

University of Bahrain

College of Engineering



Department of
Mechanical Engineering

Adoption of Building Information Modeling in Bahraini Construction Industry Using Structural Equation Model

Research Proposal submitted in partial fulfillment of the requirements
for the degree of Master of Science in Engineering Management

prepared by the researcher:

Shurooq Husamaddin Ali

ID Number: 20100059

Supervised by:

Prof. Saad Suliman

Professor of Manufacturing Systems and Processes

University of Bahrain

Kingdom of Bahrain

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جامعة البحرين

قسم الهندسة الميكانيكية

كلية الهندسة



اعتماد نمذجة معلومات البناء في صناعة البناء البحرينية باستخدام نموذج المعادلة البنائية

أطروحة مقدمة كجزء من متطلبات الحصول على درجة الماجستير
في الإدارة الهندسية

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ملخص الدراسة

الإنتاجية وانخفاض الجودة، وتأخير المشروعات، وتجاوز التكاليف هي المشاكل الرئيسية الأربع التي تواجه صناعة البناء والتشييد في العالم. وهذه المشاكل ترجع بشكل رئيسي لعدم وجود تعاون وسوء إدارة للمعلومات بين أطراف هذه الصناعة، ولكن مع ظهور تقنيات جديدة مثل نمذجة معلومات البناء والتي تعنى بجمع البيانات لإنشاء وثيقة من المعلومات المشتركة قد تقدم حلاً للمشاكل التي تواجه صناعة البناء والتشييد البحرينية حيث لا توجد رؤية واضحة لمستوى اعتمادها بعد، بالتالي فإن الهدف من الدراسة هو الوقوف على مستوى الوعي ومدى استخدام نمذجة معلومات البناء، علاوة على ذلك تحديد المؤشرات الرئيسية التي تدفع لتبني نمذجة معلومات البناء في البحرين. من خلال مراجعة الأدبيات في هذا المجال من دراسات سابقة وغيرها تم تحديد ١٢٨ مؤشراً صنف في سبع مجموعات: التكنولوجيا، العملية، الأشخاص، البيئة، التنظيم، السياسة، واعتماد سياسة نمذجة معلومات البناء. وقد اعتمدت الدراسة على المنهج الكمي باستخدام طريقتين طريقة دلفي وطريقة مسحية في صورة إستبيان، تم إجراء الدراسة على ٣٢٦ متخصص في المجال وبعد جمع الإستجابات تم رصد ٢٧٢ إجابة كاملة تم تحليلها في ثلاث أجزاء، الجزء الأول تحليل وصفي لسمات المتخصصين في صناعة البناء والتشييد في البحرين باستخدام برنامج SPSS25 والجزء الثاني تقنية نمذجة المعادلات البنائية باستخدام برنامج AMOS لتحديد المؤشرات الرئيسية التي تؤثر على اعتماد نمذجة معلومات البناء، وللعثور على تأثير نتائج التحليل الوصفي على المجموعات الست تم استخدام تحليل MANOVA عن طريق برنامج SPSS25. أشارت نتائج الإستبيان إلى أن أكثر من ٧٢% من الإجابات تدل على وعي ودراية الأشخاص بنمذجة معلومات البناء ومع ذلك ٣٩% فقط يستخدمونه في عملهم مما يشكل عقبة أمام اعتماد نمذجة معلومات البناء في مملكة البحرين، كما أظهرت النتائج أن العوامل الرئيسية التي تدفع التبني إلى مستويات أعلى، هي مجموعة العوامل المتعلقة بالبيئة والعوامل المتعلقة بالأشخاص أنفسهم، وبلغ مقياس المسار ٢٨٠، ٣٣٢، ٠ على التوالي حيث تصف المؤشرات المتعلقة بالبيئة جميع القوى الخارجية (على سبيل المثال العولمة والإستراتيجيات التنافسية، المرونة الدولية وطلب السوق وفوائد نمذجة معلومات البناء). بينما تدعم المؤشرات المتعلقة بالأشخاص الخصائص الفردية، والحاجة للإبتكار ونشره، مما يعني أنه من أجل تعزيز نمذجة معلومات البناء في صناعة البناء البحرينية يجب التركيز على دعامتين هما البيئة والجانب الشخصي أي الشخص نفسه. وقد دعم هذه النتيجة تحليل MANOVA حيث تشكل مكونات البيئة والأشخاص عاملاً مشتركاً يتأثر بسمات المتخصصين في صناعة البناء البحرينية. ومن المأمول أن توجه هذه النتائج لزيادة مستوى اعتماد نمذجة معلومات البناء في المستقبل في مملكة البحرين.

Abstract

Low productivity, low quality, project delay, and cost overrun are the four main problems facing the world construction industry. These problems are due to a lack of efficient collaboration and information management. With Building Information Modeling (BIM), it is about bringing together all data to create a robust set of information. If implemented, BIM may offer a solution for problems facing the Bahraini construction industry. In Bahrain, yet there is no clear vision of the level of BIM adoption. Hence, the aim of this study to investigate the level of awareness, usage, and adoption of BIM. Moreover, to identify the key indicators that drive BIM adoption. With a detailed literature review, 128 indicators are identified and grouped into seven groups: "Technology", "Process", "People", "Environment", "Organization", "Policy", and "BIM adoption". The study was carried out using quantitative approaches of the Delphi method and questionnaire survey. A total of 272 completed responses were collected and analyzed in three parts. The first part is a descriptive analysis of the respondent's attributes using SPSS25 software. The second part is the Structural Equation Modeling (SEM) technique using SPSS 25 and AMOS software. Moreover, the third part is a MANOVA analysis to find the effect of the respondent's attributes on the BIM components using SPSS25 software. The results of the questionnaire indicate that more than 72% of the respondents are aware of BIM. However, only 39% are using it in their work, which forms an obstacle for the BIM adoption in the kingdom of Bahrain. The structural model shows that to increase the adoption to higher levels, the "Environment" indicators, and partially "People" indicators are the leading indicators driving for BIM adoption with path coefficient value of 0.280 and 0.332, respectively. "Environment" related indicators describe all external forces, including, for example, globalization and competitive strategies, market demand; international flexibility to market; and BIM benefits. While "People" related indicators are supporting individual characteristics; and the need for innovation and the diffusion of innovation, which means that to enhance the BIM adoption in Bahrain, two pillars to depend on, external forces and people. This result is supported by the MANOVA analysis, where the "Environment" and "People" components constitute a common factor affected by the professionals' attributes. It is hoped that these findings will guide efforts to increase the level of BIM adoption in the Bahraini construction industry in the future.

Dedication

I dedicate this thesis to:

My Mother and Father, with all my heart, without their endless love and encouragement, I would never have been able to complete my post-graduate studies. I love you both, and I appreciate everything that you have done for me.

My sister Ayla, who was there for me throughout this process, and gave me lots of support.

My brothers, Abdullah and Ahmed, whom I believe embodies all things beautiful, pure and, creative.

“This achievement is the result of your true love and generous cares.”

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Glossary of Abbreviations

AGFI	Adjusted Goodness of Fit
ANOVA	Analysis of Variance
AMOS	Analysis of Moment Structure
ATU	Attitudes Towards Using
BEDB	Bahrain Economic Development Board
BI	Behavioral Intentions
BIM	Building information modeling
C	Margin of error
CAD	Computer-Aided Design
CB-SEM	Covariance Based approach
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CIDB	Construction Industry Development Board
CO	Complexity
CP	Compatibility
CRPEP	The Council for Regulating the Practice of Engineering Professions
EFA	Exploratory Factor Analysis
ETABS	Extended Three-Dimensional Analysis of Building Systems
EQS	Environmental Quality Standards
GDP	Gross Domestic Product
GFI	The Goodness of Fit Index
GOF	Goodness of Fit
GSCA	Generalized Structured Component Analysis
IDT	Innovation Diffusion Theory
IPD	Integrated Project Delivery
KI	Kurtosis Index

KMO	Kaiser-Myer-Olkin
LISREL	LInear Structural RELations
MANOVA	Multivariate Analysis of Variance
MEP	Mechanical, Electrical, and Plumbing
MI	Modification Indices
MS Project	Microsoft Project
nD	n-Dimension
OB	Observability
P	Population
PCFA	Principal Component Factor Analysis
PEOU	Perceived Ease of Use
PLS	Partial Least Squares
PMBOK	Project Management Body of Knowledge
P	Percentage picking a choice
PU	Perceived Usefulness
R²_{smc}	Squared Multiple Correlations
r	Bivariate Correlation
RA	Relative Advantage
Revit	Revise Instantly
RMSEA	Root Mean Square of Error Approximation
ROI	Return on Investment
SBM	Single Building Model
SEM	Structural Equation Modeling
SI	Skewness Index
SPSS	Statistical Package for the Social Sciences
SS	Sample Size for infinite population
STAAD Pro	Structural Analysis And Designing Program
TAM	Technology Acceptance Model

TEKLA	Teknillinen laskenta, which means technical computation.
TLI	Tucker-Lewis Index
TOE	Technology-Organization-Environment
TR	Trialability
VIF	Variance Inflation Factor

CHAPTER ONE

INTRODUCTION TO THE STUDY

- 1.1 Background**
- 1.2 Problem Statement**
- 1.3 Research Questions**
- 1.4 Research Hypothesis**
- 1.5 Aim and Objective of the Research**
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CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1Background

1.1.1 World construction industry

The Construction Industry forms one of the most critical sectors in the world. The commitment of this industry towards the worldwide Gross Domestic Product (GDP) is about 3.1% of the total (Turner and Townsend, 2017). Moreover, the World Construction Industry is a potential business generator, with about 50% of the aggregate world assets (Watch, 2010). However, construction projects are complex and require financial and resource planning. Thus, this sector is affected by many factors like delays, cost overruns, low quality, low productivity. These problems are related to the failure of the construction industry in dealing with collective labor, poor communication, and response to modern technology (Latham, 1994). Consequently, the construction industry requires many changes in its methods, as adherence to old practices is not the best solution.

To stop such popular and internationally recognized problems, optimizing information transfer efficiency of building design to create greater certainty in the delivery of construction projects is the key. Building information modeling (BIM) has emerged as a solution to these problems. BIM combines different disciplines by efficient communication, represents the project systems for constructability, analyzes the cost and time of projects using quantity takeoffs, and illustrates a big picture of projects using visualization. Reports show that BIM can lead to notable cost and

time savings from design and construction phases, also in facilities management (NBS, 2012; BIM Task Group, 2012).

BIM adoption is on the upward push. Matarneh and Hamed (2017) stated that BIM is mandatory in some nations like the US and the United Kingdom. Also, several European countries such as Sweden, Denmark, Norway, and Finland are considered as BIM leaders (Khosrowshahi and Arayici, 2012). However, Building Smart (2012) stated that the implementation of BIM in the Middle East region is not mandatory and low, especially in some countries like Bahrain and Oman.

So, why the BIM adoption in Bahrain is low? What is the real level of BIM implementation in the Kingdom of Bahrain? Are the construction industry professionals aware of it? Surely the government is doing all it can to develop the construction sector in the light of 2030 vision, but even with this, the construction industry in Bahrain has witnessed a massive drop in growth from 6.4% in 2015 to about 3.2% in 2017 (Bahrain Economic Development Board, 2017).

1.1.2 Construction industry in Bahrain

In the Kingdom of Bahrain, the government efforts resulted in diverse sources of income, the country's non-oil economy expanded by 2.8% in the second quarter of 2018, led by the construction sector with the percentage of 6.7% of the total non-oil economy expansion (BEDB, 2018). To increase the income from the construction sector, the government-driven by the Bahrain Economic Vision 2030 has decided to start many strategic projects (BEDB, 2018). Thus, as a result of the ongoing expansion in the construction sector, the GDP in the first quarter of 2018 was 228.21 BHD Million then increased to 229.76 BHD Million in the second quarter of the same year (T.E., 2018).

Bahrain construction industry provides many opportunities for developers. One of these opportunities is in residential housing, where the offered governmental housing projects are relatively low in contrast to demand. Also, the economy is more diversified than other GCC countries, and healthy government initiatives to invest in major construction projects are driving the sector. Another opportunity comes from government initiatives to invest and to encourage investments in the Bahraini construction industry. Starting from the cost of establishing and operating a construction project is very low as contrasted to other GCC countries (OXFORD Business Group, 2015) .

Many challenges are facing the construction industry in the Kingdom of Bahrain, as discussed below:

- The challenges facing the construction industry in Bahrain, include low labor productivity, low local availability of financial facilities, lack of modern equipment, delays in construction materials delivery to contractors, the high cost of construction, completion schedules are frequently experiencing severe slippage, and projects, most often, are significantly overrunning their budgets (Jarkas, 2015).
- The broad participation of international practitioners mainly due to the shortage of highly experienced local firms.
- Low oil prices are expected to threaten growth forecasts.

1.1.3 Building Information Modeling

Building information modeling is growing very fast around the world. The idea of Building Information Modelling theoretically emerged at Georgia Institute of Technology during the late Nineteen Seventies and proliferated after that. The term "Building Information Modelling" was first used in 2002. Then, it starts to grow due to the increasing attention

paid to construction teams and firms that found merits in the usage of BIM (Harris, 2013).

BIM has many definitions, it can be defined as a set of interacting policies, processes, and technologies generating a “methodology to manage the essential building design and project data in digital format throughout the building's lifecycle” (Succar, 2009). Similarly, it can be defined as a set of parametric tools and processes for the creation of an integrated collaborative database of multi-dimensional information about buildings. To improve collaboration between stakeholders, BIM will reduce the time needed for documentation of the project and produce more predictable project outcomes (NBIMS, 2007).

Building Information Modeling is becoming a comprehensive, collaborative process in the construction industry. Despite its short history, BIM has had increasing growth during the last decade. This is happening mainly due to its capabilities on construction projects where BIM can create a common language between all parties and system divisions in a project and make them an integrated team.

The role of BIM as a coordinator of the project system is quite similar to the duties of a project manager. BIM integrates different disciplines by effective communication, analyzes the project systems for constructability, estimates the cost and time of projects at any time using quantity takeoffs, and draws a big picture of projects using visualization.

