, the non-participant perspective, which is done by site visiting.

(Eze et al., 2018) evaluated the content validity using the principal component analysis technique (PCA), which is used to determine the existing relationships with the extracted factors from the study. The study claims that it used the PCA technique because it was psychometrically sound and mathematically more straightforward, as suggested by (Lamoureux et al., 2007).

2.5.2 Statistical Validity

(Enshassi et al., 2017) assessed the statistical validity of the data collected; the method used was the Spearman test which questions the relation between the coefficients of each group to the whole group.

Hwang (Hwang et al., 2019) tested the statistical validity of the data collected using many methods; The Chi-Square method was conducted to determine the apparent difference between the expected and observed frequency for each factor stated in the study (Uher & Brand, 2008). Normality was assessed using The Shaprio-Wilkinson; as for the non-normal distribution, the study used the Mann-Whitney test because it is non-parametric. The study adopted Levene's test for the homogeneity of variance, leaving group variance to utilize the Welch-Satterthwaite method.

2.5.3 Reliability Analysis

Enhassi adopted the Cronbach's Alpha in the reliability analysis with a variation from 0 to 1. Moving from 0 to 1, 1 is the most outstanding value of the internal consistency of the factors stated in the study. Therefore, the higher value between zeros to one is presented as a higher degree of internal consistency. It is calculated for each part of the entire questionnaire, and the values in this study varied from 0.671 and 0.917. The study stated that this is a high value which ensured the reliability of the rework causes and category stated in the questionnaire. As a result, the questionnaire was considered reliably valid and ready for distribution to the participants (Enshassi et al., 2017).

Hwang performed the Cronbach's Alpha to evaluate the reliability of the strategies stated in his study for the BIM implementation; the strategies stated in the study resulted from the performed T-Test with eight potential strategies. Cronbach's Alpha in this study for the strategies stated was 0.876, which is considered reliable (Hwang et al., 2019).

They Conducted two methods to evaluate the reliability of the factors in the study. The first method is the Kaiser-Meyer-Olkin (KMO), which measures the reliability of the causes stated in the study. The cut-off point was more significant than 0.5, which means that the data within this study was adequate to be used in the study analysis. The second method is the Cronbach's Alpha, which was concluded to be 0.734, making the data reliable and ready to be used in the study (Al-Janabi et al., 2020; Eze et al., 2018).

After evaluating the causes and ensuring that the data collected are reliable, prioritization of the causes is also vital.

2.6 Prioritization of Construction Rework Causes

Ranking the causes of construction rework plays a vital role in determining the most significant risk in any construction project. It helps to increase the efficiency of the project performance and take it from one level to another. In addition, ranking the causes helps identify the significant risks, which helps the project stakeholders in decision making and considering different variables for each risk that might occur (Baccarini et al., 2004).

In this study, the authors represented 18 rework causes, then introduced the rework causes in the questionnaire to study their impact and rank them according to the Malaysian construction industry. This study used the mean and standard deviation values to rank each of the proposed causes. Some problems occurred when two causes had the same mean value, meaning that the standard deviation value defined the rank of the cause (Chan et al., 2011; Ye et al., 2015). The average mean value for the causes proposed in this study was higher than 3.0, emphasizing the importance of ranking the causes. For instance, the higher-ranked causes in the Malaysian construction industry are “Poor coordination among the design team, poor quality management by the contractor, poor sub-contractor management and construction errors due to a misunderstanding of design is the most important.” (Yap et al., 2017).

Within the following studies, individual efforts were made by researchers within these papers, allowing them to represent several causing factors and were able to introduce them to the questionnaire to study the reworks' impact, which was then ranked according to each country.

39 rework causes were represented in China by using the mean and standard deviation values to rank each of the proposed cause. Some problems occurred when two causes have the same mean value, this means that the standard deviation value define the rank of the cause (Chan et al., 2011; Ye et al., 2015).

57 rework causing factors were identified according to the Nigerian construction industry. The study used the relative importance index to rank each cause proposed in the study. For example, the higher ranked causes in Nigerian construction industry are "*Poor communication between the architects and engineers, Lack of knowledge in the construction process and inadequate time and money spent on the project*" (Eze et al., 2018).

16 rework causing factors were ranked according to the Iranian construction industry. The study used the Frequency index to rank each cause proposed in the study. For example, the higher ranked causes in Iranian construction industry are "*Damage and deformation of the materials, absence of a suitable sequence of work and improper commissioning*" (Balouchi et al., 2019).

38 rework causes according to the Singaporean construction industry were identified. The study used the magnitude of rework time (MRT) to rank the causes proposed in the study. For example, the higher ranked causes "client *changes, vendor changes, and design change"* (Hwang et al., 2019).

19 rework factors were identified in highway projects in Palestine. The author used the mean value to rank the rework causes. The study showed that the higher ranked causes in Palestine highway projects are "*Change of project scope by the owner, lack of coordination between the construction stakeholders, and owner financial difficulties"* (Mahamid, 2017).

11 rework factors were identified according to the Egyptian construction industry. The study used different methods to rank the rework causes, frequency index and severity index, and total importance index. The higher ranked causes in the construction projects in Egypt *"Change of the specification through the client, poor feasibility study for the project and Sudden change in the plan and scope*" (Al-Janabi et al., 2020).

2.7 Impact of Construction Rework

Numerous studies have attempted to calculate the direct costs associated with rework in construction and engineering projects or its components project (Al-Janabi et al., 2020; Eze & Idiake, 2018; Forcada et al., 2017; Forcada et al., 2014; Hwang et al., 2009; Josephson et al., 2002; Love & Sing, 2013; Mahamid, 2016, 2017, 2020; Trach et al., 2021). It can be attributed to several factors that these reported findings differ significantly including the extent to which quality management methods have been applied, the type of project, the procurement method used, and the project's complexity (Dahanayake et al., 2016). Previous research has looked at how rework affects the cost, duration, and quality of construction projects.

Love and Edwards stated that rework expenses ranging from 5.07 per cent to 5.22 per cent of project contract values, according to a study of 115 civil infrastructure projects (Love & Edwards, 2005).

They stated that the rework value in Australia is 6.4% of the total project cost in mean of direct cost and in mean of direct cost the value decreased to 5.9% of the total project cost, as well as in Singapore after examination of 115 building the rework cost was about 5.02% to 5.7% of the total project cost (Hwang et al., 2014; Li et al., 2017).

Love stated that the average cost overruns caused by the rework is 12.6% from the contract cost and caused a duration overrun by 20.7% of the estimated schedule. These results were based on 116 samples (Love, 2002).

Abeku stated that the rework causes cost overrun by 12.58% and time overrun by 38% (Abeku et al., 2016).

Wasfy stated that the rework inclines the cost of the project by 2% to 30% and can lead to a schedule delay by 10% to 70% (Wasfy, 2010).

Hwang stated that rework impacted an average of 25% of construction duration growth in Singapore (Hwang et al., 2019).

Rework research has shown that project variables are predictors of rework’s impact on project performance. This amount shows us how significant is the rework value can cost all the parties in the construction industry. Therefore, it is essential to determine methods and strategies to enhance the construction projects performance and mitigate the rework.

2.8 Mitigation of Rework Occurrence in Construction Projects

The previous study showed different ways given in Table 2.4 to mitigate the rework causes in the construction industry, stating that some methods which can be implemented to reduce the triggers of rework.

Table 2.4: Methods to Mitigate the Rework in Previous Studies

Article Title	Barriers and benefits of quality management in the construction industry: An empirical study.	Implementing total quality management in construction firms	Applying TQM to the construction industry
Date	2010	2004	2012
Methods to Mitigate Rework	Improve the safety awareness and regulations	Enhance the productivity rate and mitigate the delivery time of the project	Enhance the project control in the project.
	Repeat the clients as the contractor will be aware of the client objectives.	Try to reduce the change order in the construction project.	Try to achieve the objectives of the project desired by the owner.
	Enhance the employee satisfaction.	Enhance the project cost controlling and performance.	Mitigate project cycle time
	Enhance the coordination between the architects and engineers.	Increase the incentive to increase motivation of the team.	Try to enhance the measurements of the performance in the project.
	Enhance the coordination and relationship with the subcontractors.	If applicable, try to reduce quality cost	Enhance the control on the project designers (MEP. Electrical, and Structural)
	Enhance the schedule performance.	Follow the client orders for the client satisfaction.	
	Reduce the change of the employee during the project.	Enhance the coordination in the project activities.	
	Try to mitigate client claims.	Remember the project objectives and make sure everyone in the team aware of the project objectives.	

All these methods and actions should take place in project management, as technology is developing every day to overcome the rework causes which is vital nowadays. In 2019, (Hwang et al., 2019) and his team were able to determine the effect of utilizing BIM in the construction industry in Singapore. Singapore is considered a leading country when it comes to utilizing the BIM in construction industry, as its government plays a vital role through investment. This pilot study in Singapore showed that the duration of the projects using the BIM is lower than the duration of the projects without using the BIM by 4.8%. Within the last decades, there have been many studies conducted to detect and mitigate the amount of rework in the construction projects.

BIM was one of the solutions to temper the amount of rework; therefore, some of the researchers developed the BIM with aim to reduce the causes of rework, and to increase quality.

Few studies have investigated the impact of BIM on rework in construction projects, and even fewer studies have presented actual evidence of rework cost/time in projects with and without BIM deployment.

2.9 BIM in Construction Industry

The first appearance of BIM was in 1970; by the mid-1990s, it had begun to gain more attention in the construction industry. This technology was mainly developed to enhance data ex-change between architects, engineers, contractors, owners, and the main facility (Bazjanac & Crawley, 1999). BIM is defined as a data platform conducted to manage the entire lifecycle of the construction process and enhance the internal/external collaboration between the parties included in the construction process. It also helps in problem-solving, making accurate decisions, managing potential risks, and improving productivity (Hwang & Yang, 2014; Li et al., 2017).

BIM represents a digital version of the building, and it is considered an innova-tive and practical approach to visualize the building information, having dif-ferent stages in the entire life cycle. Furthermore, it has excellent potential in avoiding loss of information and predicting the building life expectancy while enhancing the collaboration among different sides that interfere in the building process (Liu et al., 2010; Lu et al., 2018). BIM has been claimed to have a significant impact on the efficiency of construction projects (Dimitrov & Golparvar-Fard, 2014; Sacks et al., 2010).

BIM is divided into three main categories; (1) the 3D model, which is the three-dimensional model of the project and the quantity estimation, (2) the 4D model, which is the 3D plus the time planning of the project, (3) 5D model it is the 4D model plus the cost estimation at each phase of the project (Cerovsek, 2011). The 6D includes the sus-tainability and more specifications on the energy consumption in the construction project. The 7D is mainly about quality control, and it includes the technical specifi-cations, warranty, and maintenance manuals for owners and managers (Azhar, 2011; Khalesi et al., 2020). Many researchers developed BIM in many ways as it has immense potential to allow the experts to make developments. The desired product stated study was to determine the benefits and barriers of BIM and find the relative im-portance index for each benefit and barrier (Al-Yami & Sanni-Anibire, 2019).

In previous studies, Singapore showed a solid example of BIM implementation in the construction industry. The Singaporean government spent about $800 million on the PIC scheme to utilize BIM in the construction industry, with strict regulations applied by the government increasing the utilization of BIM in the construction industry from 20% in 2009 to 65% in 2015 (Teo et al., 2015).

The BIM industry is being developed since researchers found its importance in detecting and avoiding possible errors. According to (Lee et al., 2014) an integrated BIM framework was developed to share insufficient data between heterogeneous data sources. Moreover, (Kwon et al., 2014) proposed an integrated BIM with artificial intelligence to detect management systems automatically and some of the possible defects in the construction site. Furthermore, in 2017, the development of RFID enabled the BIM to integrate information and improve the time performance of prefabricated building projects. Intelligent buildings and RFID enabled an intelligent gateway to ease operations within three partners of prefabrication: (1) manufacturing, (2) logistics, and (3) site assembly construction. Closed-loop visibility is formed using the real-time collected where different users can trace and supervise the construction progress; this development enhances the daily operation's success and strengthens the management's decisions (Hwang & Yang, 2014; Li et al., 2017).

As aforementioned, previous research carries the title of building information modeling BIM and the development of models and the title of rework and the effect on project performance in terms of time and cost. However, there is a considerable lack of studies that show the effect of BIM on the rework and how the implementation of BIM in the construction industry will improve productivity. This issue needs to gain more attention from researchers as the cost of rework in construction projects is significant. We can use the available technologies to reduce the amount of rework to a feasible degree. The implementation of BIM in the construction industry showed an improvement of 25% in the productivity of the work (Hwang et al., 2019). The utilization of BIM will help increase the performance in the construction industry, as it will boost the profit for the organizations involved.

Recently, Saudi Arabia has been trying to invest in BIM implementation within construction projects. Therefore, this study on Saudi Arabia will find the impact of BIM on construction projects.

There are some strategies through BIM utilization to reduce the rework stated in a previous study, including the utilization of BIM in the design and construction process. Along with design phase and verification to decrease manmade and software errors, improve the BIM awareness, put rules and guidelines in the utilization of BIM, develop a new work process that fits the BIM workflow, construct a robust tracking system to avoid failure, allow on-site BIM to provide the labors with high-quality drawings, and finally employ BIM manager (Hwang et al., 2009). These strategies play a vital role in increasing the performance and gaining benefits of using BIM. According to (Bynum et al., 2013; David Bryde and Martí Broquetas and Jürgen Marc, 2013) implementation reduces cost and time. Governments of countries are trying to implement BIM in their construction industry. Regardless, BIM implementation has its pros and cons.

2.9.1 BIM Benefits and Barriers

BIM offers the possibility to address these difficulties and further develop industry execution. BIM is a creative innovation to efficiently plan and oversee development projects (Azhar, 2011; Khalesi et al., 2020; Robert Eadie and Mike Browne and Henry Odeyinka and Clare McKeown and Sean, 2013).

BIM has been embraced in the development area within the recent twenty years. This can upgrade execution by diminishing failures, further developing usefulness, and expanding coordinated effort among project partners (Farghaly et al., 2018). In addition, BIM provides awareness of the plan, the quick formation of elective plans, programmed assessment of model dependability, and the creation of reports (Sacks et al., 2010).

Benefits of Using BIM in Construction Industry:

BIM has a lot of benefits in various categories such as design-related benefits, performance-related benefits, business-related benefits, finance-related benefits, and construction-related benefits.

In 2012 Barlish and Sullivan presented some of the BIM benefits in the construction industry (Barlish & Sullivan, 2012):

- More efficient and accurate designs,
- Ease the process of comparing between alternative designs,
- Higher quality in generating efficient schedule and management,
- Very efficient in detecting drawings error,
- Enhance the communication,
- Enhance the quality in the projects,
- Greater efficiency performance on site from labors and off site from engineers,
- Increase the possibility of working different activities in parallel with minimal risk,
- Use the lesson learnt from pervious projects to prevent the mistakes,
- More client satisfaction because of more understanding to the building,
- Enhance Safety awareness during the construction process,
- Increase the efficiency of construction performance.

Barriers of Using BIM in Construction Industry:

Despite the several benefits resulted from the pilot study and previous academics; some barriers were established that make the implementation of BIM difficult in many countries, those barriers raise many challenges and risks for the governments (Azhar, 2011; Khalesi et al., 2020; Robert Eadie and Mike Browne and Henry Odeyinka and Clare McKeown and Sean, 2013). According to previous studies, there are some barriers that face management when it comes to implementing the BIM:

- Software reliance within the project,
- Excessive claims are added to project insurance.

According to (Gibbs et al., 2015; He et al., 2012; Oraee et al., 2019):

- Excessive cost of BIM process and training the staff on the utilization of the BIM,
- The high reliance on software interface in the collaboration between internal and external projects stakeholders.

Chapter 3

RESEARCH METHODOLOGY

This research aims to identify and assess the rework causes within construction projects in Saudi Arabia. Furthermore, the study seeks to prioritize the causes according to their assessment using the total importance index and compare the prioritization with other studies in different countries and measure the manageability of rework causes through BIM using the frequency index method.

The study's aim was accomplished by reviewing and analyzing an extensive body of literature on rework in the construction industry, which led to the exploration of all the cases stated in the previous studies and statistically assessing the significant causes of rework. Questionnaires have been sent out randomly to professionals, including consultants, contractors, project managers, and owners. The data collected from the survey will be analyzed and ranked by using the total importance index and frequency index.

3.1 Research Methodology Structure

Combining quantitative and qualitative methods was the best way to approach the study objectives. Therefore, the quantitative method in this study is supported by the questionnaire survey. In contrast, the qualitative method is supported by the statistical analysis utilized to assess the collected data from the survey.

A systematic literature review has been conducted and it is divided into various phases: (1) find pervious related literature; (2) document selection method; (3) identify the factors of the study; (4) Pilot survey questionnaire; (5) modify the questionnaire and conduct the survey; and (6) analysis of the results (Arrieta et al., 2020). The structure of thesis methodology is presented in Figure 3.1.

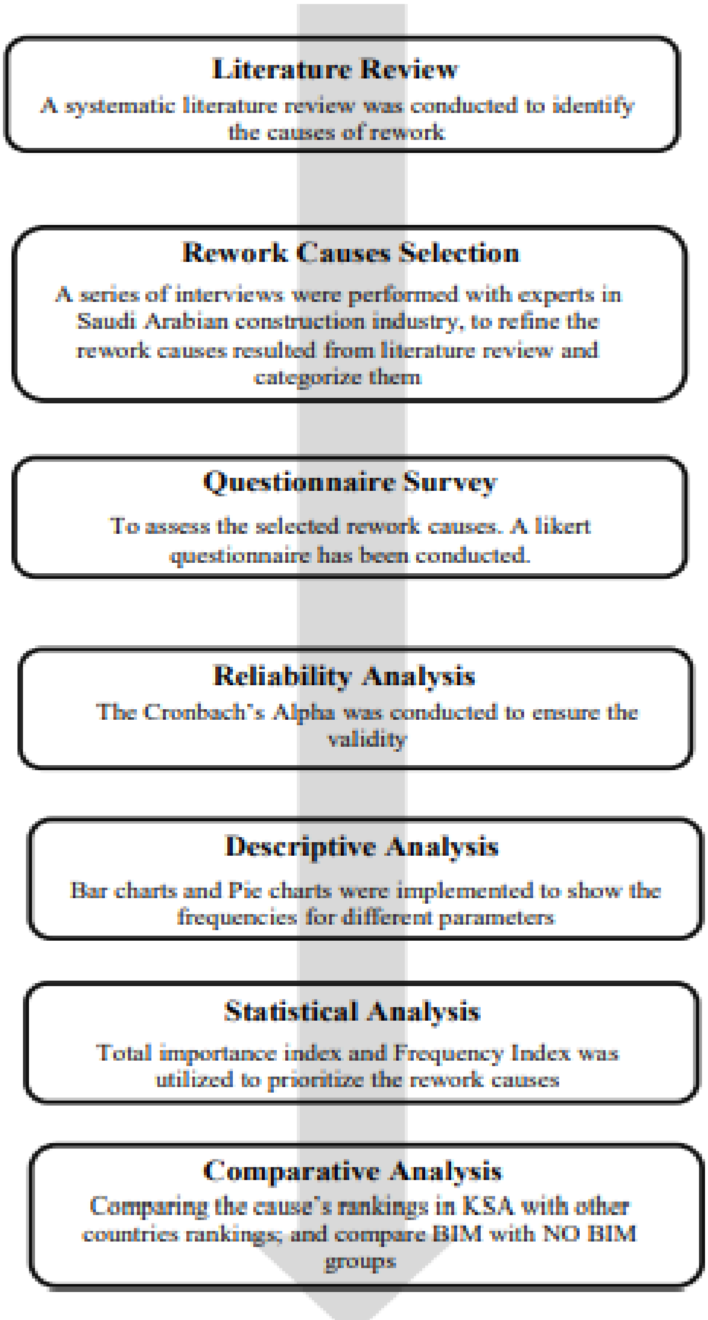

Figure 3.1: Flow Chart of Research Methodology Structure

3.2 Searching and Selecting of the Relevant Documents

The author is using Boolean operation and keywords acquired from the literature reviews. The keywords determined for this research are stated in Table 3.1.

Table 3.1: Keywords Used to Find Relevant Publications

Research Keywords	**Boolean operation**	**Research Keywords**	**Boolean operation**	**Research Keywords**
Rework	"and" "or"	Construction	"and" "or"	Causes
Remake		Building		Reasons
Redo		Infrastructure		Factors

This process identified six main studies shown in Table 3.2. Moreover, snowballing method was adopted to find the rest of the related studies.