1.1.4 Structural Equation Modeling

In recent years structural equation modeling (SEM) has gained popularity. SEM is a term for a broad collection of methods based on the linear model, mainly used in the social sciences (Hoyle, 2012). It is a set of qualitative causal hypotheses based on the theory of empirical studies that are represented by a model (Kline, 2005). SEM includes two types of

variables latent and observable; both together form the path model. It mainly consists of a measurement model and the structural model. A measurement model measures the observable variables, while the structural model measures the relationships between latent variables (Chen et al., 2016). The Relationships in both models can be examined by applying Confirmatory Factor Analysis (CFA) and regression using SEM.

The sample size is very critical in SEM more than any other multivariate tests. Especially that small samples are unreliable with statistical algorithms that are used by the SEM program (Hair et al., 2014). SEM is done through the use of various commercial statistical programs' packages such as AMOS, EQS, Mplus, and LISREL.

1.2 Problem Statement

Construction projects are becoming more and more complex and challenging to manage. And cost, time, and quality the three main success criteria for any construction project are confronting many problems during the project life cycle which is threatening the success of the projects. Low productivity of construction projects, low quality of end projects, project delay and construction cost overrun are the four main construction problems lead to construction project failure (Arayici et al., 2009; Forbes and Ahmed, 2010; Khoshnava et al., 2012 and Haron, 2013). With added pressures from the current global economic difficulties, the need to address and resolve these problems has never been greater.

The need for the project team to collaborate widely and to have a reliable source of information are factors pushing the construction industry to innovate opportunities for improving efficiency and productivity. With BIM, it is about bringing together all data to create a robust set of information for any construction project. If intelligently implemented, BIM

may offer a solution for problems facing the Bahraini construction industry.

Many economies of the world have shown remarkable results by executing BIM in their construction operations. For example, 74% of BIM users in Western European reported a positive perceived return on their investment, and the users said that they measure ROI on more than 25% of their projects (McGraw-Hill Construction, 2016). Moreover, the UK Government's found that using BIM resulted 33% reduction in the initial cost of construction; 50% reduction in the overall time, from inception to completion; 50% reduction in greenhouse gas emissions in the built environment; and 50% reduction in the trade gap between total exports and total imports for construction products and materials (Malleon, A. 2018).

All theses remarkable returns force the need for an investigation into the level of its awareness and indicators affecting its adoption in the Bahraini construction industry. Unfortunately, in Bahrain, yet no research studied the current situation of BIM adoption. Hence, there is a clear need for an understanding of the critical indicators that influence BIM, which would help promote its adoption for potential and existing users and reaching productivity improvements in the Bahraini construction industry.

1.3 Research Questions

The purpose of this study is to stand on the current situation of BIM adoption and to identify and assess different indicators responsible for driving the adoption in the Bahraini construction industry. Many types of research devoted to BIM subject; however, no study investigated the current situation of BIM adoption in the Kingdom of Bahrain.

Therefore, the research questions that were formulated in the initial phase of this study and drove further research describes as following:

- 1-What is the current state of BIM in the Bahraini construction industry?
- 2-What is the BIM level of awareness and usage among Bahraini construction industry stakeholders?
- 3-What do Bahraini construction industry stakeholders perceive as the most critical indicators driving for BIM adoption?
- 4-How to assist construction professionals in adopting BIM in the Bahraini construction industry?

1.4 Research Hypothesis

The primary purpose of the hypothesis is to support the research model after data collection (Enegbuma and Ali, 2013). A review of the literature revealed a list of BIM adoption indicators. Based on that, six main BIM adoption components identified, and related indicators proposed for each element. According to this, the following six hypotheses are formulated to test through the research:

Hypothesis 1: Environment-related indicators will have a positive effect on BIM adoption.

Hypothesis 2: Process-related indicators will have a positive effect on BIM adoption.

Hypothesis 3: Technology-related indicators will have a positive effect on BIM adoption.

Hypothesis 4: Organization-related indicators will have a positive effect on BIM adoption.

Hypothesis 5: Policy-related indicators will have a positive effect on BIM adoption.

Hypothesis 6: People-related indicators will have a positive effect on BIM adoption.

1.5 Aim and Objective of the Research

There has been increasing recognition of BIM globally due to its advantages to different stages of a building's life cycle. The research aims to develop a model enhancing the adoption of BIM, through identifying and analyzing the indicators driving BIM adoption. This model is expected to assist construction industry stakeholders in identifying indicators influencing BIM adoption in construction projects in Bahrain. For achieving this aim, the following research objectives set:

1. To gain an overall understanding of the adoption and awareness levels of BIM adoption in Bahrain's construction industry.
2. To identify leading indicators driving the adoption of BIM in the construction industry in Bahrain.
3. To establish an adoption model using Structural Equation Modeling (SEM) that examines the relationship between several indicators driving BIM adoption in Bahrain.

1.6 Research Design and Methodology

The research used several research methods. These methods acted as a supplement to each other, which made the data collection more comprehensive and meaningful.

The research methodology is carried out in four phases. The first phase will start with identifying all the indicators associated with the relevant theories through a combination of resources includes scientific journal articles, conference proceedings, books, and documentaries.

The use of expert judgment in a scientific way was essential especially in factors identifying, the listed indicators are examined and validated by a group of highly experienced experts in the construction field in Bahrain, including experts from both governmental and private sectors who are using or not using BIM, this mini Delphi technique will form the second phase.

The third phase will start after the listed indicators were confirmed by the consensus of all experts. A quantitative survey approach is carried out involving professionals (Project managers, Architects, Civil engineers, Mechanical engineers, Electrical engineers, and any other related specialization) in the construction industry in Bahrain.

Finally, the fourth phase, which is the data analysis phase, is divided into three parts. Part one is a descriptive analysis of the respondent's attributes. In part two, a conceptual research model is formulated using SEM. Hence, the conceptual model is used to evaluate the research hypothesis. In part three, MANOVA analysis is used to identify the significant relationships among the attribute's analysis of part one and BIM adoption components. The research methodology is schematically outlined in Figure (1.1).

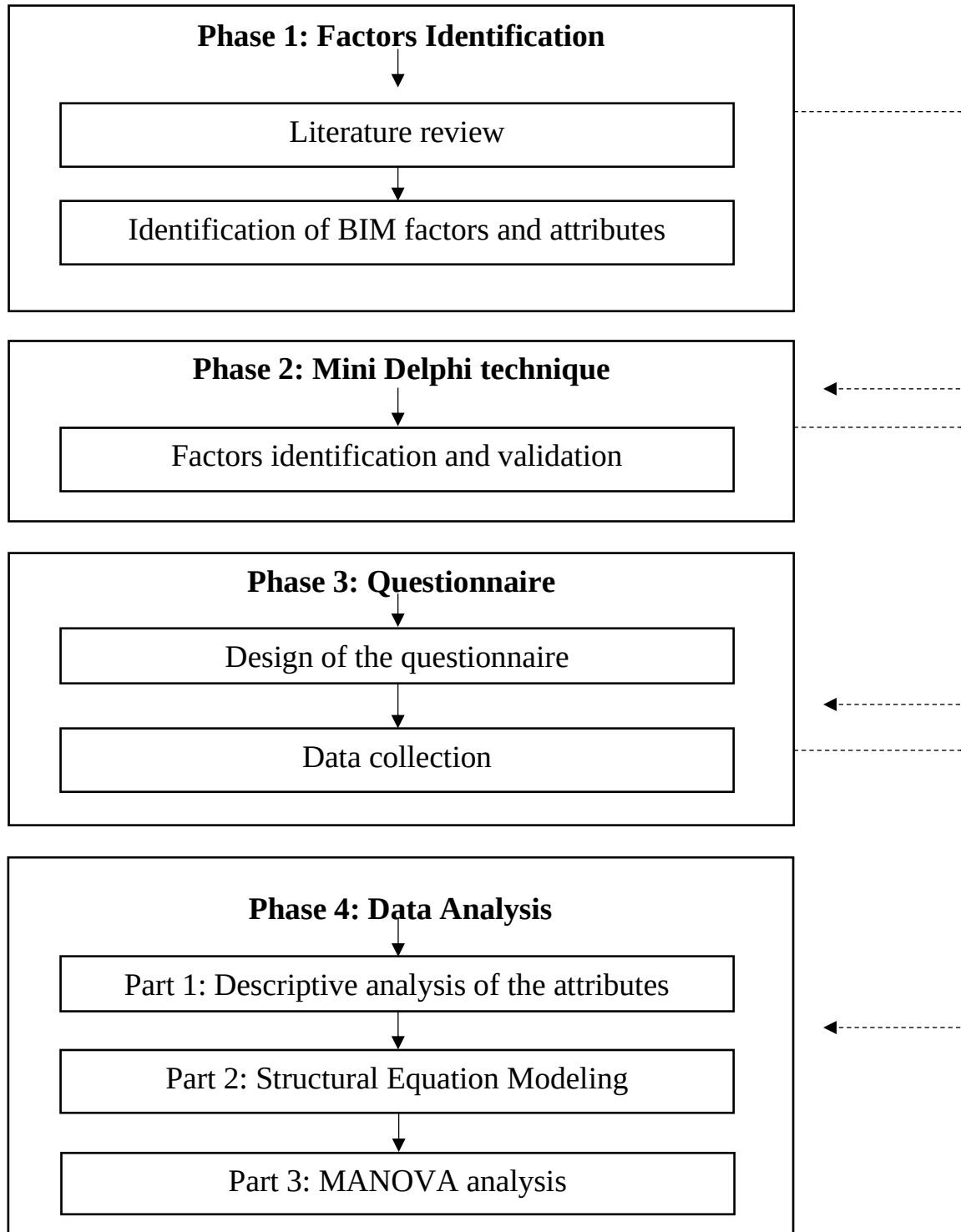


Figure 1.1: Research Methodology

1.7 Methods of Data Analysis

The main point when deciding research analysis methods focuses on the research problem and how to achieve the aim and objectives of the study. Based on that, the following analytical methods were set:

- Data screening phase for checking missing values, testing the normality assumption, and detecting multicollinearity.
- Exploratory Factor Analysis (EFA) which is used to identify the number and nature of indicators, by grouping (categorizing) them.
- Construction of the research model.
- Validation of the research model using Confirmatory factor analysis (CFA).
- Development of the SEM model using AMOS software to test relationships between the model's variables.
- Testing the hypotheses and discussing the results of the model to reach a conclusion and recommendation.
- Testing the effect of the results of the descriptive analysis of the respondent's attributes on the components driving for BIM adoption in the Bahraini construction industry using MANOVA analysis.

1.8 Research Significance

The results of this research are expected to be of great importance to professionals working in the construction industry in Bahrain because it is:

1-Being the first of its kind in Bahrain, and providing support to the urban development, especially in the light of the 2030 Vision to place Bahrain on the map of the countries that are witnessing unprecedented urban growth.

2-Gaining an overall understanding of the state of BIM in Bahrain and exploring the perceptions of the Bahraini industry about the benefits of BIM.

3-Consolidating joint movements towards broader adoption of BIM in Bahrain and forms a base for developing a sound BIM strategy and guidance.

4-Producing a quantitative theoretical model, i.e., SEM that will assist in implementing BIM in Bahrain.

5-Paving a solid foundation for a quick transition to BIM, helping the construction industry to gain a powerful tool that may offer a solution for all problems facing it.

1.9 Thesis Outline

The thesis is structured as follows:

Chapter 1- Introduction to the Study

Presents a general view of the background and describes briefly the main problem and what this research aims to achieve.

Chapter 2- Literature Review

In the second chapter, the theoretical framework of the research is demonstrated. The most important subjects regarding BIM and SEM are viewed from different resources such as scientific journals and books. Also, it reviews previous related models and their theories of adoption of BIM.

Chapter 3- Research Model Development

This chapter presents the research model and how it is developed. Also, it discusses the mini Delphi technique method used in factors identification and validation.

Chapter 4- Data Collection

This chapter first discusses the targeted group of respondents, the data sampling methods, and explains the questionnaire design and forms of distribution.

Chapter 5- Data Analysis

Chapter 5 presents and analyses the research results and findings of the empirical data which are collected through the questionnaire. The analysis is carried out in three parts, a descriptive analysis of the respondent's attributes, SEM, and MANOVA analysis.

Chapter 6- Results and discussion

Based on the scientific review and survey results, this section develops a debate where the researcher elaborates on some ideas, articulates his opinions, and sustains his proposals.

Chapter 7- Conclusion, Recommendations, and Future Research

The researcher concludes this study by summarizing the answers to the research questions of this thesis, emphasizing the most critical indicators, and outlining the pathway for BIM adoption. Also, recommendations are made, and further research is suggested.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

2.2. Building Information Modeling

2.3. Structural Equation Modeling Method

2.4. Review of Models from Previous Studies

2.5. Literature Summery

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

With a commitment of about 3.1% of the total world GDP, the construction industry was able to book a seat between important industries (Turner and Townsend, 2017). However, nowadays, construction companies are experiencing fragmentation, low productivity, time, and cost overrun. This is caused by change order, wrong design information, inaccurate information transfer, unreliable data and incorrect deliveries (Harris et al., 2017). All these are among the issues that require BIM to be implemented effectively, especially with the failure of the construction industry in dealing with various data, and a large number of professionals are working on the same project.

In this chapter, the theoretical framework of the study will be presented, as it will form a strong base for the research to depend. It includes three major sections. The first section is related to BIM, which is the context that this study is relevant to. Different perspectives and definitions of BIM are addressed, its main features are described, and important aspects are clarified. The second section describes the area of SEM which is the primary statistical technique used in the research. The third section will draw on the related models and their theories of “adoption of BIM” to identify the related indicators and study relationships between them.

2.2 Building Information Modelling (BIM)

In the construction industry, the target always to find new ways to increase productivity, efficiency, quality of the outcome, and to reduce the cost and time of the project. Azhar et al. (2007) stated that BIM is a tool that offers possibilities for the construction industry to achieve its targets. Nowadays, many projects have successfully implemented BIM with considerable advantage, and the awareness of the use of BIM is increasing more and more among the industry professionals (Xu et al., 2014). However, many professionals are still not aware of BIM and its capabilities due to some factors acting as a barrier for BIM implementation such as fear of unknown and uncertainty; therefore, they hesitate to adopt these new systems in their works (Sunil et al., 2017).

The following literature review will provide a reliable base for this research to depend on and help the reader to get better information about BIM topic

2.2.1 BIM evolution and development

Information technology always has been the trump card when it comes to the construction industry. It consistently appears as a solution to many construction industry problems, especially as the world gets in a new phase of buoyant economic achievements. This digital transformation also offers construction professionals everywhere a huge opportunity to take a new and better approach.

Traditionally data exchanged among construction process participants often include numerous files and drawings. This process creates mistakes due to the massive number of files and drawings, especially that they are usually in paper-based layout, hence that is not well controlled and no principals for collaboration and visualization of the design. This all ends up in miscommunication among them (Zakaria et al.,

2013; Abubakar et al., 2014).

The role of information technology started with Computer-Aided Design (CAD) software applications that have been used in the construction industry for about three decades (Parvan, 2012). The 2D design was the only approach to deal with information on construction sites, and with the manual reviewing, the process rarely satisfies the users (Ding et al., 2015). This process consumed much time, especially for large, complicated designs (Zahrizan et al., 2014).

BIM supported software applications appear now as the next revolution after CAD technology in the construction industry (Guiyou and Li, 2016). It is a motive for the construction industry to overcome the problems faced with productivity, communication, and collaboration between industry professionals (Abubakar et al., 2014). Globally, BIM has already existed for more than twenty years. The idea of BIM appeared at Georgia Institute of Technology in the late 1970s by Professor Charles M. Eastman. In 1986 Graphisoft introduced ArchiCAD as its new software, which formed at the time of its appearance a new revolution in the construction industry. With ArchiCAD, the creation of three-dimensional models made a massive improvement in CAD software at that time (Rokooei, 2015).

In the beginning, BIM meant creating any building component as a “parametric object”. This object is in a database and associated with properties and information like physical entities, geometric data and shows different relationships between different building elements, unlike the previous CAD models, which deals with building elements as regular graphical entities (Panuwatwanich and Peansupap, 2013; Samuelson and Björk, 2013). Now BIM is the true meaning of the full integration between the construction parties, which will result in a model created from different objects. With the strenuous efforts, BIM is not only a 3D dimension, but it

is now "fourth" (4D), "fifth" (5D), and even "sixth" (6D) dimensions (Migilinskas et al., 2013).

National Institute of Building Science (2007) defines BIM as "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle". However, it is tough to find a consensus about the definition. One may get ten distinct definitions from ten distinctive experts (Chen et al., 2012).

A large number of researches in the field of BIM have resulted in a large number of different definitions, and it nonetheless has no single, broadly standard definition (Migilinskas et al., 2013). This large number of interpretations has resulted from two reasons, first having professionals with different backgrounds, experiences, perspectives, from which they judge BIM and results that they expected to gain (Blanco and Chen, 2014). Second, BIM, as a concept, is broad (Samuelson and Björk, 2013). This diversity in definitions indicates the tendency for misinterpretation between industry professionals. (Barlish and Sullivan, 2012). Some see BIM from a technological aspect as a software application; some define it as a process that organizes building information in the construction industry; while others say it is an entirely new method to manage and enhance the construction industry, which will need a set of new rules and protocols between all project parties.

As indicated earlier, researchers proposed various definitions for BIM; thus, their views should be considered while defining BIM to have an agreement on a standard accepted definition. Table (2.1) was tabulated by identifying seven keywords from 31 different definitions of BIM, to come up with an explanation that considers all aspects and perspectives of BIM. The chosen keywords: Technology, Process, Policy, Information, Collaboration, Digital, and Model, appeared at least three times in all 31

different definitions of BIM. The keywords: Information, Digital, and the Process had emerged more than any other from the keywords mentioned in Table (2.1).

From the results of Table (2.1), BIM for this research can be defined as: *the production of project data in a digital information model, by exploiting the uses of computer-aided modeling technology, which requires the implementation of new set of policies and processes, with the purpose of improving collaboration, integration, management and communication between stakeholders throughout construction project life-cycle.*

BIM regularly understood as a mean for visualizing the projects to keep mistakes and clashes (Barlish and Sullivan, 2012). The above definition removes any misconceptions when referring to BIM as software. BIM is a process, not a software. Yes, the software is at the technological core of BIM, but that forms about ten percent only. The other ninety percent of BIM is sociology. As such, we refer to it as a sociotechnical system. BIM is about having accurate information in one place, and in a useable format so that people can access it and use it when needed. By adopting a BIM mindset and approach, you could save time and costs, improve safety and efficiency.

Table (2.1): BIM Definition Keywords

References	Technology	Process	Policy	Information	Collaboration	Digital	Model
1. Son et al., 2014	√						√
2. Harris et al., 2017	√	√					
3. Al-btoush and Haron, 2017	√	√	√			√	√
4. Gaudin, 2013	√			√		√	
5. Kassem and Succar, 2017	√	√	√				
6. Silva et al., 2016		√				√	
7. Succar, 2009	√	√	√			√	
8. Hatem et al., 2018		√		√		√	
9. Zahrizan et al., 2014	√	√		√	√	√	
10. Chan, 2014				√		√	
11. Rokooei, 2015	√			√		√	
12. Fazli et al, 2014		√		√	√		
13. Morlhon et al., 2015				√		√	
14. Enegbuma et al., 2015		√		√	√	√	√
15. Acquah and Oteng, 2018					√	√	√
16. Lee et al., 2012				√		√	
17. Panuwatwanich and Peansupap, 2013						√	
18. Enegbuma et al., 2016		√		√	√	√	
19. Enshassi and AbuHamra, 2016				√			√
20. S. Lee et al., 2015				√		√	
21. Jin et al., 2017	√					√	√
22. Chen et al., 2012	√	√		√			√
23. Dowsett and Harty, 2016		√		√	√	√	√
24. Masood et al., 2014		√				√	
25. Liu et al., 2015	√	√		√			
26. Migilinskas et al., 2013	√			√			√
27. Blanco and Chen, 2014	√			√			√
28. Vukovic et al., 2015				√	√		
29. Barlish and Sullivan, 2012		√		√		√	√
30. Venkatachalam, 2017		√		√		√	√
31. Matarneh and Hamed, 2017		√		√		√	

2.2.2 The concept of BIM

The main idea behind BIM is to be able to construct the project in a virtual medium through an online system with all needed information, including time and cost, before building it physically in the real environment (Lindblad, 2013). This concept will help in solving any potential problems before facing them on the site (Haron, 2013). Nisbet and Dinesen (2010) stated that the core of BIM lies in the ability to form and share reliable building information.

The next two subheadings will discuss the concept of BIM as a process and as a technology to get a comprehensive understanding of the BIM concept.

a. BIM as a process

Traditionally, any building construction process involves a large number of professionals where each of them does his tasks and then passes it to the next professional in a sequential exchange of drawings process (Brynjolfsson and Karathodoros, 2013). This leads to the complexity of communication between them. Within this complex communication network, the operation of the circulation of project information is not consistent, project delivery not in an organized way, and collaboration between stakeholders is not constant nor stable.

On the other side, BIM stands on two essentials for any construction project: communication and collaboration. BIM performs an integrated collaborative approach that works as a shared platform for all stakeholders from all disciplines in all project phases. It involves the use of technology to produce an online single virtual model that contains all the necessary information for the entire project (Lindblad, 2013). This process will give all stakeholders the chance to collaborate more precisely and better than the traditional way (Azhar et al., 2012). While each professional is working

on his part of the project, the produced model can be modified and reviewed to fit any new changes in project requirements or details to get the most delicate virtual model before executing the real one. Figure (2.1) illustrates the difference between “traditional “and “BIM” process.

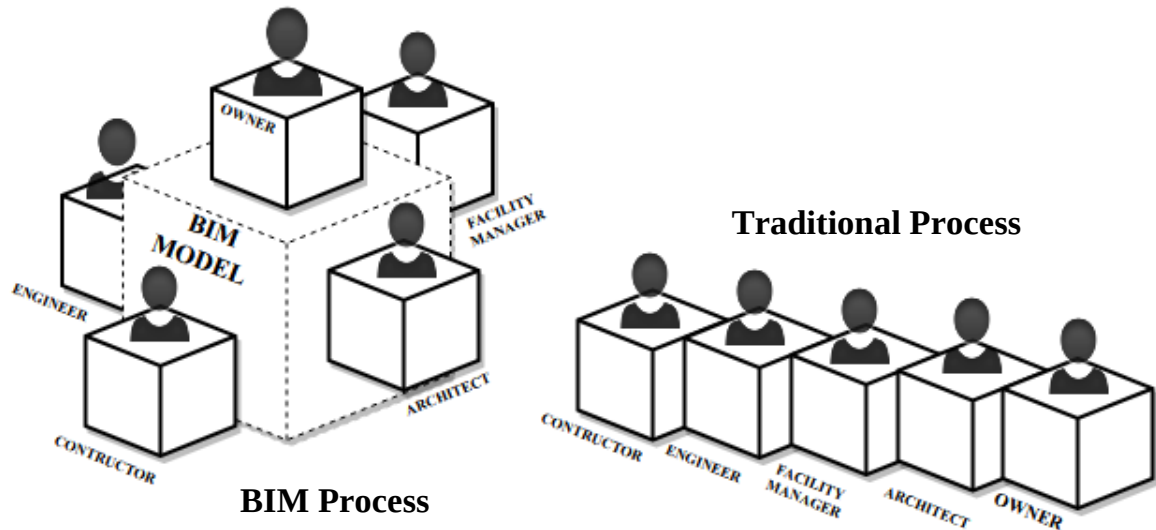


Figure 2.1: BIM Vs. Traditional Process

Newly BIM process allowed the creation of a new concept called The Integrated Project Delivery (IPD) (Gaudin, 2013). IPD is a workflow method which allows all project stakeholders, including suppliers and project owner to function in a time earlier than the traditional way. This early interference enables team members to work in an integrated environment with optimized collaboration from all aspects throughout the project life cycle (Brynjolfsson and Karathodoros, 2013). The demand for IPD is increasing around the world, and nowadays it is the chosen project delivery system for all BIM projects in the United States (McGraw-Hill Construction, 2008).

b. BIM as technology

From a technological viewpoint, the model produced with BIM is deferent from the models produced by CAD software. BIM data input gained a vast potential as it works based on a 3-dimensional object-

oriented approach, while in CAD it is based on traditional coordinate x and y-axis system (Ngowtanasawan, 2017).

In conventional design drawings produced by CAD software, building elements are recognized as graphical elements without any information linked to them; they are just individual elements such as lines or circles (Gaudin, 2013). These graphical elements need to be explained by people, not like elements produced by BIM, which can be defined by computer and transmitted to all project stakeholders through the project life cycle (Samuelson and Björk, 2013). This is because building elements produced by BIM are based on object-oriented parametric modeling technique, which is recognized as components ‘smart objects’ rather than just geometric representations such as columns, beams, and walls (Succar, 2009). Those objects are related to information and data that is directly used in all project phases starting from planning until the operation and maintenance phase (Panuwatwanich and Peansupap, 2013).

What characterized BIM as technology is that editing any of the produced drawings, will not need the editing of the rest as everything will be updated automatically to all stakeholders at the same time. On the other hand, traditional CAD technology will need an update for each view alone, which will increase errors and lead to documentation problems between project stakeholders (Azhar et al., 2012).

2.2.3 Difference between CAD and BIM

The BIM revolution is different from the traditional CAD system, according to (Olugboyega, 2017). Utiome (2010) highlighted that researchers discuss the difference between more than one perspective. Some consider it in terms of the design process; some think it in terms of technology, while others find it in terms of cost.

Brynjolfsson and Karathodoros (2013) pointed out that BIM is different from CAD by three main points:

1- Consistency:

The information, drawings, and data produced by BIM are comprehensive and consistent. Thus, it gains the advantages of being able to be used, communicated directly, and integrated through the project stakeholders, unlike the conventional CAD data, which generates the building project by separate 3D views (Brynjolfsson and Karathodoros, 2013).

2- Object-oriented design:

One another difference is that CAD drawings are presented as graphical entities only; for example, a wall will be shown as lines only with no details about its specifications.

On the other hand, BIM drawings gain a critical feature that is intelligent. Where coded digital objects present elements, for example, a wall be shown as a wall object with all associated details and specifications (Brynjolfsson and Karathodoros, 2013).

3- Data-rich parametric model:

The created BIM models are more than just coded objects; these objects include all the information related to the building that can be used and reviewed during the building life cycle by all stakeholders; they are more like a repository of information. They include all characteristics from different perspectives, starting from the concept stage until facility operations and maintenance stage.

Additionally, BIM models acquire the parametric character by containing information that represents how all building objects are connected. This information is not only representing the dimensional relationships between objects; moreover, it also relates objects to thermal performance, carbon emissions, cost, repair, and replacement cycles.

2.2.4 BIM implementation maturity levels

BIM develops in levels where the level of information collaboration identifies each level. Researchers have suggested these levels and are reviewed as below.

According to Bew and Richards (2008), BIM maturity levels are divided into four levels as follows:

1- BIM Level 0:

Characterized by the usage of 2D design that is generated manually or by CAD. It is usually called unmanaged CAD coordination; most formats are papers and electronic, e.g., Pdf file. These formats result in ineffective communication among project stakeholders (Haron, 2013).

2- BIM Level 1:

In this level, object-based 3D modeling software within one discipline is used. It is usually called managed CAD in 2D or 3D format with the addition of a collaboration tool, which provides a combined data environment, however, without any model-based exchange between different disciplines. Also, it is characterized by the possibility of the use of standard data structures and formats (Zakaria et al., 2013).

3- BIM Level 2:

By reaching level 2, the stakeholders are sharing object-based models with digital information, which will be called a managed 3D environment. Data exchanged is shared and communicated by a common platform based on proprietary exchange formats. This approach may include 4D programmed data and 5D cost data creating a multidisciplinary model that enhances the collaboration between project stakeholders (Zakaria et al., 2013).

4- BIM Level 3:

The last level is featured by having full Integration of several multi-disciplinary models and data using model servers or other network-based

technologies. This fully open process with a single project model and data integration and exchange, strengthen the collaborative process and coordination throughout the construction process (Zakaria et al., 2013).