Table 3.2: The Main Previous Studies

Article Title	Analysis of direct rework costs in Ukrainian construction	Factors Causing Rework and Their Impact on Projects' Performance in Egypt	Reworks causes and related costs in construction: case of Parand mass housing project in Iran	Analysis of rework risk triggers in the Nigerian construction industry	Rework in Malaysian building constructio n: impacts, causes and potential solutions	Analysing Causes for Reworks in Construction Projects in China
Validatio n	Polish Academy of Science	Journal of Civil Engineering and Management	International Journal of Quality & Reliability Management	Organization, Technology and Management in Construction	Journal of Engineerin g, Design and Technology	American Society of Civil Engineers
Date of Publish	2021	2020	2019	2018	2017	2015

3.3 Identification of Construction Rework Causes

The rework causes were determined from relevant studies. A total of thirty-one causes were identified, shown in Table 3.3. These thirty-one causes have been evaluated for similarities and concept overlapping. Eventually, twenty-four causes were obtained by removing similar causes and merging the rest.

Table 3 3: Total Rework Causes from the Literature Review

ID	Cause of Rework
1	Change In Plan of the work
2	Material Replacement in Project
3	Specifications Change
4	Inadequate Project Objectives
5	Taking Wrong Decisions
6	Occurrence Of Financial Problems
7	Government Change Laws and Regulations
8	The Change of The Goods Supplier During the Project
9	Inappropriate Design Details
10	Confusion In Design
11	Incomplete Design Detailed Drawings
12	Change The Material or Construction Process
13	Weather Obstacles and Bad Site Conditions
14	Improvements In Constructability
15	Construction Quality
16	Lack In Quality Control
17	Design Errors
18	Completely Relaying on It Design Software.
19	Poor Design
20	Less Communication Between Client and Designers.
21	Lack Of Communication Between Consultants and Contractors.
22	Errors In Construction Procedures
23	Errors In Activities and Tasks
24	Poor On Site Drawing
25	Insufficient Labours for Certain Activity.
26	Lack Of Trained Labours
27	Lack Of Contractor Knowledge
28	Conflict Between the Supplier and The Construction Team.
29	Overload Work Cause Stress
30	Accidents and errors occur during transportation
31	Insufficient Check of The Goods Transported to The Site

The causes refining process was performed by experts in the Saudi Arabian construction industry. Additionally, the twenty-four rework causes were categorized into five group-related distinctions shown in Table 3.4.

Table 3.4: Rework Causes after Filtration and Categorization of the Causes

ID	Cause of Rework after filtration and categorization
Owner related issues	
Rc1	Change In Plan and specification of the project
Rc2	Change in material in the Project
Rc3	Inadequate Project Objectives
Rc4	Making Wrong Decisions
Rc5	Occurrence Of Financial Problems
Procurement related issues	
Rc6	Mistakes related to material and service Supplier During the Project
Rc7	Issues related to material quality
Rc8	Conflict Between the Suppliers and The Construction Team.
Rc9	Accidents and errors occur during material transportation
Design related issues	
Rc10	Inappropriate Design Details
Rc11	Confusion In Design
Rc12	Incomplete Design Drawings
Rc13	Lack of Communication Between Designer and either of Client, consultant, and contractors
Contractor related issues	
Rc14	Errors In Construction Procedures
Rc15	Lack of experienced contractors
Rc16	Insufficient Labours for Certain Activity.
Rc17	Lack of Quality Control including Goods Transported to The Site and service-related activities
Rc18	Lack Of Communication Between Consultants and Contractors.
Rc19	Lack Of Contractor Knowledge
Rc20	Insufficient supervision on labours
Rc21	Overload Work Cause Stress
Rc22	Lack Of experienced and Trained Labours
External issues	
Rc23	Government Change Laws and Regulations
Rc24	Weather Obstacles and Bad Site Conditions

3.4 Research Questionnaire Development

Typically, a questionnaire survey identifies the behavior of an idea, phenomenon, or occurrence that raised doubts. The questionnaire contained three sections:

1. The respondent’s background.
2. Covered project type and construction job sector.

3. Covered twenty-four rework causes to be rated on a Likert scale.

A Likert scale was issued to enable participants to respond according to their point of view. This method of scaling is claimed by (Assaad et al., 2020) to cause a reduction in subjectivity by minimizing the bias of respondents. The Likert scale was configured as one to five, applied to assess each cause stated. The respondent's resolution of the questionnaire is based on these numerical values. The following sections addressed the ranging parameters:

3.4.1 Scale of Probability

Scale of frequency		
Numerical values	Description	Chances
1	Very rare to occur	less than or equal 10%
2	Minor probablity of occurrence	More than 10% and less than or equal 35%
3	Moderate probablity of occurrence	More than 35% and less than or equal 65%
4	Good chance to occur	More than 65% and less than or equal 90%
5	Most probably it will occur	More than 90%

3.4.2 Scale of Impact on Cost

Scale of Cost		
Numerical values	Description	Chances
1	Negligable impact	(5% ≥ cost)
2	Minor impact	(5% < cost ≤10%)
3	Moderate impact	(10% < cost ≤20%)
4	Signficant impact	(20% < cost < 50%)
5	Severe impact	(50% or greater)

3.4.3 Scale of Impact on Time

Scale of time		
Numerical values	Description	Chances
1	Negligable impact	(5% ≥ time)
2	Minor impact	(5% < time ≤10%)
3	Moderate impact	(10% < time ≤20%)
4	Signficant impact	(20% < time < 50%)
5	Severe impact	(50% or greater)

3.5 Distribution of the Survey

Old methods of data collection, such as personal interviews, or by sending a mail are costly and needs a lot of time to get a response. However, using the internet it can be more efficient to collect responses from the respondents. For example, sending emails with an online survey form or by using the social media such as LinkedIn to reach the targeted people. Therefore, it is practical and effective for obtaining information on sensitive themes or when reaching out to respondents is difficult. (Al-Janabi et al., 2020; Desai et al., 2015; Eze et al., 2018; Regmi et al., 2016). Furthermore, the ongoing pandemic is a constraint, particularly for physical contact.

Questionnaire surveys have been used to collect data for academic and research in a variety of fields. The internet is commonly used in the whole globe. Therefore, data gathering via an online survey appears to give a huge amount of people who we can collect data from efficiently, and cheaply (Al-Janabi et al., 2020; Cobanoglu & Cobanoglu, 2003; Desai et al., 2015; Eze et al., 2018; Regmi et al., 2016). In addition, the online survey method is beneficial for gathering data from difficult-to-reach groups. Furthermore, persons with circumstances, such as impairments, may be burdensome to reach in face-to-face meetings.

Like paper-based surveys, online questionnaire surveys can include a wide range of questions. It might be constructed to increase the response rate for each item; for example, respondents could be asked to answer a question before proceeding to the next subject (Regmi et al., 2016). The electronic review for this exploration is Google Forms because it is an easy interface with an effective information extraction process.

3.6 Targeted Regions

Saudi Arabia is considered one of the largest contributing countries to the construction industry (Al-Hammadi, 2015; Al-Husein & Sadi, 2015; Regmi et al., 2016), Therefore, it is the region targeted in this research. However, it is notorious for delayed project execution, cost overruns, and long delays (Alrashed et al., 2014). Their discovery of oil has led to the conspicuous development of the desert area into one of the fastest-growing modern countries globally. Due to increasing investments, demand for structures, and rules that encourage international investors, the construction industry has maintained a constant upward trend (Al-Hammadi, 2015; Al-Husein & Sadi, 2015; Geyer, 2012; Regmi et al., 2016).

3.7 Sample Size

Commonly, in survey research: factors, events, and occurrence of causes must be analyzed to enhance the reliability of the study. Experts answered the research questions according to their perspectives. This study has targeted the expertise in construction projects consisting of owner, consultant, contractor, and project management. The population, which must be more than 30 and less than 500 (Hill, 1998), is defined as the whole set of experts to get their point of view according to their experience. Using purposive sampling is a technique that decisively determines a member of the population due to the characteristics they own (Etikan et al., 2016). It is beneficial because it allows for obtaining a specified sample size efficiently.

The chosen sample population responded to the questions posed to gather the required data while keeping their own best interests in mind, which was configured of people who have had experiences that influenced this study while containing an entire group of cases from which the author's sample is tabbed. This study's target group consists of construction project stakeholders such as the client/owner, consultant, and contractor who worked on non-infrastructure construction projects. The goal of sampling was to select the respondents who had expertise in Saudi Arabian construction industry. The following equation will determine the target population:

$$n = \frac{z^2 x\ \hat{\mathbf{p}}(\mathbf{1} - \hat{\mathbf{p}})}{e^2}$$

Where:

n = the amount required for the sample

Z = Z-statistic is needed to the choose the significant value α.

$\hat{\mathbf{p}}$ = is the population proportion

e = Allowable error margin

3.8 Pilot Study and Questionnaire Modification

The main participants in this pilot study are from the Saudi Arabian construction industry consisting of owners, contractors, consultants, and project management to confirm that the twenty-four causes within the questionnaire are relevant. In addition, the pilot test was conducted in interviews with the experts who participated in this study, such as the project manager, project engineer, managing director, and research assistant.

Their recommendation was to refine the list because some of the causes were redundant. However, based on the pilot study results, the questionnaire is relevant to the research topic, and no modifications are needed.

3.9 Reliability Analysis

Cronbach's Alpha method was performed to verify the reliability of collected data and to determine the internal consistency (Al-Janabi et al., 2020; Khalesi et al., 2020). In this research, the statistical package for the social sciences SPSS V28 software was adopted to determine a few measures; alpha for the probability of occurrence and severity impact concerning the cost and time. If the alpha is more than 0.7, it is considered acceptable and reliable, showing the internal consistency of the collected data (Gamil & Abdul Rahman, 2020).

3.10 Descriptive Analysis

Descriptive analysis, a simplification of collected data (Chan et al., 2014), plays a vital role in explaining the data collected. Therefore, the analysis of the collected data from the first two sections was based on descriptive statistical tools, such as pie charts and bar charts, which then displayed the frequencies of the respondents in pie charts and the division of each category. At the same time, bar charts were used to apply some cross-tabulations between different parameters.