From another point of view, Succar (2009) specified the BIM maturity levels differently. BIM maturity is divided into three levels according to the stage of BIM implementation: Stage 1: object-based modeling; Stage 2: model-based collaboration; Stage 3: network-based integration. This classification introduces a tool to benchmark the stage of implementation. Those stages are described briefly below:

The pre-BIM status: pre-BIM status represents conventional construction practice by using papers to represent documents and drawings. This way of dealing with a massive number of papers and drawings throughout any construction project shows many problems and difficulties. Human errors are one major problem.

Moreover, it increased the possibility of being exposed to loss or damage. This all lead to problems in terms of project control, information management, and understanding of construction documents.

1- BIM Stage 1: Modeling

This stage is characterized by the transition from 2D to 3D and object-based modeling and documentation. Where these models are smart elements with full information and specifications. However, in this stage, the BIM model is still produced individually for each disciplinary, and the output is much like CAD output.

2- BIM Stage 2: Collaboration

While stage 1 is only modeling stage, stage 2 witnesses the transition from modeling to collaboration. The importance of collaboration appears in the construction industry clearly, where collaboration enhances the communication and management among all project stakeholders. The type of data required for stage 2 is integrated data and data sharing among

project stakeholders to improve this stage collaborative approach.

3-BIM Stage 3: Integration

Stage 3 is moving from collaboration to integration, which is the main idea behind the BIM concept. At this stage, project stakeholders interact at the same time to generate the optimal construction documents and drawings for each of the project life cycles. BIM models in stage 3 become multi-disciplinary with n-Dimension (nD) models. These models visualize the building from the early concept stage to construction, thus, helping to solve any problems in the early stages.

From the above, the researchers are heading towards the same idea, which is the integration, the last stage to reach what could be called the ideal implementation of BIM. The development of BIM requires different capabilities of people, process, and technology. The existence of different stages of implementation allows BIM to be implemented widely according to the capabilities of each organization. Also, it is a powerful tool that contributes significantly to the study of the current situation of the construction industry in Bahrain and thus helps in the clarity of vision of the trend towards development by taking the next step in the stages of implementation.

2.2.5 BIM dimensions

For any construction project, the need for only full detailed drawing is not enough. The existence of fully detailed drawings with the consideration of project schedule, cost, energy-saving, and even the management during the operation stage is essential to be executed successfully. BIM Model allows this integration with the extension of nD model through the entire project cycle. With the simulation of the whole life cycle of a project, decision making improves, and uncertainties reduced heading the project towards success. The nD model includes 4D, 5D, 6D, and 7D (Brynjolfsson and Karathodoros, 2013).

The 4D includes 3D with time schedules. After modeling the whole project, the time needed for each activity is planned and linked accordingly with the previously created 3D model. In this way, the project team will be able to manage the real-time project simulation with the construction of the project.

5D contains three things, the 3D model with the time scheduling and cost estimations. This dimension allows the project team to check the allocation of the budget over time with the link to the full detailed 3D model. This enhances the competence of the quantity take-off process and helps in producing an accurate cost estimate for the project.

The 6D is mainly concerned with after the construction stage, which is the operation stage. For facility management purposes, BIM with 6D provides a comprehensive visualization for the whole building that can be used as a store for all necessary information to aid in facility management.

With the increasing importance of energy-saving, the 7D helps the project team and especially the designers to create a design alternative that responds to the requirements for carbon emissions, for instance, in selecting building materials and finishes.

The nD models help project stakeholders to take care of every single detail and hence solve any potential problems in a very early phase before constructing the building in the real environment within the time and budget. With the adaptability and flexibility of BIM, BIM models will be able to respond to different projects according to their requirements.

2.2.6 BIM benefits

The benefits of BIM among companies that used it have been known widely among all industry stakeholders, and the increased rate of BIM adoption helped effectively in creating a reliable and confirmed database of these benefits.

According to the literature review of previous studies, using BIM correctly has the potential to benefit the construction industry in different ways directly and indirectly (Lewis, 2014). Benefits varied between benefits from using BIM software tools in the construction life cycle, benefits associated with the financial aspect, and indirect benefits from both of these areas.

The most numerous benefits in previous studies are organized in Table (2.2) in three categories. Direct benefits are benefits that directly affect the process and its outcome from the design stage until the maintenance stage as a result of using BIM software tools. For example, reduce drawings errors, reduce rework and design changes, minimize. The second category is indirect benefits, which are mainly concern with the benefits gained regarding time, quality, productivity and the management of the process through the whole life cycle. The last category is dealing with the financial gains from using BIM in the construction process.

Unfortunately, the lack of quantitative data from monitoring the real benefit of BIM contributed significantly to the absence of reliable base information on this issue. However, by tracking the return on investment (ROI) of some BIM users, McGraw Hill (2009) reported that about two-thirds of the users witness a positive ROI. Moreover, others said that BIM has a significant contribution in placing them in a better competitive position, which helped them in getting more clients. The McGraw report also showed that some BIM users witness an increase in their productivity due to reduced errors, changes, and conflicts through the construction process (Enegbuma et al., 2015). According to Azhar (2011), BIM can reduce unbudgeted change by an estimated 40%, the time to finish the project by about 7%, and the time to calculate a cost estimation by up to 80%.

Table (2.2): BIM Benefits from Literature Review

Num.	Type	Benefits	References
1	Direct	Reduce drawings errors.	Son et al., 2014; Al-btoush and Haron, 2017; Jin et al., 2017; Hosseini et al., 2016; Barros Neto, 2016
2		Reduce rework and design changes.	Son et al., 2014; Wang et al., 2016; Ahuja et al., 2016; Hosseini et al., 2016; Barros Neto, 2016; Silva et al., 2016
3		Minimize clashing.	Harris et al., 2017; Silva et al., 2016; Zahrizan et al., 2014; Chan, 2014; Morlhon et al., 2015; Ahuja et al., 2016; Panuwatwanich and Peansupap, 2013; Jin et al., 2017
4		Present construction information in an accessible and common way.	Harris et al., 2017; Zahrizan et al., 2014; Lee et al., 2012; Abubakar et al., 2014
5		Accurate production of quantity surveys and cost estimating and time.	Silva et al., 2016 ; Hatem et al., 2018; Chan, 2014; Rokooei, 2015; Acquah and Oteng, 2018 ; Ahuja et al., 2016; Coates et al., 2010 ; Enshassi and AbuHamra, 2016
6		Visualization of construction process and design details.	Chan, 2014 ; Rokooei, 2015; Ding et al., 2015; Acquah and Oteng, 2018; Ahuja et al., 2016; Lee et al., 2012; Kim et al., 2015 ; Jin et al., 2017; Blanco and Chen, 2014 ; Bosch-Sijtsema et al., 2017
7		Provide project analysis.	Rokooei, 2015; Morlhon et al., 2015; Lee et al., 2012; Enshassi and AbuHamra, 2016; Hafez and Fung, 2014; Bosch-Sijtsema et al., 2017
8		Automatically monitoring the integrity of the model and reports.	Ding et al., 2015 ; Acquah and Oteng, 2018
9	Indirect	Reduce project time /lead times.	Son et al., 2014; Ahuja et al., 2016; Enshassi and AbuHamra, 2016; Jin et al., 2017; Bui et al., 2016; Yaakob et al., 2016 ; Wang et al., 2016; Bui et al., 2016 ; Panuwatwanich and Peansupap, 2013
10		Minimizing material wastages.	Silva et al., 2016; Enshassi and AbuHamra, 2016

Table (2.2): BIM Benefits from Literature Review (Continue)

Num.		Benefits	References
11	Indirect	Ensure project coordination.	Harris et al., 2017; Rokooei, 2015; Ahuja et al., 2016; Coates et al., 2010; Kim et al., 2015; Hosseini et al., 2016; Migilinskas et al., 2013; Bosch-Sijtsema et al., 2017
12		Provide Information integration.	Bui et al., 2016; Chan, 2014; Abubakar et al., 2014
13		Reduce uncertainties and conflicts.	Bui et al., 2016; Chan, 2014; Ahuja et al., 2016
14		Work as communication platform.	Ding et al., 2015; Ahuja et al., 2016; Coates et al., 2010; Kim et al., 2015; Abubakar et al., 2014; Liu et al., 2015; Bosch-Sijtsema et al., 2017
15		Improves customer services.	Bui et al., 2016; Acquah and Oteng, 2018
16		Promote collaboration among project teams.	Acquah and Oteng, 2018; Ahuja et al., 2016; Kim et al., 2015; Abubakar et al., 2014; Liu et al., 2015; Blanco and Chen, 2014
17		Better project management in all life cycles.	Silva et al., 2016; Acquah and Oteng, 2018; Coates et al., 2010; Lee et al., 2012; Barros Neto, 2016; Chan, 2014; Enshassi and AbuHamra, 2016; Ding et al., 2015;
18		Improve the productivity.	Son et al., 2014; Al-btoush and Haron, 2017; Ding et al., 2015; Ahuja et al., 2016; Panuwatwanich and Peansupap, 2013; Abubakar et al., 2014; Barros Neto, 2016
19		Increase quality of project.	Yaakob et al., 2016; Coates et al., 2010; Kim et al., 2015; Panuwatwanich and Peansupap, 2013; Silva et al., 2016
20		Streamline construction processes.	Harris et al., 2017; Al-btoush and Haron, 2017
21	Finan	Reduce project cost/rework cost.	Bui et al., 2016; Yaakob et al., 2016 ; Wang et al., 2016; Acquah and Oteng, 2018; Kim et al., 2015 ; Jin et al., 2017

2.2.7 The use of BIM in construction life cycle

The main goal of BIM is to offer support for all project stakeholders throughout the project life cycle. The use of BIM varies according to the role of each project stakeholder in the project considering owners, designers, engineers, contractors, and project managers. Moreover, it depends on which stage of the project BIM is used at. As an overall it can be said that BIM helps project team to collaborate and manage the project successfully (Bui et al., 2016). The following explanation shows the importance of BIM to different stakeholders, whether that is for the owners, designers, contractors, or project managers.

Owners:

The awareness of BIM between projects owners is increasing around the world, and the request of using BIM from owner's side is being one of the most influencing factors to adopt BIM. This is mainly due to the benefits that owners gain from using BIM in their projects.

BIM helps building owners to reduce errors and rework and hence this will help in reducing the cost and time of the construction. It also helps building owners to keep track of their projects, and to make decisions in a fast and easy way (Ahmad et al., 2012). Stanford University Center for Integrated Facilities Engineering (CIFE) figures based on 32 major projects using BIM indicates benefits such as (CIFE, 2007) Up to 40% elimination of unbudgeted change and up to 7% of overall project duration. It can also provide savings in the contract of about 10%.

The benefits from BIM to building owners continue even after the construction of the building, as they can use the data in BIM model during occupancy for maintenance and management of the building (Acquah and Oteng, 2018).

Designers:

The use of BIM from designers' side is presented in three stages: pre-construction, construction and project closure.

In the pre-construction stage designers use BIM for visualizing the building, and this allows them to be able to study different alternatives in order to reach the optimum design concept that satisfies the owner's needs. This process increases the interaction between the designer and the owner and enhances the confidence between them as the owner will be able to see the building as it will be exactly constructed.

BIM model also allows designers to increase their design quality with the feature of clash detection, which helps in showing any clashing between building systems before construction, and hence decreases rework and design changes. Also, the analysis feature offered by BIM helps designers in decision making process, as BIM is used for energy, structural, lighting, and mechanical analysis.

Project managers:

Project Management Body of Knowledge (PMBOK) sets the scope of project managers in the construction industry to cost, time, quality, safety and risk management. Also, project managers are responsible to ensure communication and integration between project's stakeholders in the most efficient way. These responsibilities match the roles of BIM in construction industry, and that is why BIM is treated as management tool more than a technical tool (Rokooei, 2015). As a managerial tool BIM helps project managers to ensure a successful project ending by being able to deliver the project according to its designed specifications, within budget and time, and with owners' satisfaction (Lahdou and Zetterman, 2011).

BIM multi-dimensional models help project managers to draw a comprehensive picture of the project by ensuring the optimum integration

and communication between different disciplines. Moreover, BIM helps in estimating the time and cost of projects by using quantity takeoffs feature (Rokooei, 2015; Morlhon et al., 2015).

One more judicious use of BIM for project managers is the level of the project in 3D with the ability to offer a walkthrough showing the progress in the project day by day (Acquah and Oteng, 2018).

Contractors:

Contractors often care about making sure that the progress of the project will be as it is planned without any error, to avoid rework and thus lose time and money. BIM helps contractors in this issue, as it allows coordination between all stakeholders in the early stages to expose any errors or clashes that would delay the work or because cost overrun or decrease the workers' productivity (Yang and Lin, 2014).

BIM enables contractors to get a full set of information and a comprehensive overview of the whole building (Bosch-Sijtsema et al., 2017). With this they will be able to have details and specifications about every element in the building, which helps them in the management of materials and equipment procurements (Chen et al., 2012). Another use of BIM for contractors is that it allows them to compare between planned and actual workflow of the construction process, thus avoiding any delays in scheduled time or any cost overruns in budget (Brynjolfsson and Karathodoros, 2013).

2.2.8 BIM operating cost and ROI

There are several direct costs associated with BIM, which can affect all members of the design and project teams (Olatunji, 2011):

1. Cost for planning.
2. Personnel: including education and training cost; miscellaneous expenses (travel budget, etc.).

3. Infrastructure: software purchase, software maintenance fees, hardware infrastructure, infrastructure maintenance costs.
4. Process change costs: inefficiency expenses and learning curve.

Return on Investment (ROI) of using BIM not clearly defined; thus, it forms one of the barriers (Ahmed, 2014). Three case studies show the ROI after implementing BIM, and the results varied considerably from 16% to 1,654% (Giel and Issa, 2011). Because of the large data spread, it is hard to conclude a specific range for BIM ROI. The probable reason for this spread is the varying scope of BIM in different projects. In some projects, BIM savings were measured using “real” construction phase “direct” collision detection cost avoidance, and in other projects, savings were computed using “planning” or “value analysis” phase cost avoidance (Azhar, 2011).

Additionally, it was confirmed that a higher return on investment was achieved on the larger more complex construction projects. Savings will still be realized regardless of the size of the project. However, the magnitude of those savings is directly associated with the scale of the contract (Ibrahim et al., 2016).

2.2.9 BIM adoption and implementation: A global status

BIM adoption is on the upward push; it could be visible that many countries have realized the significance of BIM in the construction industry. However, the adoption of BIM is on different levels according to its maturity in different countries (Silva et al., 2016). Those different maturity levels divided the countries into countries leading the adoption, new-comers, and countries with shallow adoption.

The Nordics – Finland and Norway – are considered as BIM leaders. The first European country that mandated BIM was Finland in 2007 (Masood et al., 2014). Finland has a small construction industry, but it is

very advanced from a technological perspective, this enabling environment paves the way for BIM to grow. BIM is the standard for any design in any construction project in Finland with about 70% of the projects done with BIM, and the awareness among industry stakeholders reaches 90% (Travaglini et al., 2014).

For the new-comers, UK, Netherlands, Sweden, Denmark, Germany, and Italy are considered in the way of adopting it (Silva et al., 2016). UK government has published its BIM strategy in 2011 which contributed actively to increase the adoption of BIM, and the adoption rate has increased from 60% to 95% for the last three years. In 2016 BIM has become mandatory for public sector (Silva et al., 2016).

For Asian countries, Malaysia has officially adopted BIM since 2009. First government's project that uses BIM was the National Cancer Institute in Sepang. The project was completed three weeks earlier from the planned completion date (Harris et al., 2017). However, the Malaysian construction industry still lags behind other industries in BIM implementation (Zahrizan et al., 2014).

Countries with low adoption rates include France, China, Middle East countries and developing countries in Africa. In France, BIM adoption is new, with only seven projects in France used BIM in their construction (Gaudin, 2013). BIM diffusion in China is in its early stage, where it is only used in a few huge projects (Guiyou and Li, 2016). However, new governmental initiatives and policies could play an essential role in the increase in BIM usage (Jin et al., 2017).

In Africa, where all countries are under-development, the implementation of BIM is low (Bui et al., 2016). For instance, in Nigeria, although the extent of BIM cognizance is excessive (Ogwueleka, 2015), implementation of the method is taken into consideration to be low as it is

facing significant challenges including contractual problems, employees' inadequacies, and capabilities improvement (Kekana et al. 2014).

2.2.10 BIM adoption and implementation: Middle east status

Al-btoush and Haron (2017) reported that the Middle East has the lowest BIM implementation rate, as the public sector is reluctant to implement its use.

The Dubai Municipality was the first public authority in the Middle East to mandate the use of BIM for most large-scale projects in the Emirate. However, Building Smart (2011), reported on the adoption of BIM in the entire Middle East region concluded that the use of BIM in the Middle East region is not mandatory. Although the survey showed that only 25% of the construction industry professionals are using BIM, it was stated that the use of BIM has improved quality control and productivity and reduced design errors. However, still, the adoption of BIM in the Middle East is low, especially in some countries like Bahrain and Oman (Almuntaser et al., 2018).

2.2.11 Implementing BIM

It's not just governments looking at BIM. As the public sector mandates the process, private industry has shown more interest in working with BIM. Right now, there is no clear consensus on how to implement or use BIM (Azhar et al., 2012). Unlike many other construction practices, there is no single BIM document providing instruction on its application and use (Azhar et al., 2012). Autodesk company, the creator of the essential BIM software packages identified ten necessary steps that help to implement BIM in organizations using published references and guides as follows (Autodesk, 2019):

1. Get to know BIM.: Learning more about BIM will affect the way to achieve it.

2. Communicate the change to your people: High-level leaders should take a leading role in letting people know the firm is moving to BIM.
3. Account for software and hardware needs: Explore available software, and consider whether your current hardware has sufficient processing power.
4. Develop a change management plan: This plan should document at a high level how your team anticipates BIM changing established workflows, who needs training and when they'll get it, and how you'll support people when they have questions and issues.
5. Start a pilot program, and train the pilot team: the purpose of this point is to capture lessons learned from an initial pilot as it happens.
6. Document preferred processes: It's tempting to try to create standards during or before running a pilot.
7. Cultivate BIM champions: Put BIM champions on every pilot project, and provide them with the additional training and support they need to help teammates adopt BIM.
8. Train and transition other teams: It is essential to provide training to people who are about to begin a BIM project.
9. Integrate with other models: Share BIM models with other firms that are also working in BIM.
10. Expand and innovate with BIM: Communicate the value of BIM to current and potential clients.

Using published references and guides for implementing BIM standards and best practices such as these is a good starting point, but there is no established road map that will fit the situation of every organization.

2.3 Structural Equation Modeling Method (SEM)

2.3.1 Introduction

Structural Equation Modeling (SEM) is one of the most popular statistical techniques used to deal with linear relations in multivariate data mainly in the social sciences (Hoyle, 2012). Although SEM can be interpreted in various manners, the widely understood interpretation is that it is a combination of multiple regression or path analysis and factor analysis (Ding et al., 2015). This combination infused structural equation modeling the critical advantage of examining several dependence relationships at the same time. So that what distinguishes it from the rest of multivariate techniques such as factor analysis, multiple regression, multivariate analysis of variance, etc., which can examine only one relationship at a time (Hair et al., 2014).

SEM is a powerful technique that combines latent constructs with observable variables forming a path model. Relationships in path models can be examined by applying Confirmatory Factor Analysis (CFA) and regression using SEM. In this section, essential elements of SEM, its uses, the sample size required, how to define a model to be tested by SEM and ways of assessing SEM models will be presented.

2.3.2 SEM definition

SEM is a statistical modeling technique, which is mostly used in the behavioral sciences. Hair et al. (2014) defined SEM as a group of statistical models that attempt to study the relationships between various variables. SEM is a confirmatory technique; thus, it is used to determine whether a particular model is valid, rather than to create a suitable model. SEM models are mainly concerned with theoretical constructs, and thus it is constructed from unobservable (latent) constructs, which are hypothesized

concept that can be explained by measurable variables. Measurable variables are collected through surveys, tests, and observational methods (Ngowtanasawan, 2017). Thus, all structure equation models are differentiated by being able to test observed and unobserved multiple and interrelated relationships between variables within a model and being able to estimate process errors (Hair et al., 2014).

SEM includes a measurement model and the structural model. A measurement model measures the observable variables, while the structural model measures the relationships between latent variables (Chen et al., 2016).

2.3.3 Graphical representation of structural equation models

Structural equation models are represented by a graphical model called the path diagram (Hox, J. J., and Bechger, 1998). Between SEM users, path diagram has become the selected and the only method for visualizing statistical models. Path diagrams are a more precise and more efficient way of drawing the dependences among multivariate data, not like the algebraic system where the dependencies are shown by equations (Hoyle, 2012).

Hence the benefits of path models appear not only as a visualizing tool and a way to help in drawing a model but also as a communication tool between researchers. For this, many softwares have appeared to help in creating path models for SEM like for example Analysis of Moment Structure (AMOS), Environmental Quality Standards (EQS), and LInear Structural RELations (LISREL), these programs have met the desirability of users for their ease of use and accuracy.

In path diagrams, latent variables (also called constructs, factors or unmeasured variables) are variables that cannot be measured directly and are represented by a circle or ellipse node, while observed variables (also called measured, manifest variables, or indicators) are directly measured and represented by a rectangle or a square node. Error is also added as a latent construct represented by a circle node with letter e inside.

To connect these nodes, two types of arrows are used with different indications. A single headed arrow indicates that the tail of the arrow causing the variable at the arrow point means starting from the independent variable and ending at the dependent variable. A double-headed arrow indicates covariance or correlation linking two variables. Statistically, the single-headed arrows or paths represent regression coefficients and double-headed arrows represent covariance.

In order to distinguish between latent constructs other terms are used, namely, exogenous and endogenous constructs. Exogenous is the independent latent constructs, indicated by factors outside of the model. In path diagrams for exogenous constructs, no headed arrows are pointing towards it. On the other hand, an endogenous construct is the latent dependent variable and will have an arrow pointing to it from any exogenous variables (Hair et al., 2014). As a result, exogenous and endogenous variables can be in two types, latent and observed (Hoyle, 2012).

To help in differentiating between endogenous and exogenous constructs, for exogenous constructs are usually referred to as X variables, whereas endogenous construct indicators are usually referred to as Y variables. Figure (2.2) is an example showing the graphical presentation of a path model in SEM with three latent factors and four observed (measured) variables.

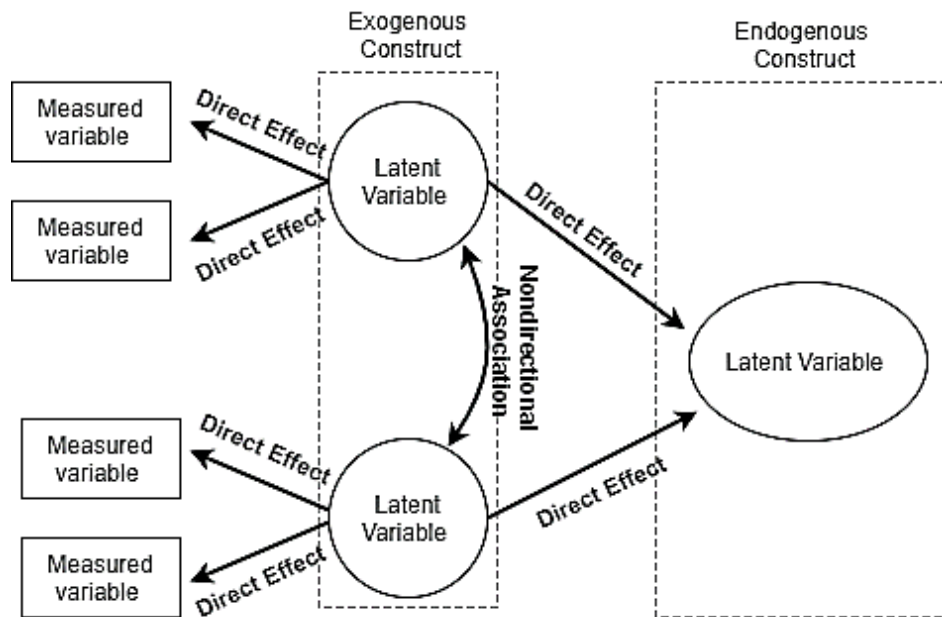


Figure 2.2: SEM Path Diagram

2.3.4 Types of SEM models

To illustrate the theory in an easy way the best manner is to construct a model (Hair et al., 2014). A theory could be drawn from previous experiences, studies or practices, in order to create a diagram that not only studies the effect of independent variables on dependent variables but also draw a logical sequence for these relationships (Hoyle, 2012). In SEM terminology there are two types of models, the measurement model, and the structural model, both together form a complete SEM model.

The measurement models

The measurement model (also called the outer model) study the relationship between the latent construct and the measured variables that are used as an indication for it. This type of dependence relationship is illustrated by a single-headed arrow connecting measured variables with unmeasured variables in the path model.

The structural model

The structural model (also called the inner model) study the relationship between latent constructs. The study of the structural

relationships between latent constructs answers whether such relationships exist or not. If it exists, an arrow is drawn; if not, then no arrow is drawn. Two types of relationships are possible among constructs: dependence relationships and correlational relationships.

Figure (2.3) is an example showing the visual of representation measurement and structural model relationships in a simple SEM model with three latent factors and four observed (measured) variables.

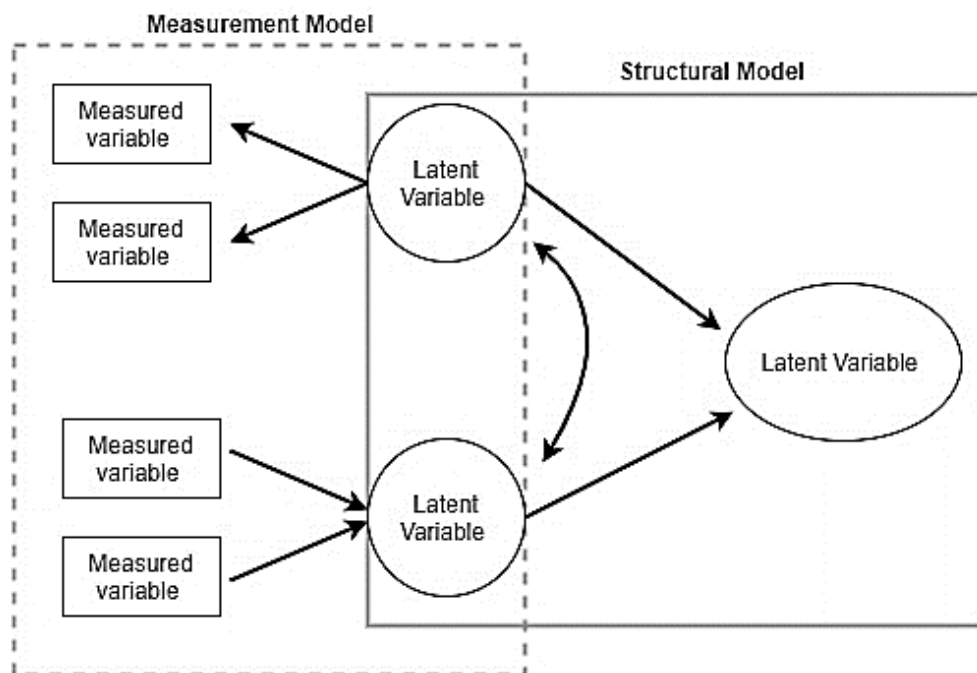


Figure 2.3: Visual Representation of a Measurement and Structural Model

2.3.5 SEM sample size determination

The most important decision to be made when using SEM is the minimum sample size, particularly in the design stage of research. This is mainly for three reasons, first the need to get reliable results, second, the determination of minimum sample size will assist in avoiding waste and low-power investigations, and third the ability of SEM to model complex relationships between multivariate data, which is sensitive to minimum sample size.

The sample size is very critical in SEM more than any other multivariate tests. Especially that small samples are unreliable with statistical algorithms that are used by the SEM program (Hair et al., 2014).