3.11 Total Importance Index

The data collected was used to analyze the probability of occurrence by the frequency index and impact on time/cost by the severity impact index to find the total importance index, which was then carried out to determine an overall rank for causes stated in the questionnaire and rank the categories of the construction rework stated in this study. Moreover, the frequency index was used to compare the two groups of projects declared in the study: with and without BIM.

Frequency index (F.I)

$$F.I\ \% = \sum a\left(\frac{n}{N}\right) x\ \frac{100}{4}$$

Where:

a = expressing the weight of each respondent (1 to 5)

n = the probability of occurrence of each cause responses

N = total number of responses

Severity Index (S.I) for impact on time and cost

$$S.I\ \% = \sum a\left(\frac{n}{N}\right) x\ \frac{100}{4}$$

Where:

a = expressing the weight of each respondent (1 to 5)

n = the probability of occurrence of each cause responses

N = total number of responses

Importance Index (Imp. I) for impact on time and cost

$$Imp\ .I\ \ \% = \ [F.I\ \%\ x\ S.I\ \%]/100$$

Where:

F.I % = Frequency Index percentage of each cause

S.I % = Severity Index percentage of each cause

Total Importance Index:

After finding the importance index for time and cost, two values will be stated (importance index for impact on time and importance index for impact on cost); the total importance index is the average of these two values.

3.10 Prioritization of Rework Causes

Prioritization is an essential element for any risk management, as it helps enhance the process. In addition, to focus on the most important causes, the ranking was based on each cause’s total importance index. There were two viewpoints: group rankings and overall rankings. The group ranking was categorized into five individual groups, while the overall ranking was the order of each cause concerning all causes.

The frequency index and each cause’s ranking were determined within BIM and non-BIM projects. These two groups were developed to compare and determine the impact of adopting BIM in construction projects.

3.11 Comparative Analysis

In this respect, the research contains two groups of data to be compared which were studied to establish the importance of BIM in the construction industry and what causes the most damage. In this study, a table test was employed to approach the main goal of the comparative analysis. Furthermore, the table test was utilized to compare the study’s results concerning the rank of the causes according to several studies in various countries.

Chapter 4

RESULTS AND DISCUSSION

4.1 Sample Size Results

The confidence level of the population size is 90% with level of respondents 69. This means that (z) = 1.66. Assume that the population portion is 50%, the marginal error I = 10%, giving the required sample size (n) = 69.

$$n = \frac{z^2 x\, \hat{\mathbf{p}}(\mathbf{1} - \hat{\mathbf{p}})}{e^2}$$

The questionnaire was distributed among 221 respondents, a total of 74 respondents returned the questionnaire back, 33.4% was found to be the response rate. The following Table 4.1 will show the estimated and the actual response rate.

Table 4.1: Sample Size Report

	Estimated	**Actual**
Total Questionnaire Sent	221	221
Returned Questionnaires	69	74
Response Rate (%)	31.20%	33.40%

4.2 Descriptive Statistical Analysis

The responses were categorized as shown in Table 4.2. It is divided into six categories; profession category in the construction field, gender, age, level of education, years of experience in the construction field and whether they used BIM in their construction projects or not.

Table 4.2: Responses Frequency

Frequencies		
Job Category in the construction field		
	No. Of Responses	Percentage %
Consultant	11	14.90%
Contractor	37	50.00%
Owner	1	1.40%
Project Management	25	33.80%
Total	74	100.00%
Gender		
	No. Of Responses	Percentage %
Female	1	1.40%
Male	73	98.60%
Total	74	100.00%
Age		
	No. Of Responses	Percentage %
+50 Years old	7	9.50%
20 – 30 Years old	25	33.80%
30- 40 Years old	38	51.4%
40- 50 Years old	4	5.40%
Total	74	100.00%
Level of Education		
	No. Of Responses	Percentage %
Bachelor’s degree	60	81.10%
High School or Equivalent Degree	1	1.40%
Master’s Degree	12	16.20%
PhD Or Higher degree	1	1.40%
Total	74	100.00%
Years of experience in construction industry?		
	No. Of Responses	Percentage %
+ 15 Years	18	24.30%
10 – 15 Years	15	20.30%
3 – 10 Years	30	40.50%
Less than 3 Years	11	14.90%
Total	74	100.00%
Did you use Building information modeling (BIM) in your Project?		
	No. Of Responses	Percentage %
No	40	54.10%
Yes	34	45.90%
Total	74	100.00%