Hair et al. (2014) stated that the sample size in SEM depends on five main things:

- (1) Multivariate normality of the data.
- (2) Estimation technique.
- (3) Model complexity.
- (4) The amount of missing data.
- (5) The average error variance among the reflective indicators.

The researcher has proposed different opinions regarding sample sizes needed when using SEM. Table (2.3) reviews the most critical finding of the researcher regarding this issue.

Table (2.3): Summary of Sample Size Required in SEM

Reference	Year	Sample size rules
Nunnally, 1967	1967	10 cases per variable
Boomsma, 1982, 1985	1982 1985	Minimum sample size of 100 or 200
Bentler and Chou, 1987 Bollen, 1989	1987 1989	5 or 10 observations per estimated parameter
Tinsley and Tinsley, 1987 Anderson and Gerbing, 1988 Ding et al., 1995 Tabachnick and Fidell, 2001	1987 1988 1995 2001	Minimum sample size of 100 -150
Hoogland and Boomsma, 1998 Boomsma and Hoogland, 2001 Kline, 2005	1998 2001 2005	Sample size of 200

Table (2.3): Summary of Sample Size Required in SEM (Continue)

Reference	Year	Sample size rules
Powell and Schafer, 2001	2001	Found that sample sizes varied from 25 to 9,600.
Kline, 2005	2005	For multi-group modeling, the rule of thumb is 100 cases/observations per group.
Fan and Fan ,2005	2005	1- Larger sample sizes yielded higher values of statistical power. 2- Sample sizes below 100 with relatively weak linear slopes.
Hair et al., 2014	2014	1- Minimum sample size—100: Models containing five or fewer constructs, each with more than three items (observed variables) and with high variables communalities (0.6 or higher). 2- Minimum sample size—150: Models with seven constructs or less, modest communalities (0.5), and no under identified constructs. 3- Minimum sample size—300: Models with seven or fewer constructs, lower communalities (below 0.45), and/or multiple under identified (fewer than three) constructs.

As a result of reviewing the previous studies, most of the researchers agreed on a minimum sample size of 200. So, a larger sample size is always needed for a stronger model result.

2.3.6 Computer software

To perform SEM, various commercial statistical programs' packages are available such as AMOS, EQS, Mplus, and LISREL. Those softwares form an easy tool for researchers to draw path diagrams, and input the data for analyses (Hoyle, 2012). Each of these softwares has unique features that distinguish it from others; however, they all share the same core

analytic features. Table (2.4) is a review of the uses and functions of softwares that are used in SEM models.

Table (2.4): SEM Software Comparison

	Uses	Main Features	Source
LISREL	• Structural equation modeling. • For data manipulation. • For hierarchical linear and non-linear modeling. • For generalized linear models. • For generalized linear models of multi-level data.	• First SEM program and the most widely used. • LISREL is packaged as a suite of applications. • Can be applied in different situations (i.e., cross-sectional, experimental, quasi-experimental, and longitudinal studies).	Hoyle, 2012 Jöreskog and Sörbom, 1996 Hair et al., 2014
EQS	• Regression, • Factor analysis, • Test structural models • Management tasks, for example conditional case selection, and variable labeling.	• Widely available program. • Ease of use. • Contains a large number of different statistical methods. • Provides a wide range of graphical and analytic procedures. • Reports maximal, model-based, and greatest lower-bound reliability coefficients.	Hoyle, 2012 Hair et al., 2014

Table (2.4): SEM Software Comparison (Continue)

	Uses	Main Features	Source
Amos	• Structural Equation Modeling. • Path analysis • Confirmatory factor analysis.	• A module in SPSS • User-friendly program • The first SEM programs to use a graphical interface with no use of syntax commands or computer code.	Hair et al., 2014 AMOS, 2016
M plus	• Estimates regression, path analysis, exploratory and confirmatory factor analysis (EFA and CFA), structural equation (SEM), growth, and discrete- and continuous-time survival analysis models.	• Has the ability to analyze cross-sectional, longitudinal data, single-level, and multilevel data. • Has the capabilities for Monte Carlo simulation studies.	Mplus, 2018

After reviewing several different aspects of the most popular SEM softwares, it is noticeable that the softwares are sharing multiple features, especially that developers of these softwares are seeking to keep pace with the evolution. Now, it mainly depends on the researcher to choose which software to use. Hoyle, 2012 stated that the choice of the software depends on three main points: the familiarity of the researcher with the used software, types of models tested, the input method whether it is graphical or textual.

2.3.7 SEM model assessment

In order to answer the fundamental question:” Is the model valid?” a model assessment test or called “model fit “is done. With a large number of tests for model assessment, the choice of the technique that the researcher finds it clear and suitable for the research become the right decision especially with the lack of consensus of the researcher to choose one way only (Hooper et al., 2008).

Model assessment in SEM consists of three steps: starting with measurement model assessment; then structural model assessment; and finally ends with assessing the overall SEM model.

a. Assessment of measurement model

Confirmatory Factor Analysis (CFA)

As mentioned before the measurement model consists of the latent constructs and its measured indicators. The validating procedure of the measurement model is called the Confirmatory Factor Analysis (CFA) (Chen et al., 2016). CFA is a particular form of factor analysis that is performed for all latent constructs before the formulation of the structural model (Ahmad et al., 2016). The main reason for using CFA is to test the validity, reliability and the overall fit of the measurement model (Lee et al., 2015).

CFA is applied by measuring the factor loading for each indicator, and an indicator that has low factor loading will be considered not fitting the measurement model and must be removed from the model (Zainudin, 2014). Table (2.5) outlines the acceptable measurement for factor loading.

Table (2.5): Measurement for Factor Loading

Source	Measurement for Factor Loading
Hair et al. ,1998	Factor loading greater than 0.5 is considered very significant.
Hair et al., 2014	Although factor loadings of ± 0.30 to ± 0.40 are minimally acceptable but 0.50 or higher, and ideally 0.70 or higher generally considered necessary for practical significance.
Zainudin, 2014	Any factor loading less than 0.6 and an R^2 less than 0.4 should be deleted.
Hong et al., 2016	The minimum acceptable factor loading is 0.5.
Chen et al., 2016	Indicators with factor loading less than 0.45 are removed.
Ahmad et al., 2016	The items that have factor loading below 0.60 should be deleted.
Ngowtanasawan, 2017	The factor loading values lower than 0.4 would be eliminated.

b. Assessment of structural model

After achieving the acceptance of the measurement model and it is now reliable and valid, then the next step is to test the structure model to make sure that it is valid and dependable as well. Note that if the measurement model does not reach the needed level of reliability and validity, then the structural model assessment cannot be performed.

Hair et al., 2014 stated that the structural model is considered valid if the parameter estimates are:

1. Statistically significant, and
2. Nontrivial.

c. Overall SEM model assessment

The goodness of Fit (GOF) tests the values of covariance for the observed and the estimated matrices and indicates their similarities (Hair et al., 2014). According to previous studies, a model reflects a good fit by satisfying the constrained values of the statistics shown in Table (2.6):

Table (2.6) Goodness of Fit Tests Required Values

GOF index	Value	Sources
Chi -square (χ^2)	≤ 3.0	Hair et al., (2009)
GFI (goodness of fit index)	> 0.85	Maruish, (2004)
PGFI	≥ 0.5	Mulaik et al., (1989)
RMR	≤ 0.1	Garson, (2014)
TLI	≥ 0.9	Bentler and Bonett, (1980)
RMSEA (root mean square error of approximation)	< 0.10	Steiger, (2007)
CFI (comparative fit index)	> 0.90	Hair et al., (2009)
AGFI (adjusted goodness-of-fit index)	> 0.8	Maruish, (2004)

d. SEM approaches

There are three main approaches to SEM:

- 1- Covariance-based approach (CB-SEM).
- 2- Partial Least Squares (PLS).
- 3- Component-based SEM known as Generalized Structured Component Analysis (GSCA).

The following Table (2.7) compares the different characteristics of the three approaches.

Table (2.7): Comparison of SEM Approaches

Criterion	CB-SEM	PLS	GSCA
Uses	Confirming or rejecting theories through testing of hypothesis (parameter oriented).	Estimates linear relationships between constructs. Used when research objective is exploratory (prediction use).	To calculate the overall measures of model fit by offering a global least square optimization criterion.
Applied field	Social science.	Behavioral sciences, marketing, organization, management information system and business strategy.	-
Data distribution	Normal distribution.	No assumptions about data distribution.	Non-linear latent variables.
Approach	Covariance based.	Variance based.	-
Number of latent variables	Max. 8 .	Any number.	-
Number of observed variables per construct	3-4 minimum to meet requirements.	Unlimited number of indicators One or more (decrease consistency with large).	Unlimited number of indicators.

Table (2.7): Comparison of SEM Approaches (Continued)

Criterion	CB-SEM	PLS	GSCA
Accuracy	Highest parameter accuracy and consistency.	Not consistent and show higher variability in coverage.	Less than CB-SEM.
Sample size	Large sample (more than 250 observations).	Small sample (100 to 200).	-
Suitable software applications	AMOS, EQS, LISREL and MPlus.	PLS-Graph, VisualPLS, SmartPLS, and WarpPLS.	VisualGSCA or GeSCA.
Model complexity	Large model (>100 indicator problematic).	Can deal with large models.	-
Sources	Reinartz et al., 2009 Wong, 2013 Rigdon et al., 2017 Becker et al., 2018	Reinartz et al., 2009 Wong, 2013 Afthanorhan et al., 2016 Rigdon et al., 2017	Wong, 2013 Afthanorhan et al., 2016

2.4 Review of Models from Previous Studies

Through the literature search and readings, BIM is an area that is hard to explain easily. Firstly, because the BIM concept has various meanings for various parties, secondly, because it is multidimensional (Chen et al., 2016; Lindblad and Vass, 2015). Because of this multidimensional nature, the establishment of a comprehensive BIM adoption model may be difficult. Moreover, the reliability and the validity of the models continue to be questionable due to the lack of solid justifications (Chen, Dib, and F. Cox, 2014).

A review of previous studies shows no shortage of BIM frameworks, proposals or models (Chen et al., 2016). However, the problem is that those studies have looked to BIM from a limited perspective without considering its multidimensional nature (Ahuja et al., 2016). Hence, the resulted models lack a comprehensive view of the subject. In this research, the researcher studied the adoption models in the literature. However, it is found to be only limited to one BIM adoption model. For this reason, the researcher thought of extending the review of models in the literature to include all BIM related models especially the ones used SEM in their data analysis plan in order to have the research same statistical technique.

Some studies focused on one dimension of BIM. Taking the technological aspect of BIM as an example, the Technology Acceptance Model (TAM) is the most widely used model to investigate technology acceptance behavior. Davis (1989) created the famous TAM and has been widely used in studying consumers' behavioral acceptance of technologies such as Smartphones, LED TV, and other innovative devices. In the field of BIM (Lee et al., 2011; Lee et al., 2015; Pang and Zhai, 2018; Acquah and Oteng, 2018) used TAM theory to determines

user acceptance of BIM from an information technology perspective. The acceptance of users is measured by factors including perceived usefulness (PU), perceived ease of use (PEOU), attitudes towards using (ATU) and behavioral intentions (BUI). However, TAM model rise some limitations such as it looks to BIM from one perspective only such as technology; it is based on individual beliefs and expectations; hence bias and errors can occur, it does not consider external factors; and it lacks flexibility in the model factors.

Davis (1989) Innovation Diffusion Theory (IDT) model is another example of models that studied one dimension of BIM. The model shows the diffusion of the innovation and the framework of the determinants of customer response to an innovation. In this model, BIM is specified as an innovation (Ngowtanawan, 2017). IDT model includes adopter, BIM, firm, and environment characteristics. However, also with some limitations like it does not integrate the overlapping effects of the different contexts and domains and ignores cultural norms, IDT model is not comprehensive enough to study BIM adoption in the Bahraini construction industry.

In some studies, two models are combined. For example, TAM is combined with other theories like the "IDT". Xu et al. (2014) and Kim et al. (2015) used the combined TAM and IDT model to study BIM. Combining TAM and IDT gives a more comprehensive perspective to the BIM technology diffusion. However, the model explains the process for technologies to diffuse after being accepted and does not consider the continuity of use after acceptance; these limitations prevented this model from being the suitable model for Bahrain situation.

For more comprehensive perspective some researches combined three dimensions of BIM, like Technology-Organization-Environment model (TOE) (Wang et al., 2016; Ahuja et al., 2016), TOE is based on TAM and DOI by (Tornatzky et al.,1990). TOE combines three domains: technology, organization, and environment those are the main elements that are affecting firms' adoption of new technology. The TOE theory is distinctive from other adoption theories in that it accounts for the influence of technological characteristics. However, the factors outside of the TOE framework were not examined, and this affects the flexibility of the model.

BIM perception model also studied BIM from three different dimensions (Enegbuma et al., 2015; Enegbuma and Ali, 2013). The model draws its structure from challenges facing BIM adoption, people, process and technology perceptions. However, it ignores other factors like organization, risk, and cost. Moreover, it studies the adoption from the three aspects only, hence factors outside the framework were not examined.

Since this research aims to come up with a comprehensive model that combines all aspects affecting the adoption of BIM, all related BIM theoretical models from previous studies are analyzed as follows in Table (2.8).

Table (2.8): Summary of Models Related to BIM

Model	History	Characteristics	Advantages	Limitations	References
BIM Adoption Model	-	- Focuses on the mediating effect of collaboration on BIM adoption. - Study the perception of industry stakeholders on business process reengineering, collaborative processes and their relationship with BIM adoption.	Assess the connections between business process changes experienced in the construction industry.	The model is designed to be suitable to the adoption stage in Malaysia construction industry (adopted by government and beginning in the local construction industry).	Enegbuma et al., 2016
Technology Acceptance Model (TAM)	A famous model Originally developed by (Davis,1989) and has been widely used in studying consumers' behavioral acceptance of technologies such as Smartphones, LED TV, and other innovative devices.	-A theory that determines user acceptance of an information technology. -TAM hypothesis that the level of success of an information system measured by factors including perceived usefulness (PU), Perceived ease of use (PEOU), attitudes towards using (ATU) and behavioral intentions (BUI). •Revisions to TAM creates TAM2 then TAM3.	Examine the individual's technology acceptance behavior	-Looks to BIM from one perspective only as technology. -Based on individual beliefs and expectations, hence bias and errors can occur. -Dose not consider external factors. -Lack of flexibility in the model factors.	Lee et al., 2012 Lee et al., 2015 Pang and Zhai, 2018 Acquah and Oteng,2018

Table (2.8): Summary of Models Related to BIM (Continue)

Model	History	Characteristics	Advantages	Limitations	References
Innovation Diffusion Theory (IDT)	Rogers (2003) suggests that “diffusion is the process of communicating innovation among members” and defines innovation as “an idea, practice, or objective that is perceived as new by an individual or another unit of adoption”.	-In this model, BIM is specified as an innovation. -The diffusion of innovation model includes adopter, BIM, firm, and environment characteristics. -IDT has four characteristics that determine innovations rate of adoption: relative advantage, complexity, observability, compatibility.	The model shows the diffusion of the innovation and the framework of the determinants of customer response to an innovation.	-Model does not integrate the overlapping effects of the different contexts and domains. -Dominated by the assumption that users adopt new technology to maximize their utility. -It doesn't count for individual's resources or social support to adopt the innovation. -Diffusion research ignores cultural norms.	Ngowtana sawan, 2017
(TAM) with (IDT)	- IDT is a theory to recognize the motivators of an innovation use (Robertson and Antignou,1991). -IDT helps to understand how and why a certain innovation is diffused into a certain system (Rogers ,2003).	-TAM and the IDT models are mostly used test the acceptance and diffusion of information technologies. -TAM and IDT factors are closely related. -TAM and IDT often complement each other. •IDT has five elements Relative Advantage, Compatibility, Complexity, Trialability, and Observability.	Combining TAM and IDT gives a more comprehensive perspective to the technology diffusion.	-IDT explains the process for technologies to diffuse after being accepted. -IDT model does not consider the continuity of use after acceptance. -IDT applied at individual and organizational levels only.	- Xu et al., 2014 - Kim et al., 2015

Table (2.8): Summary of Models Related to BIM (Continue)

Model	History	Characteristics	Advantages	Limitations	References
Technology-Organization-Environment model (TOE)	TOE is based on Technology Acceptance Model (TAM) and Diffusion of Innovation (DOI) by (Tornatzky et al.,1990).	-TOE combines three domains: technology, organization and environment. -The TOE has been provided for the technology on organization level.	The TOE theory is distinctive from other adoption theories in that it accounts for the influence of technological characteristics.	-TOE model must be expanded for including the firms' BIM adoption. For: a- Cost and ROI. b-Risk preference of project leader. - Factors outside of the TOE framework were not examined.	Wang et al., 2016 Monko et al., 2017
BIM Perception model	-	The model draws its structure from challenges facing BIM adoption, people process and technology perceptions.	Assess the effects of people, process and technology on BIM adoption.	-Ignores other factors like organization, risk and cost. -Study the adoption from the aspects only, hence factors outside the framework were not examined.	Enegbuma et al., 2015
BIM perception model combined with Strategic IT in Construction	-	Builds on BIM perception in the construction industry towards effective BIM penetration incorporating strategic IT application (Betts, 1999), technology acceptance model, business process re engineering and collaborative construction.	The research model encompasses research gaps on BIM perceptions and the effects on penetration for construction industries adopting building information modelling.	-The constructs are unperceived. -The model is not tested yet; it is just a theoretical model. -The model is designed to be suitable to the adoption stage in Malaysia construction industry.	Enegbuma and Ali, 2013

Table (2.8): Summary of Models Related to BIM (Continue)

Model	History	Characteristics	Advantages	Limitations	References
Building Information modeling maturity model (BIMM)	-	- Initial 27 BIMM indicators were broken down into 53 specific BIMM attributes. - One common dimension is information management, which is a direct measurement of the delivered information and product. -The three major dimensions is combined in the model, information management, process management, and technology management.	Offers insights into the complex relationships among the causal factors and BIMM.	-The study is confined to the United States and might not be able to be generalized directly to other countries. -Potential response bias based on the respondents' assessment of the BIMM level. - Results of this study needs further confirmation.	Chen et al., 2016
Behavior intention of BIM utilization model	-	-Five factors contributing to decisions of adopting (or not) BIM. -These five factors are: knowledge structure, BIM capability, management support, motivation and technical defects of BIM.	Reveal the underlying mechanism of architects' BIM adoption which overcomes the limitations of descriptive orient studies.	-Didn't consider the relationship between management support and motivation. -The model is studied only on one group of professionals (architects).	Ding et al., 2015

2.5 Literature Summery

This chapter has presented an overview of the two main concepts in this study which are BIM, and SEM. The literature aimed to give a background about BIM and its definition to come up with a comprehensive explanation based on previous definitions suggested by other researchers. Also, it discussed BIM maturity levels and what characterized each of them and how BIM is different than the traditional method used in the construction industry. Moreover, the literature gives background about SEM, explaining its concept, definition, softwares, assessment methods and approaches. Finally, all related BIM theoretical models from previous studies are analyzed by discussing their history, characteristics, advantages, and limitations.

CHAPTER THREE

REASEARCH MODEL DEVELOPMENT

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CHAPTER THREE

REASEARCH MODEL DEVELOPMENT

3.1. Introduction

Most previous studies focused on the use of descriptive statistical analysis for studying the adoption of BIM; however, this way of analysis does not provide comprehensive results for the adoption situation. It only provides a simple description of the sample data. As a result, this way of analysis does not provide statistical testing of hypothesis, concerning industry practitioners' populations' (Ding et al., 2015).

To draw a complete result for the adoption of BIM to a whole population, an inferential statistic is used, and a theoretical model is drawn to test the hypothesis of the research. The theoretical model will provide a way to examine the indicators that are affecting the adoption of BIM in practice based on real data from the current situation. Also, this is the aim of this research to build an SEM to identify the key indicators affecting the adoption of BIM in the Bahraini construction industry.

Therefore, the development of the theoretical research model will be discussed in order to explain the bases of the development, the theory behind it, indicators' collection and the bases of their grouping. Therefore, a mini Delphi method (one round) is used to develop a final set of those indicators. Finally, the review of the final conceptual model of the research to prepare it to the next stage of data collection in Chapter four.

3.2 The Proposed BIM Adoption Model Overview

The results of analyzing the theoretical models in Table (2.8), showed limitations in three main areas: first regarding BIM nature; second BIM levels of maturity and the level at which it is adopted in the construction industry in different countries; third regarding the formulation of the model.

Limitations regarding BIM nature include the lack of a model which study BIM from all its related aspects considering its multidimensional nature (Chen et al., 2014). Regarding BIM adoption levels of maturity, each country has its unique situation, whether it is at zero, first, second, or third BIM level, and hence, the adoption model needs to consider these levels. Furthermore, the level at which it is adopted should be considered whether it at individuals, organizational, projects or market level. For the limitation regarding the formulation of the model, some models are not considering external factors. Moreover, lack of flexibility in the model factors; studying the adoption after being accepted; being suitable to the adoption stage in certain countries; finally, some models need further confirmation.

These limitations impose the need for a unique model that will meet the current situation of BIM in the Kingdom of Bahrain and the multidimensional nature of BIM. The reasons for creating a new model are as follows:

1- Reasons regarding BIM:

- BIM is a multidimensional concept and not limited to the technology dimension only, which lacks the reviewed models as most of them look to BIM from a technological aspect only.
- The implementation of BIM requires a change in all aspects of a business, such as technology, process, and people (Chen et al., 2016).
- Lack of flexibility in the reviewed models, where any factor outside the model primary constructs cannot be added.

- Most of the models ignored external factors affecting BIM adoption.

2- Reasons regarding the Bahraini construction industry:

- The adoption of BIM in the Kingdom of Bahrain is not apparent, especially with the lack of published studies regarding this issue.
- Many informal short interviews carried out by the researcher to solicit industry professionals' opinions before conducting the survey, which shows the absence of BIM use in the construction industry.
- Importance of investigating BIM surrounding environment, to make sure it will enable the adoption.
- The study goal is to examine the BIM adoption at macro-level including private and governmental sectors with different professionals, while most of the reviewed models studied BIM on an organizational or individual level.

Currently, there is no international BIM adoption model (Ahmad et al., 2012), especially as the level of adoption is different, the competencies and skill pool, the used software packages, and the barriers are different. Therefore, a question emerged, how we can create a BIM adoption framework to suit the situation of the Kingdom of Bahrain? The objective of this research is to identify the indicators that would influence the adoption of BIM in the Bahraini construction industry. Using SEM, a model is developed that establishes relationships between these indicators by testing the professional's actual perception toward those important indicators and puts forward hypotheses that would assess the significance of those indicators to the adoption issue (Hair et al., 2014). Finally, when the results are evaluated, the indicators affecting BIM adoption in the Kingdom of Bahrain can be generalized for the construction industry in both governmental and private sectors for a successful and smoother transition.

This section starts with the process of identifying the initial adoption indicators, passing through the mini Delphi method (one round) in order to reach the final set of indicators and grouping them into different categories. Finally, the final causal model is formulated to come up with the research hypothesis.

3.3 Adoption Indicators Identification

The first stage of formulating BIM adoption model is to do a comprehensive literature review of the existing literature related to BIM in order to determine all related indicators (Mohammad et al., 2018; Megahed, 2015; Ahuja et al., 2016).

A total of 222 papers are explored for the primary search as stage one. First, these papers are exported to Mendeley software to remove duplicates. The second stage, the papers are reviewed, and unrelated papers are eliminated. In the third stage, the remaining studies are subjected to a detailed assessment in order to extract all indicators related to BIM. This process leads to 92 papers pass all previous stages.

The 92 papers published over the past 9 to 10 years have point out a number of potential indicators that impact BIM adoption such as (Al-btoush and Haron, 2017; Yaakob et al., 2016; Hatem et al., 2018; Zahrizan et al., 2014; Won and Lee, 2010; Chan, 2014; Enegbuma et al., 2015; Kim et al., 2015; Panuwatwanich and Peansupap, 2013; Arayici et al., 2011; Lee et al., 2015; Jin et al., 2017; Sunil et al., 2017). These indicators involved; drivers, barriers, challenges, constraints, critical success factors, initiatives, and other issues that are associated with BIM aspects.

However, the researcher still does not understand what indicators make the industry adopt BIM. Hence, the focus of this study is to find out what are the leading indicators that drives Bahrain's construction industry to adopt BIM. In

the fourth stage, a comprehensive mind map is created to combine all indicators from the 92 reviewed papers. The main goal of this process is to come up with a list of indicators that covers all aspects of BIM, especially those indicators that have appeared in researches done in different countries with different adoption levels. The result is a primary indicators list with 155 indicators (Appendix 1). Then these indicators are subjected to a qualitative examination to review the idea that each indicator is describing, and indicators revolved around the same ideas are joined. This fifth stage offers a reduced indicators list that introduces 128 indicators.

The next stage is grouping these indicators into categories. Grouping helps in organizing conceptual clusters of factors sharing mutual characteristics (Succar, 2009). From the literature review, there is no clear pattern for the grouping of the indicators that to be considered. Through the analysis of categorization from the literature review, six categories are emerged and presented in Table (3.1) under different labels according to different researchers. The six main categories are technology, environment, organization, process, people, and information.

Table (3.1): Categorization of BIM Indicators

Author and Year	Technology	Environment	Organization	Process	People	Information
Enegbuma and Ali, 2013	Technology			Process	People	
Xu et al., 2014	Technology	Recognition from the Government	Organizational Culture		People	
Zahrizan et al., 2014		External Push	Internal Push			
Enegbuma et al., 2015	Technology			Process	People	
Ahuja et al., 2016	Technological context	Environmental Context	Organizational context			
Chen et al., 2016	Technology management			Process management		Information management
Ahmed L. et al., 2017	BIM /innovation	External environment	Internal environment			
Monko et al., 2017	Technology	Environment	Organization		Social	Interoperability
Sunil et al., 2017	Technology			Process	People	Information
Venkatachalam , 2017	Technology			Process	People	

The 128 indicators are classified initially in these six groups. The researcher finds that the sixth group 'Information', could be combined with the 'Technology' group as both of them are mainly concerned with the technical and technological aspect of BIM. Furthermore, there is a need for a new category to appear in order to include indicators that mainly revolve around project delivery methods, types of contracts and regulations (Succar, 2014). These indicators will be under the title 'Policy'. Finally, one indicator is extracted and added to BIM adoption in

order to satisfy the SEM technique requirements for the stage of data collection and analysis which is 'BIM self-efficacy'.

The final result shows 24 indicators in the 'Technology' category, 26 in the 'People' category, 19 in 'Process' category, 10 in 'Policy' category, 22 in 'Organization' category, 26 in the 'Environment', and 1 in 'BIM adoption' category (Appendix 2).

3.4 Mini Delphi Technique

Once the 128 indicators are categorized, the Delphi technique is used to identify and validate the indicators that are most suitable to the situation of the Bahraini construction industry. The Delphi technique is a group confirmation process of the experts that targets direct screening and discussions of a particular subject (Ngowtanasawan, 2017). In this research, the Delphi technique is used for several reasons: first, to reach a consensus on the final list of indicators, second to reduce the number of indicators to be suitable for SEM.

The implementation of the Delphi technique in the research begins with selecting a group of eleven highly experienced engineers and experts in related fields, including:

- Four engineers with more than ten years of experience in the Bahraini construction industry, from the public and the private sector, and
- Seven experts in BIM, from the private sector.

The interviewees are asked to answer a questionnaire consists of two sections in individual interviews conducted by the researcher (Appendix 3).

The first questionnaire section in the "personal profile". It includes questions about the interviewee's names, position title, place of work, how long they have

been working in the construction industry. It also asks the interviews about their awareness and usage of BIM, and in case of using BIM, they were asked to indicate the BIM software that they are using.

Section two is about BIM adoption in Bahrain. It includes two main questions. In the first question, the eleven experts are asked to express their opinion about the 128 indicators with a 5-level Likert scale ranging from "Very inapplicable" to "Highly applicable". In the second question, they are asked to rank the main six categories from most to least influential to the adoption of BIM in the Bahraini construction industry.