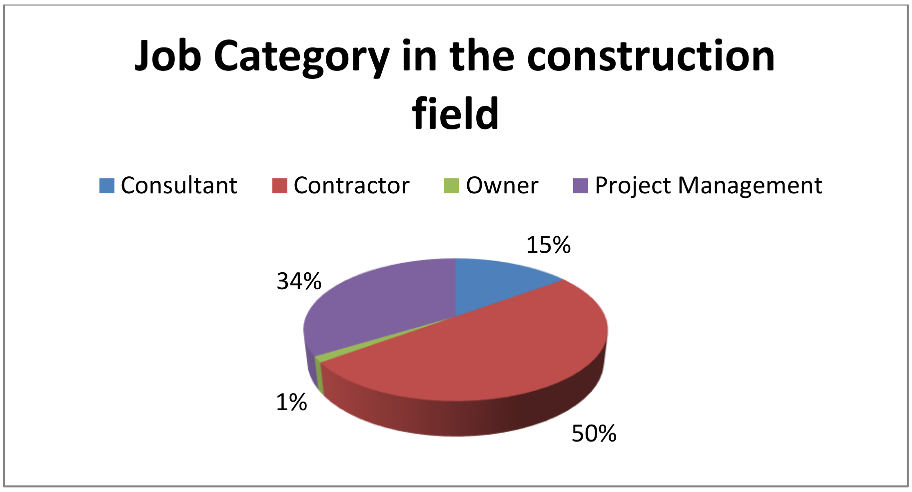

Figure 4.1: Job Category in the Construction Field

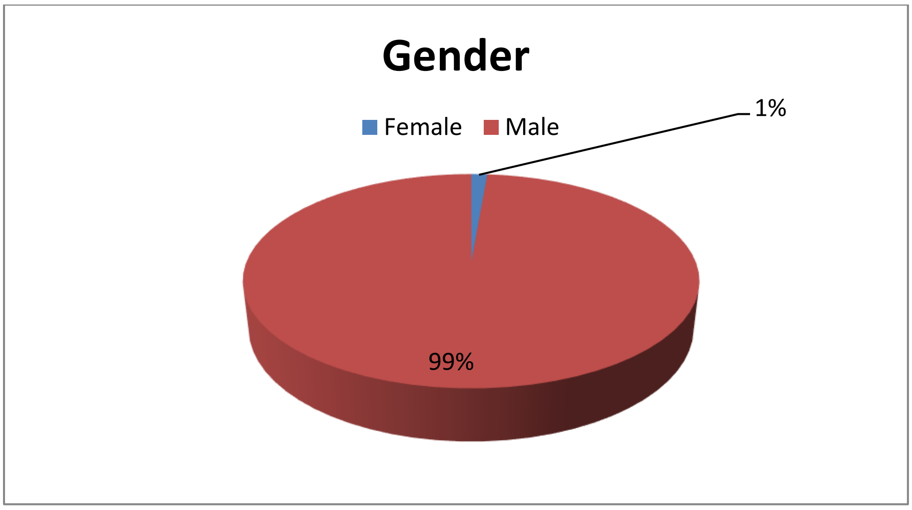

Figure 4.2: Division of Responses Gender

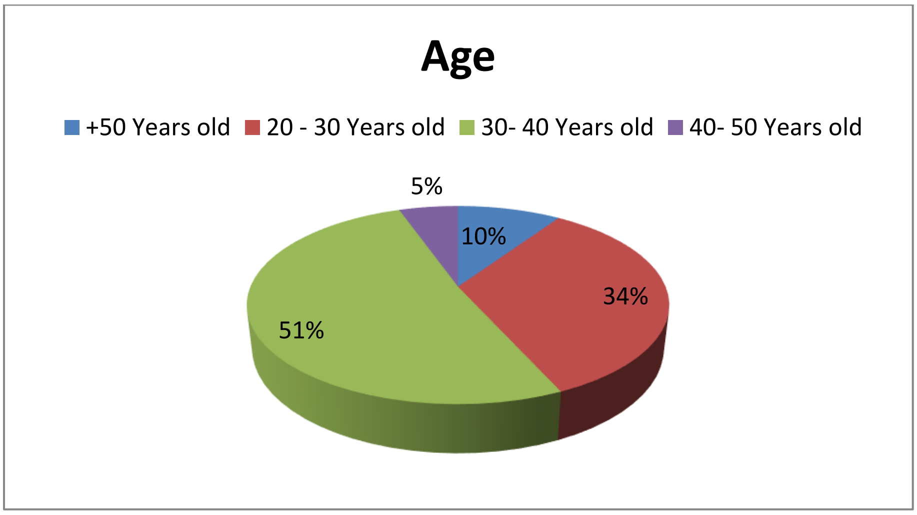

Figure 4.3: Division of Responses Age

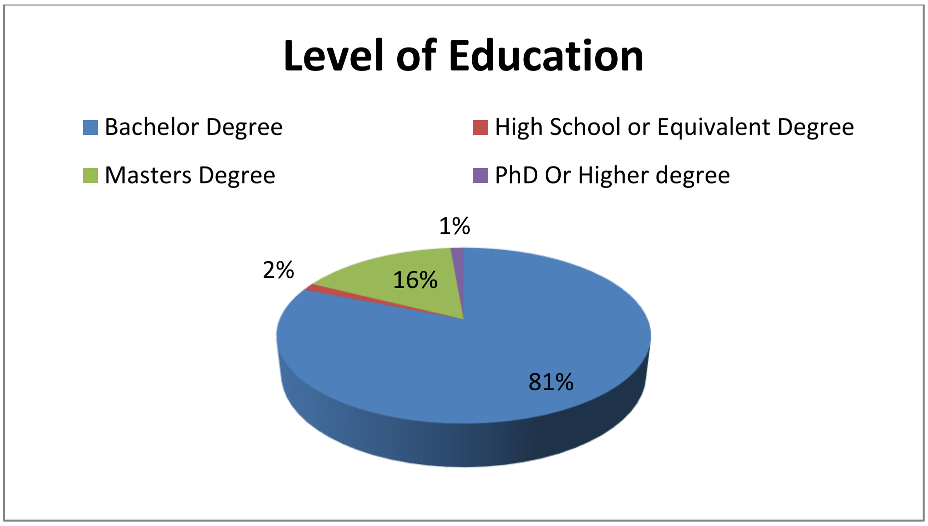

Figure 4.4: Level of Education

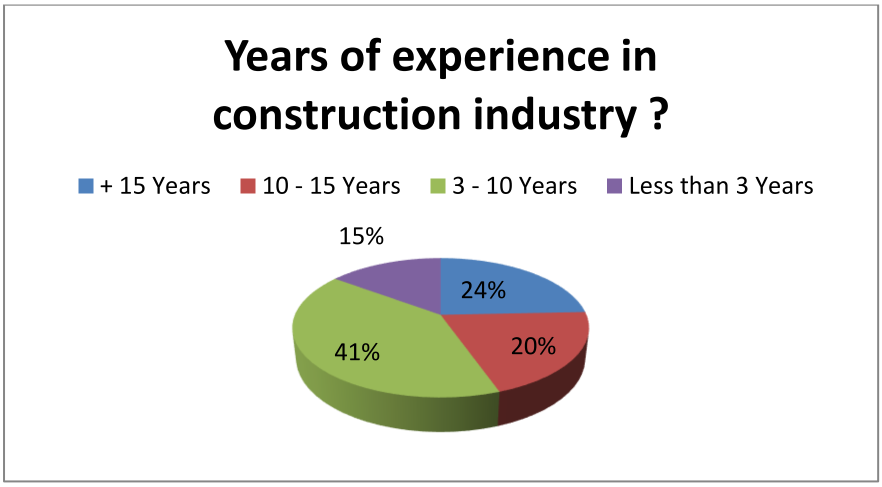

Figure 4.5: Years of Experience

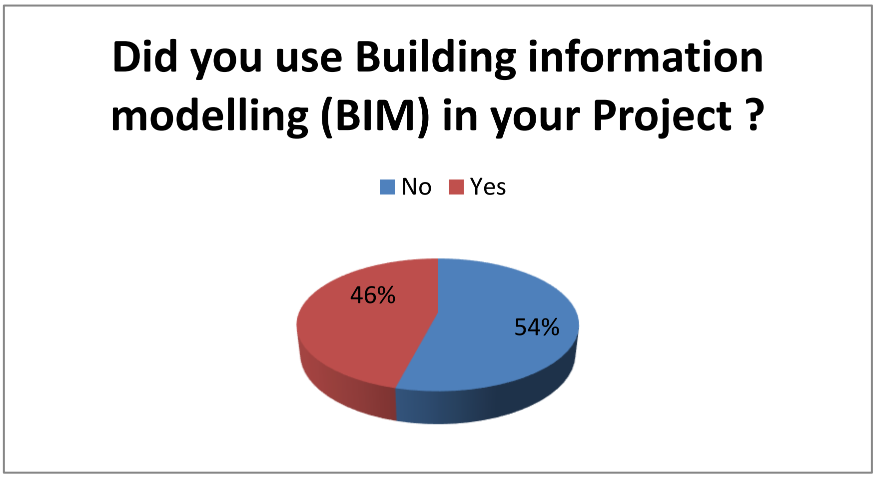

Figure 4.6: BIM Utilization in Construction industry

4.3 Cross-Tabulation Relationships

In this study, three cross-tabulations will suffice; (1) profession in the construction field with the level of education, (2) profession in construction field with years of experience, and finally (3) profession in construction field with the utilization of BIM. Tables and bar charts will be provided for each cross-tabulation, starting with the profession in construction and the level of education, see Table 4.3 to 4.5 till Figure 4.7 to 4.9.

Table 4.3: Job Category with Education Level

		Level of Education							
		Bachel degree		**High School or Equivalent Degree**		**Master Degree**		**PhD Or Higher degree**	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Job Category in the construction field	**Consultant**	9	15.00 %	0	0.00%	2	16.70%	0	0.00%
	Contractor	32	53.30 %	1	100.00%	4	33.30%	0	0.00%
	Owner	0	0.00%	0	0.00%	0	0.00%	1	100.00%
	Project Management	19	31.70 %	0	0.00%	6	50.00%	0	0.00%
Total		60	100.00%	1	100.00 %	12	100.00%	1	100.00%

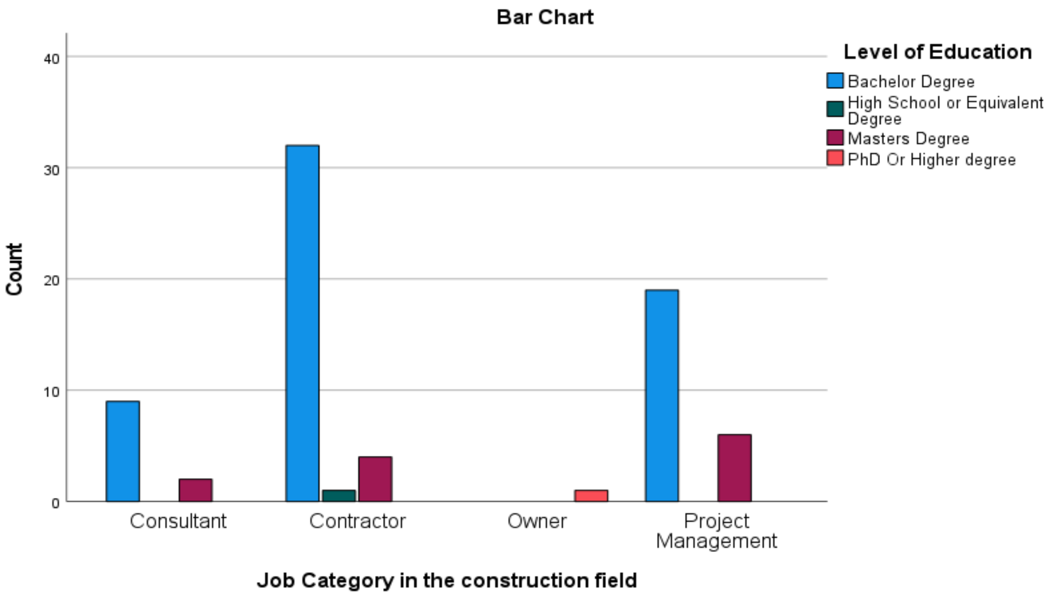

Figure 4.7: Bar Chart for Job Category with Education Level

Table 4.4: Job Category with Experience Level

		Years of experience in construction industry?							
		+ 15 Years		**10 – 15 Years**		**3 – 10 Years**		**Less than 3 Years**	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Job Category in the construction field	**Consultant**	2	11.10%	2	13.30%	5	16.70%	2	18.20%
	Contractor	10	55.60%	9	60.00%	15	50.00%	3	27.30%
	Owner	0	0.00%	0	0.00%	0	0.00%	1	9.10%
	Project Management	6	33.30%	4	26.70%	10	33.30%	5	45.50%
Total		18	100 %	15	100 %	30	100.0%	11	100%

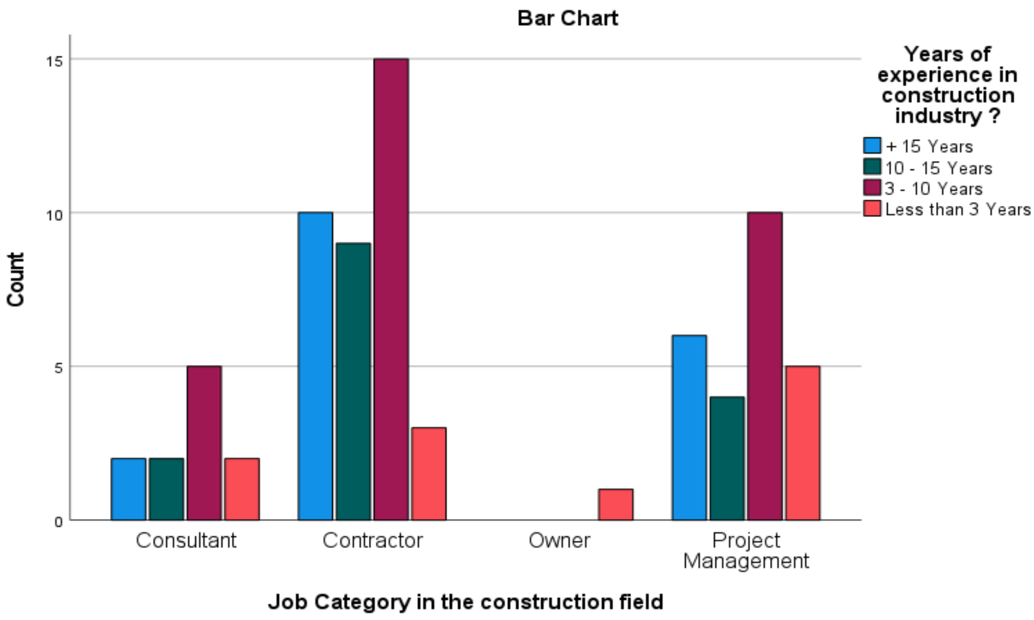

Figure 4.8: Bar Chart for Job Category with Experience Level

Table 4.5: Job Category with BIM Utilization

		Did you use Building information modelling (BIM) in your Project?			
		No		Yes	
		No.	%	No.	%
Job Category in the construction field	Consultant	4	10.00%	7	20.60%
	Contractor	21	52.50%	16	47.10%
	Owner	1	2.50%	0	0.00%
	Project Management	14	35.00%	11	32.40%
Total		40	100.00%	34	100.00%

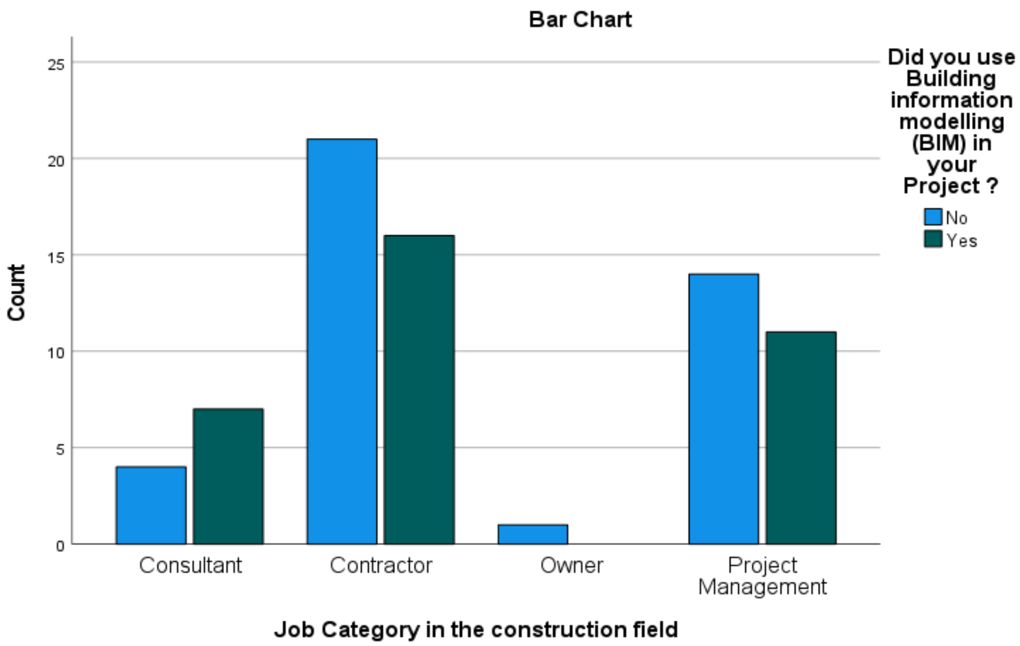

Figure 4.9: Bar Chart for Job Category and the Use of BIM in Construction Projects

4.4 Reliability Test Results

Cronbach's alpha method is implemented to test the reliability of the construction rework causes. The questionnaire was conducted to measure the responses from different perspectives, such as the frequency of occurrence, impact on time, impact on cost and manageability of each cause. The Cronbach's alpha method has been applied to each perspective separately.

To Find the Cronbach's alpha the SPSS V28 was used for each perspective as well as the overall alpha. The following steps were done to apply the reliability Cronbach's alpha:

1. Identify the causes variables as numerical from "variable view" window.
2. Go to Analyze → Scale → Reliability analysis
3. Choose the Items "All causes in the perspective (probability of occurrence)"
4. Choose model "Alpha"

5. Then Press “OK”

6. Repeat the steps for other perspectives.

The results occurred from the reliability test for all perspectives that includes the probability of occurrence, impact on time, impact on cost and manageability, the overall alpha is bigger the 0.9 which means that the internal consistency of the questionnaire is excellent. The following Table 4.6 shows the summarized results for the reliability test.

Table 4 6: Reliability Test Analysis

	C r o n b a c h ’ s	**Number of items selected**
Probability of occurrence	0.956	24
Impact on Time	0.953	24
Impact on Cost	0.952	24
Manageability	0.945	24
Overall	**0.972**	**96**

4.5 Total Importance Index

The questionnaire was returned by 74 respondents, these rework causes were divided into five categories: (1) owner related issues, (2) procurement related issues, (3) design related issues, (4) contractor related issues, and (5) external issues. For each rework cause, frequency index, severity index impact on time/cost, and total importance index were calculated. Furthermore, the total importance index was used to determine group rank and an overall rank for each cause.

4.5.1 Owner Related Issues

The literature review shows that previous studies stated the owner related issues are the primary reason for the construction rework (Chidiebere & Ebhohimen, 2018; Eze & Idiake, 2018; Forcada et al., 2017; Mahamid, 2016, 2017; Yap et al., 2017) . (Al-Janabi et al., 2020) stated that the cost of rework caused by the owner is about 6% of the total rework cost, while in other studies they found a value ranging between 7-15% of total rework cost (Hwang & Yang, 2014; Liu et al., 2020).

As shown in table 4.7, the owner related issues contain five main causes in the Saudi Arabian construction industry. According to the conducted questionnaire the most significant cause was *"Occurrence of financial problem"* ranking at the top of all causes with total importance index = 44.84%. The second critical factor for this category is *"making wrong decisions"* with total importance index= 40.80%, ranking as 9 out of 24 in overall causes. The third critical factor is *"Change of the material in the project"* with a total importance index = 38.42%, ranked as 11 out of 24 in the overall ranking.

The primary cause in the owner related issues is *"Change in plan and specification of the project"* according to (Al-Janabi et al., 2020; Arain, 2006). In this study the rank of this cause differs as the total importance index = 37.72% ranked 4 out of 5 in the group ranking and 14 out of 24 in the overall ranking.

Table 4.7: Ranking of Causes in Owner Related Issues

ID	F.I %	S.I % on time	S.I % on Cost	Imp. I Rework Time %	Imp. I Rework Cost %	Total. Imp. I Rework Impact %	Group Rank	Overall Rank
Rc1	53.00%	73.00%	69.00%	39.00%	37.00%	37.72%	4	14
Rc2	56.00%	69.00%	69.00%	39.00%	38.00%	38.42%	3	11
Rc3	50.00%	71.00%	73.00%	35.00%	36.00%	35.90%	5	18
Rc4	57.00%	72.00%	71.00%	41.00%	41.00%	40.80%	2	9
Rc5	60.00%	78.00%	71.00%	47.00%	43.00%	44.84%	1	1

4.5.2 Procurement Related Issues

The procurement related issues in Saudi Arabia are not critical as they come in fourth place regarding category rank with an average total importance index of 35%, containing four rework causes. The critical cause is *"Mistakes related to material and service supplier during the project"* with a total importance index of 38.156%, ranked as 12 out of 24 in the overall ranking. The following Table 4.8 shows causes stated in this category.

Table 4.8: Ranking of the Causes in Procurement Related Issues

ID	F.I %	S.I % on time	S.I % on Cost	Imp. I Rework Time %	Imp. I Rework Cost %	Total. Imp. I Rework Impact %	Group Rank	Overall Rank
Rc6	58.00 %	68.00%	64.00%	39.00%	37.00%	38.16%	1	12
Rc7	51.00 %	58.00%	54.00%	29.00%	28.00%	28.52%	4	24
Rc8	60.00 %	62.00%	59.00%	37.00%	36.00%	36.47%	2	17
Rc9	57.00 %	64.00%	59.00%	36.00%	34.00%	35.20%	3	22

4.5.3 Design Related Issues

As the design phase is one of the most important stages in any construction process and the most time consuming, making the design related issues at the top of rework categories with an average of total importance index = 42%. As other studies ranked the following category at the same status (Enshassi et al., 2017; Feng et al., 2009; Hossain & Chua, 2014).

Table 4.9 shows the rework causes in this category. The analysis of this study gives a result, that *"incomplete design drawings"* comes in first with a total importance index of 42.376%, while it ranked as second within the overall ranking. However, in other studies it did not show up in the first place, for instance, (Al-Janabi et al., 2020) showed that the *"Incomplete design drawings"* comes in third of rank of his study and the *"Change in design"* came in first. The second critical cause in this study is "*Confusion in design*", it has a value of total importance index of 41.575%.

Table 4.9: Ranking of the Causes in Design Related Issues

ID	F.I %	S.I % on time	S.I % on Cost	Imp. I Rework Time %	Imp. I Rework Cost %	Total. Imp. I Rework Impact %	Group Rank	Overall Rank
Rc10	59.00%	71.00%	68.00%	42.00%	40.00%	40.81%	4	8
Rc11	60.00%	70.00%	68.00%	42.00%	41.00%	41.58%	2	6
Rc12	61.00%	70.00%	68.00%	43.00%	42.00%	42.38%	1	2
Rc13	62.00%	72.00%	61.00%	45.00%	38.00%	41.48%	3	7

4.5.4 Contractor Related Issues

Contractor and subcontractor related factors are vital reasons influencing rework in other countries (Ye et al., 2014; El Hossein, 2014; Love et al., 2004). Furthermore, (Liu et al., 2020) mentioned that the contractor and subcontractor are responsible for 20.10% and 10.54% of the total cost of rework in Chinese residential buildings.

In this category, 9 factors have been studied shown in Table 4.10. The critical cause is *"Errors in construction procedures"* with a total importance index of 42.233%, ranked as third in the overall ranking.

Table 4.10: Ranking of the Causes in Contractor Related Issues

ID	F.I %	S.I % on time	S.I % on Cost	Imp. I Time %	Imp. I Cost %	Total. Imp. I Impact %	Group Rank	Overall Rank
Rc14	69.00%	67.00%	55.00%	46.00%	38.00%	42.23%	1	3
Rc15	59.00%	67.00%	61.00%	40.00%	36.00%	38.07%	5	13
Rc16	60.00%	72.00%	58.00%	44.00%	35.00%	39.43%	4	10
Rc17	53.00%	71.00%	62.00%	37.00%	33.00%	35.21%	9	21
Rc18	56.00%	68.00%	64.00%	38.00%	36.00%	36.95%	7	16
Rc19	64.00%	70.00%	61.00%	44.00%	39.00%	41.63%	3	5
Rc20	56.00%	64.00%	63.00%	36.00%	35.00%	35.52%	8	19
Rc21	64.00%	69.00%	61.00%	44.00%	39.00%	41.75%	2	4
Rc22	59.00%	65.00%	63.00%	38.00%	37.00%	37.44%	6	15

4.5.5 External Issues

The following Table 4.11 listed the rank of the two factors related to the external group causing rework in the Saudi Arabian construction industry, "*Weather obstacles and bad site condition*" ranking 20 out of 24 with a total importance index of 35.347%, showing that the site condition and the weather in Saudi Arabia is not a critical factor; and "Government change in laws and regulations", ranking 23 out of 24 in the overall rank with a total importance index of 30.694%. This shows the stability of the Saudi Arabian construction industry as they notify facilities beforehand when it comes to new regulations.

Table 4.11: Ranking of the Causes in External Issues

ID	F.I %	S.I % on time	S.I % on Cost	Imp. I Rework Time %	Imp. I Rework Cost %	Total. Imp. I Rework Impact %	Group Rank	Overall Rank
Rc23	52.00%	64.00%	54.00%	33.00%	28.00%	30.69%	2	23
Rc24	55.00%	66.00%	63.00%	36.00%	34.00%	35.35%	1	20

4.6 Category Prioritization

After assessing the rework causation and rank them according to the total importance index. Figure 4.10 shows the top ten causations among twenty-four causes of reworks. As it is prioritized by the total importance index the higher value is the most important cause as it is more likely to occur and have a more negative impact on cost and time. These ten causes have the highest effect on the project budget and duration in Saudi Arabia. Table 4.12 shows the rework category ranking.

Table 4.12: Rework Causes Category Ranking

Category of Rework	Average Total Importance Index of each Category	Ranking
Design related issues	41.56%	1
Owner related issues	39.53%	2
Contractor related issues	38.69%	3
Procurement related issues	34.59%	4
External issues	33.02%	5

The first cause is the occurrence of financial problems due to the taxes Saudi Arabian government enforced in the recent years, this shows a negative impact in the construction industry, as well as the effect of the COVID-19 pandemic. Additionally,

Table 4.13 shows a comparative study between the rankings of causes in different studies. The second critical cause was the "*Incomplete design drawings*", this cause appeared in two previous studies in Egypt and Nigeria, ranking as 14th and 11th places respectively.

The third cause is "*Errors in construction procedures*", this happens due to multiple elements such as unclear instructions from site engineers to foreman or ambiguous procedures from the client to the contractor. This cause came in the 1st place in Iran, 11th in China, and 25th in Egypt.

The fourth cause in Saudi Arabia is "*Overload work stress*", which was a unique cause to be ranked in the top ten of any study as the workload in Saudi Arabia is critical, most of the projects are fast-tracked as they obtain huge economic benefits the earlier, they finish.

The fifth cause is "*Contractors Lack of Knowledge*", this cause appeared in different studies: for example, in Iran ranked as 5th, in China ranked 25th, and in Egypt ranked 40th; meaning that it is a prominent cause within the industry.

The sixth cause is "*Design Confusion*", this happens due to lack of communication between the designer team. This cause appeared in two different studies; the first was based in Egypt ranked as 51st, the second study was based in Malaysia ranked as 4th among 18 causes.

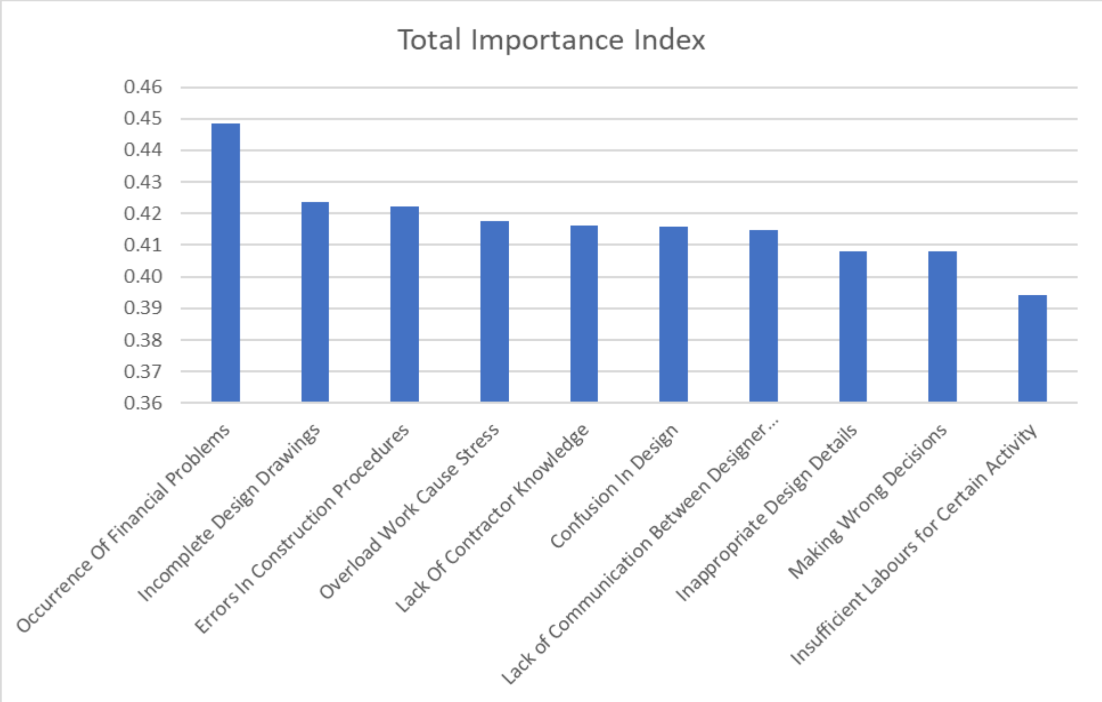

Figure 4.10: Graph for Top 10 Rework Causes in Saudi Arabia

The seventh cause is "*Lack of communication between the designers, client, consultant, and contractor*" where the author merged three causes into one.

The eighth cause is "*Inappropriate design details*", which is a common cause among most of the studies; stated in a study based in Egypt ranked as 26th, in Malaysia ranked as 12th, in China ranked as 5th and finally in Iran ranked as 4th.

The ninth cause is "*Making wrong decisions*" which may be made by top managers, project managers, and site engineers in different stakeholder's categories.

The tenth cause is "*Insufficient labors for the activity*" stated in two studies; in Egypt, ranked as 9th and in China, ranked as 27th.

Table 4.13: Comparison of Rankings Between Different Studies

Cause of Rework	This Study (Saudi Arabia)			In Egypt			In Malaysia			In China			In Iran		
	No. of Causes	Ranking	Method to Rank	No. of Causes	Ranking	Method to Rank	No. of Causes	Ranking	Method to Rank	No. of Causes	Ranking	Method to Rank	No. of Causes	Ranking	Method to Rank
Change In Plan and specification of the project	24	14	Total Importance index%	87	6	Total Importance index%	18	9	Mean and Standard Deviation	39	7	Mean and Standard Deviation	8	N/A	Frequency/cost
Change in material in the Project		11			N/A			N/A			13			N/A	
Inadequate Project Objectives		18			5			5			1			7	
Making Wrong Decisions		9			13			N/A			12			N/A	
Occurrence Of Financial Problems		1			8			N/A			22			N/A	
Mistakes related to material and service Supplier During the Project		12			72			N/A			N/A			2	
Issues related to material quality		24			59			N/A			3			N/A	
Conflict Between the Suppliers and The Construction Team.		17			N/A			N/A			N/A			N/A	
Accidents and errors occur during material transportation		22			N/A			17			N/A			N/A	
Inappropriate Design Details		8			26			12			5			4	
Confusion In Design		6			51			4			17			N/A	
Incomplete Design Drawings		2			14			N/A			N/A			N/A	
Lack of Communication Between Designer and either of Client, consultant, and contractors		7			12			1			6			N/A	
Errors In Construction Procedures		3			25			N/A			11			1	
Lack of experienced contractors		13			15			N/A			N/A			6	
Insufficient Labors for Certain Activity.		10			9			N/A			27			N/A	
Lack of Quality Control including Goods Transported to The Site and service related activities		21			28			2			10			N/A	

Lack Of Communication Between Consultants and Contractors.		16			74			15			18			N/A	
Lack Of Contractor Knowledge		5			40			N/A			25			5	
Insufficient supervision on labors		19			44			7			N/A			3	
Overload Work Cause Stress		4			N/A			N/A			N/A			N/A	
Lack Of experienced and Trained Labors		15			20			N/A			N/A			N/A	
Government Change Laws and Regulations		23			1			N/A			34			N/A	
Weather Obstacles and Bad Site Conditions		20			86			11			26			N/A	

One of the objectives for this study is to find whether the utilization of BIM will have an impact on the probability of the causes' occurrence. Thus, a comparative study has been performed.

4.7 Comparison Results

To compare between the projects which applied BIM and non-BIM, a question in the survey was added. The results stated that thirty-four out of seventy-four respondents used the BIM in the projects which is 45.90% of the total responses.

It is necessary to divide the respondents in two groups to find the ranking of the rework causes and compare them with the other group; the first group will be the projects with no BIM while the second group will be the projects with BIM.

In this study the author will use frequency index to rank and compare the rework causes. Table 4.14 shows the ranking of the causes according to the frequency index for both groups.

Table 4.14: Ranking of Causes According to F.I %

Cause of Rework	Frequency Index			
	NO BIM	Rank	BIM	Rank
Errors In Construction Procedures	71.25%	1	66.91%	1
Overload Work Cause Stress	63.75%	4	64.71%	2
Conflict Between the Suppliers and The Construction Team.	56.25%	17	64.71%	3
Incomplete Design Drawings	61.25%	10	61.77%	4
Lack of Communication Between Designer and either of Client, consultant, and contractors	63.13%	6	61.03%	5
Lack Of Contractor Knowledge	67.50%	2	59.56%	6
Occurrence Of Financial Problems	61.88%	9	58.82%	7
Confusion In Design	63.13%	5	57.35%	8
Inappropriate Design Details	60.00%	13	57.35%	9
Accidents and errors occur during material transportation	57.50%	15	56.62%	10
Insufficient Labors for Certain Activity.	64.38%	3	55.88%	11
Lack of experienced contractors	62.50%	7	55.88%	12
Insufficient supervision on labors	56.25%	18	55.88%	13
Mistakes related to material and service Supplier During the Project	60.00%	12	55.15%	14
Change in material in the Project	56.25%	16	55.15%	15
Weather Obstacles and Bad Site Conditions	55.00%	19	55.15%	16
Lack Of experienced and Trained Labors	62.50%	8	54.41%	17
Making Wrong Decisions	60.63%	11	52.94%	18
Change In Plan and specification of the project	53.13%	22	52.94%	19
Lack of Quality Control including Goods Transported to The Site and service related activities	53.75%	21	52.21%	20
Lack Of Communication Between Consultants and Contractors.	59.38%	14	52.21%	21
Government Change Laws and Regulations	54.38%	20	50.00%	22

Issues related to material quality	51.88%	23	50.00%	23
Inadequate Project Objectives	50.00%	24	50.00%	24

The utilization of BIM shows an obvious impact on decreasing the probability of occurrence in "*Errors in the construction procedures*", "*Lack of contractor knowledge*", "*Occurrence of Financial problems*", "*Confusion in design*", "In appropriate design details", etc.

The average frequency index for the non-BIM group was 59.4%, on the other hand, the BIM group averaged 56.6%. This shows about 3% decrease of the occurrence probability for the rework causes. Figure 4.11 shows the difference between F.I% for each cause in both groups' projects with BIM and non-BIM.

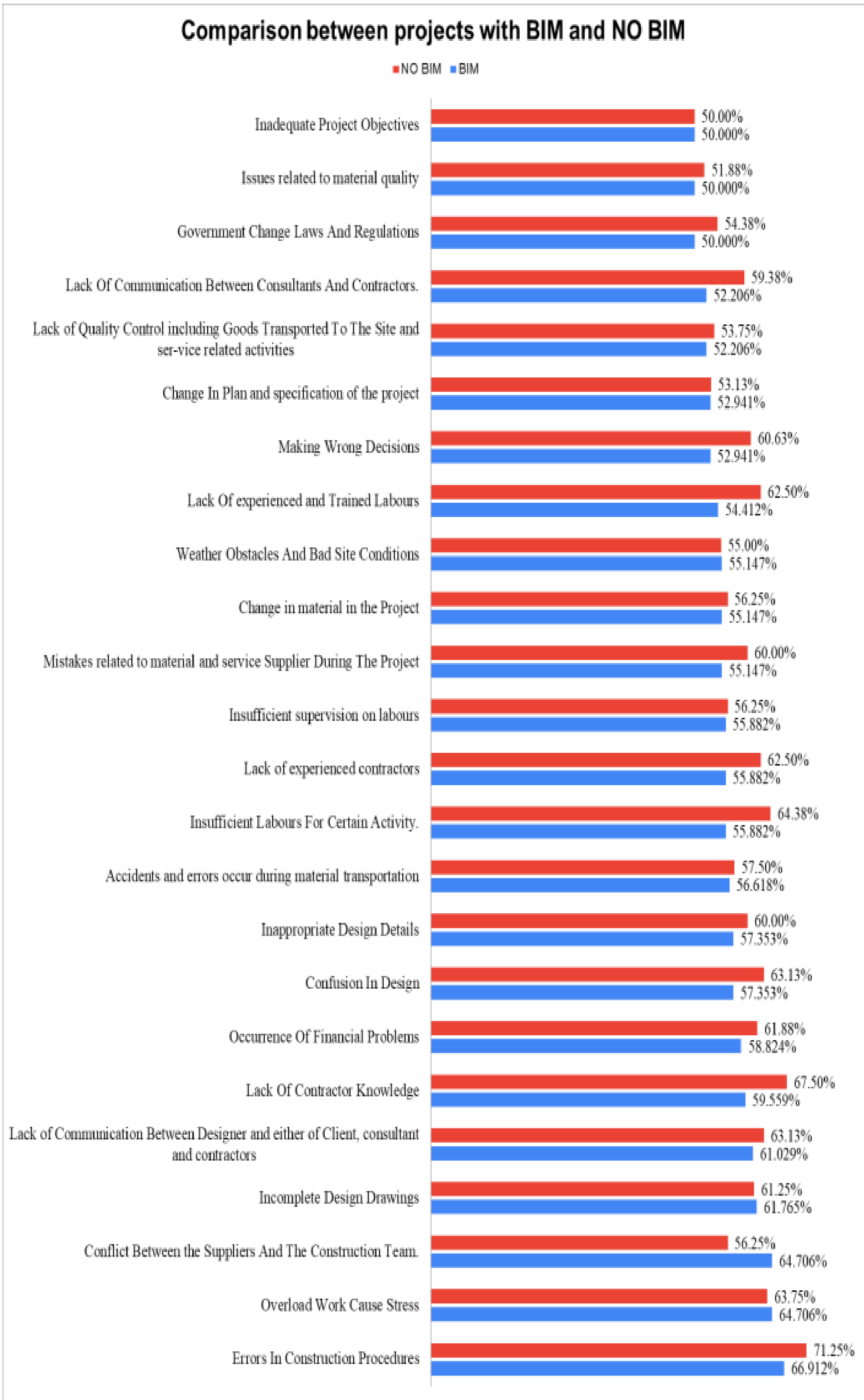

Figure 4.11: Comparison Between Projects with BIM and NO BIM

Chapter 5

CONCLUSION AND FURTHER RESEARCH SUGGESTIONS

Usually, projects are plagued with construction rework, which creates cost overruns, leading to an attempt to improve project time and cost. Although one of the most common causes of overruns is the rework, within this study, the author will be analyzing Saudi Arabian construction as a case study to obtain a better perspective of rework elements.

A systematic literature review was launched in this study to identify twenty-four rework reasons. Additionally, a pilot study and questionnaire were conducted to establish professional points of view using the Likert scale. The questionnaire was distributed to 221 people, and 74 people returned the questionnaire. The response rate was 33.40%, while the assessed significance level was 69, meaning that the minimum number of answers should be 69 or higher.

For this study, a systematic framework was constructed, including the following processes: (1) question formulation; (2) searching for suitable materials; (3) document selection; (4) factor identification; (5) pilot questionnaire, (6) questionnaire modifications, and lastly (7) analyze and synthesize the results.

The rework causes were extracted from extensive research of relevant articles from the formulated research questions by applying the Boolean operations and some keywords tabbed from literature reviews. In addition, the snowballing method was adopted to find the rest of the related studies.

The definition of rework causes identified thirty-one reasons that contribute to rework. To ensure that these thirty-one causes are relevant: a pilot test was conducted in interviews with experts involved in this study; a project manager, a project engineer, a managing director, and an academic researcher assistant. Those experts suggested that twenty-four causes mentioned in the questionnaire were enough for this study. These twenty-four rework causes are divided into five categories: owner-related issues, procurement-related issues, design-related issues, contractor-related issues, and external issues.

The Cronbach's alpha reliability check technique was executed to test the product of the questionnaire, which confirmed that the Cronbach's alpha for every cause is more than 0.90, elaborated that the inner consistency is excellent.

Each rework cause: frequency index, severity index impact on time and cost, and total importance index were calculated. Furthermore, the total importance index was used to determine group rank and an overall ranking for each cause. Several factors cause construction rework; country-to-country differences depend on the extent of economic and cultural development of this industry. Additionally, Table 4.13 shows a comparative study between the rankings of causes in different studies. It is necessary to divide the respondents into two groups to find the ranking of the rework causes and compare it with the other group. The first group will be the projects with no BIM, and the second group will be the projects with BIM. The author used a frequency index to rank and compare the rework causes in this study. Table 4.14 shows the ranking of causes according to the frequency index for both groups.

In conclusion, the current study is beneficial for academia and the construction field as it determines many rework causes. Furthermore, the author contributes some recommendations for the construction industry and allows more enlightenment regarding some topics for the researchers to study. According to the research and the statistical analysis the author did, the following tips were presented to decrease the rework in construction projects:

- Using BIM will enhance the collaboration between the parties in the construction projects, as well as help reduce the probability of occurrence of some rework causes.
- Both the contractor and subcontractor should initially design a quality control system with approval of the client.
- Clients should prepare a proper document with distinct objectives to avoid misunderstandings.
- Proper project planning and cost control are necessary as the occurrence of financial problems was number one cause in rework.

Recommendations for further research:

- Use different methods to study and rank the rework causes stated in the research.

- Divide the construction industry sectors into industrial sector, residential building sector, and infrastructure sector then study the causes of the rework accordingly.
- Using several approaches to lessen the rework in construction industry, compare it with the adoption of BIM and how it will affect the occurrence of rework.

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APPENDIX

Questionnaire

Please answer the following survey questions about rework in construction projects

***Introduction and Instruction*:**

This dissertation mainly measures the rework probability of occurrence and its impact on duration and budget through the construction projects; twenty-four rework parameters have been determined to be assessed and discussing its manageability using BIM.

SECTION 1:

Gender?

- Male
- Female

Age?

- < 30
- $30 \le x \le 40$
- $40 \le x \le 50$
- > 50

Educational Level?

- Ph.D. or higher
- Master's Degree
- Bachelor's degree
- High school or equivalent Degree

SECTION 2:

Which one of the following categories best describes your position in the construction field?

- Client
- Consultant
- Contractor/Subcontractor
- Project Management

Years of experience you have in the construction field.

- < 3 years
- 3 ≤ Years ≤ 10
- 10 ≤ Years ≤ 15
- > 15 Years

SECTION 3

The following issues have been recognized as potential sources of rework in building construction. The survey below was created using a five-point Likert scale to assess the influence of each reason on the overall cost and time escalation of building development. Please rate the following rework factors based on their likelihood, effect, and manageability in the project under consideration.

DEFINITION OF RISK EVALUATION PARAMETERS:

Scale of frequency		
Numerical values	Description	Chances
1	Very rare to occur	less than or equal 10%
2	Minor probablity of occurrence	More than 10% and less than or equal 35%
3	Moderate probablity of occurrence	More than 35% and less than or equal 65%
4	Good chance to occur	More than 65% and less than or equal 90%
5	Most probably it will occur	More than 90%

Scale of Cost		
Numerical values	Description	Chances
1	Negligable impact	(5% ≥ cost)
2	Minor impact	(5% < cost ≤10%)
3	Moderate impact	(10% < cost ≤20%)
4	Signficant impact	(20% < cost < 50%)
5	Severe impact	(50% or greater)

Scale of time		
Numerical values	Description	Chances
1	Negligable impact	(5% ≥ time)
2	Minor impact	(5% < time ≤10%)
3	Moderate impact	(10% < time ≤20%)
4	Signficant impact	(20% < time < 50%)
5	Severe impact	(50% or greater)

ID	Cause of Rework	Probability					Impact on time					Impact on cost				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Owner related issues																
1	Change In Plan and specification of the project															
2	Change in material in the Project															
3	Inadequate Project Objectives															
4	Making Wrong Decisions															
5	Occurance Of Financial Problems															
Procurmenet related issues																
6	Mistakes related to material and service Supplier During The Project															
7	Issues related to material quality															
8	Conflict Between The Suppliers And The Construction Team.															
9	Accidents and errors occur during material transportation															
Design related issues																
10	Inappropriate Design Details															
11	Confusion In Design															
12	Incomplete Design Drawings															
13	Lack of Communication Between Designer and either of Client, consultant and contractors															
Contractor related issues																
14	Errors In Construction Procedures															
15	Lack of experienced contractors															
16	Insufficient Labours For Certain Activity.															
17	Lack of Quality Control including Goods Transported To The Site and service related activities															
18	Lack Of Communication Between Consultants And Contractors.															
19	Lack Of Contractor Knowledge															
20	Insuffienct supervision on labours															
21	Overload Work Cause Stress															
22	Lack Of experienced and Trained Labours															
External issues																
23	Government Change Laws And Regulations															
24	Weather Obstacles And Bad Site Conditions															