The experts are asked to answer a questionnaire in individual interviews without meeting each other. The main emphasis while carrying the interview is to evaluate the indicator according to how far it applies to the Bahraini construction industry's current situation. The final result of the Delphi technique is a definitive list of indicators consensus by all eleven experts (Appendix 4). The list is consisting of fifty-one indicators. Moreover, the list consistent with ranking the categories, where the ranking is as follows: technology; process; people; environment; organization; and policy-category.

However, as the most critical issue before using SEM is that the relevant variables must be chosen and linked together in order to draw a clear conceptualization of the theory (Hair et al., 2014), the researcher makes some adjustments on the chosen indicators list in order to consolidate the BIM adoption theory.

First, the only chosen indicator in the 'Policy' category is divided into two indicators: the availability of regulation, and policy; and the availability of industry standards. Because it is a compound indicator that may lead to an incorrect result when answered. Second, the researcher decides to add two more

indicators in the same category, namely: required project delivery modes; and the increased demand for design and build contracts. It is found that these two indicators contribute to drawing a more precise theory to BIM adoption through 'Policy' category.

The final list of indicators as shown in Table (3.2), contains 54 indicators that are confirmed by the eleven experts and are categorized into seven categories (components), they will be used to formulate a conceptual research model in the next stage.

Table (3.2): Final BIM Adoption Indicators List

Technology	1 Information Format 2 Usefulness of digital transfer of data/information 3 Security of confidential information on project data 4 Visualization 5 Technical competence of staff 6 Technological capability of organization 7 Automation 8 Data richness/ Real-time data 9 Hardware equipment/ Hardware upgrade 10 Observability 11 Uninterrupted power and a strong Internet 12 Awareness of the technology among industry stakeholders 13 BIM libraries
Process	1 Developing data exchange standards 2 Companies' collaboration experience with project partners 3 Standard and rules 4 Collaboration (project) management tools 5 Desire to speed up the design process 6 Communication 7 Shared norms and collective expectations diffused through information exchange activities 8 Contractual sharing norms 9 Leadership of senior management 10 Shared liability between project participants 11 Providing guidance on use of BIM 12 Information Availability and Sharing
People	1 Process and workflow training 2 Qualified cadres and experts to train BIM software 3 Need for innovation, and the diffusion of innovation 4 Supporting individual characteristics 5 Software and technology training 6 Interest in learning BIM 7 level of awareness of BIM and the knowledge about BIM 8 Observable large productivity gain 9 Professional development 10 Project team expectations

Table (3.2): Final BIM Adoption Indicators List (Continue)

Environment	1 Globalization and competitive strategies 2 Market demand 3 International flexibility/adaptability to market 4 Competitive advantages in market (core/unique) 5 Pressure from competitors 6 Influence from partners who have adopted BIM 7 Best practices for Constructability Implementation 8 Comparative advantage 9 BIM benefits 10 Enabling environment
Organization	1 Top management support 2 Performance measures and benchmarking for continuous improvement. 3 Financial resources of organization 4 BIM supporting organizational structure
Policy	1 Regulation, policy 2 Industry standards 3 Project delivery modes 4 The increase of design and Build.
BIM	1 Self-efficacy

3.5 Overview of Indicators Affecting the Adoption of BIM in Bahrain

Based on the previous stages, the final set of indicators influencing the adoption of BIM in the Kingdom of Bahrain contains 54 indicators, divided into seven categories. The following is a brief overview of each category and the adoption indicators related to it.

1- Technology-related indicators:

The technology field is a fundamental part affecting the adoption of any innovative technology (Wang et al., 2016). Technology includes the technological context and its availability and characteristics internally and externally. For example, BIM modeling tools, software, hardware, networks, interoperability, security of confidential information on project data, knowledge of BIM software, reference material and component database, output quality, also the characteristics of visualization and automation (Enegbuma and Ali, 2013; Succar, 2014; Kalinichuk, 2015; Lee et al., 2015; Yaakob et al., 2016). The following list contains indicators under the technology related category:

1.1 Technical competence of staff: the competence and knowledge concerning technical aspects of BIM tools, techniques and computer softwares (Ahmed et al., 2017; Zahrizan et al., 2014; Zakaria et al., 2013).

1.2 Technological capability of organization: this includes the organizations' existing experiences and capabilities in technology related issues (Ahmed et al., 2017; Wang et al., 2016).

1.3 Data richness: it is concerned with organizational activities related to information and data for each construction project, including the creation, collection, processing, storage, distribution, and exchange of information (Chen et al., 2016).

1.4 Automation: automation is essential for construction industry professionals especially for time-consuming and repetitive tasks like measurements, quantity take-offs, clash detection etc. (Sunil et al., 2017).

1.5 Hardware equipment/hardware upgrade: the availability and update of the hardware infrastructure which is suitable for BIM adoption (Chen et al., 2016; Lee et al., 2015; Jin et al., 2017).

1.6 Awareness of the technology among industry stakeholders: BIM awareness amongst project participants and stakeholders, may affect the success of adopting it (Ahmed et al., 2017; Yaakob et al., 2016; Ahuja et al., 2016; Abubakar et al., 2014; Hong et al., 2016).

1.7 Information format; each organization professionals always prefer their structure of information and documentation, which may cause some consistency problems, but with BIM all information is in the same format (Sunil et al., 2017).

1.8 Usefulness of digital transfer of data: digital data management, which avoids the problems from the traditional way of working (Nikas et al., 2007; Monko et al., 2017).

1.9 Visualization: the detailed 3D model visualization feature of BIM can be very useful for understanding of the design and features of the building and visual clash detection analysis (Sunil et al., 2017).

1.10 Security of confidential information on project data: Stakeholders require the security of confidential data, which is available in the BIM model (Yaakob et al., 2016; Hatem et al., 2018).

1.11 BIM libraries: developing office BIM templates, and libraries (Zahrizan et al., 2014).

1.12 Uninterrupted power and a strong Internet: The available uninterrupted power and a strong Internet in the Kingdom of Bahrain (Hatem et al., 2018).

1.13 Observability: the easier it is for individuals to see the results of an innovation, the more likely they are to adopt it (Wang et al., 2016).

2- Process-related indicators:

The collaboration process is one of the essential processes in the construction industry, mainly that the process of building includes various professional areas. The process field includes the management of the collaboration process, management of the group of people who procure, design, construct and manage. Also, it includes BIM requirements, availability and use of execution plans by different stakeholders towards such BIM process requirements, availability (Succar, 2014; Kalinichuk, 2015). The following list contains indicators under the process related category:

2.1 Developing data exchange standards: setting data exchange standards through the use of BIM among project stakeholders (Chan, 2014).

2.2 Companies' collaboration experience with project partners: collaboration between stakeholders is considered the key for a successful practice; hence the effective collaboration in BIM-involved projects may drive its adoption (Jin et al., 2017).

2.3 Standards and rules: systems of rules of conduct or methods of practice by the government (Soon et al., 2013; Yaakob et al., 2016; Hatem et al., 2018; Zahrizan et al., 2014; Ahmed et al., 2017; Chen et al., 2016; Sunil et al., 2017).

2.4 Collaboration (project) management tools: collaboration is an essential requirement for the construction industry, which needs to be very well managed (Zahrizan et al., 2014; Arayici et al., 2011; Lee et al., 2015).

2.5 Desire to speed up the design process: the need to speed up the design process for faster project completion (REIZGEVIČIUS et al., 2015).

2.6 Communication: the desire for better, improved communication among project stakeholders (Soon et al., 2013; Yaakob et al., 2016; Hatem et al., 2018).

2.7 Shared norms and collective expectations diffused through information exchange activities: through formal education; associations participation; conference communication; and professional consultation (Ahmed et al., 2017; Zahrizan et al., 2014).

2.8 Contractual sharing norm: contracts clearly outline norms for how members will and should interact with one another (Ahmed et al., 2017).

2.9 Leadership of senior management: senior leadership encouragement for the adoption of new methodologies; workflow changes; and technological innovation (Yaakob et al., 2016; Zahrizan et al., 2014; Won and Lee, 2010; Sunil et al., 2017).

2.10 Sheared liability between project participants: proper sharing of the risks and liability between the parties of construction contract (Zahrizan et al., 2014).

2.11 Providing guidance on the use of BIM: the availability of BIM User Guide (Chan, 2014).

2.12 Information availability and sharing: BIM has significant potential in eradicating the chronic issue of lack of data and information availability (Sunil et al., 2017).

3- People-related indicators:

This part includes human interaction with the BIM system, professional BIM roles, challenges with availability of BIM skills, and learning and training opportunities. People culture in any organization influences the rate of BIM adoption (Enegbuma et al., 2014; Zakaria et al., 2013). The following list contains indicators under the people related category:

3.1 Process and workflow training: the existence of standard workflows training can help fostering acceptance of the new processes, and provide insight to the challenges in modifying processes (Al-btoush and Haron, 2017; Yaakob et al., 2016; Hatem et al., 2018; Zahrizan et al., 2014; Won and Lee, 2010; Chan, 2014; Enegbuma et al., 2015; Kim et al., 2015; Panuwatwanich and Peansupap, 2013 ; Arayici et al., 2011 ; Lee et al., 2015; Jin et al., 2017; Sunil et al., 2017).

3.2 Qualified cadres and experts to train BIM software: the availability of a large number of training providers (Hatem et al., 2018).

3.3 Need for innovation, and diffusion of innovation: exposure to innovative technologies, and the willingness to innovate (Ahmed et al., 2017).

3.4 Supporting individual characteristics: industry professionals with adequate personal characteristics such as necessary computer skills, enjoyment of learning, self-confidence and commitment to the use of IT (Panuwatwanich and Peansupap, 2013).

3.5 Software and technology training: providing training courses on BIM tools and softwares (Al-btoush and Haron, 2017; Ahmed et al., 2017; Zahrizan et al., 2014; Chan, 2014; Enegbuma et al., 2015; Kim et al., 2015; Panuwatwanich and Peansupap, 2013; Arayici et al., 2011; Lee et al., 2015; Jin et al., 2017; Sunil et al., 2017).

3.6 Interest in learning BIM: growing interest in the learning and the use of BIM for stages of a building's life cycle (Ahmed et al., 2017).

3.7 Level of awareness of BIM and the knowledge about BIM: to what extent project stakeholders are aware of BIM, and the effect of the level of awareness on implementation (Zakaria et al., 2013).

3.8 Observable large productivity gain: BIM adopters saw a huge significant productivity gain, hence encourage others to adopt it (Panuwatwanich and Peansupap, 2013).

3.9 Professional development: the desire by individuals, organizations, and markets for professional development (Panuwatwanich and Peansupap, 2013).

3.10 Project team expectations: managing the expectations towards BIM, which represent the project team's beliefs and intent towards the model and the process (Poirier et al., 2015).

4- Environment-related indicators:

Environment-related indicators will study the effect of all external forces on the adoption of BIM (environmental context). Including government role, client requirements, global changes and requirements, industry characteristics and competition (Zahrizan et al., 2014; Ahuja et al., 2016). The following list contains indicators under the environment related category:

4.1 Globalization and competitive strategies: increased competition and competitive pressure due to globalization, push construction industry markets to take more effective technology to improve its core competitiveness (Ahmed et al., 2017; Wang et al., 2016).

4.2 Market demand: international and national market demand pushes towards BIM adoption (Ahmed et al., 2017; Silva et al., 2016).

4.3 International flexibility/adaptability to market: the ability to adopt any changes in the international market (Ahmed et al., 2017).

4.4 Competitive advantage in the market: the desire of gaining core, and unique competencies in the market (Ahmed et al., 2017).

4.5 Pressure from competitors: the pressure from competitors who adopted BIM (Ahmed et al., 2017).

4.6 Influence from partners who have adopted BIM: the influence of collaborators or other stakeholders in the construction industry (Ahmed et al., 2017).

4.7 Best practices for constructability implementation: BIM is now known for being the best process for building construction (Ahmed et al., 2017).

4.8 Comparative advantage: comparative advantage refers to the ability of a company to produce a particular good or service at a lower opportunity cost than another company (Wang et al., 2016).

4.9 BIM benefits: expected benefit is a decisive factor for BIM adoption (Wang et al., 2016).

4.10 Enabling environment: in the form of policies and legislation of government towards the adoption (Abubakar et al., 2014).

5- Organization-related indicators:

Organization-related indicators specialize in everything related to the internal forces coming from the organization itself, including culture, training and learning, communication, leadership, structure, processes, and practices. The following list contains indicators under the organization related category:

5.1 Top management support: (Son et al., 2014; Enegbuma et al., 2015; Ahmed et al., 2017; Enegbuma et al., 2015; Ahuja et al., 2016; Zakaria et al., 2013; Son et al., 2014; Kim et al., 2015; Lee et al., 2015; Jin et al., 2017).

5.2 Performance measures and benchmarking for continuous improvement (Ahmed et al., 2017).

5.3 Financial resources of organization (Ahmed et al., 2017).

5.4 BIM supporting organizational structure: by the availability of BIM department or the ability to share the knowledge across the organization (Ahmed et al., 2017; Zahrizan et al., 2014; Won and Lee, 2010; Sunil et al., 2017).

6- Policy-related indicators:

Policy-related indicators focus on a pivotal preparatory, regulatory and contractual role in the design, construction, and operations process (Eadie et al., 2014; Succar, 2014). The following list contains indicators under the policy related category:

6.1 Regulation and policy: (Ahmed et al., 2017).

6.2 Industry standards: Industry standards are the generally accepted requirements followed by the members of industry (Ahmed et al., 2017).

6.3 Project delivery modes: (Poirier et al., 2015).

6.4 Increased demand of design and build: It is a delivery method of a project in which the design and construction services are done by the same company (Ahmed et al., 2017; Zakaria et al., 2013).

7- BIM adoption indicator:

As discussed before, this factor is concerned by BIM characteristic; hence, it does not fall under any category. So according to SEM requirements that each construct must contain at least one factor, the BIM self-efficacy indicator is added to the BIM-related indicators category.

7.1 Self-efficacy: the capabilities of BIM to produce designated levels of performance that encourage and push industry professionals to adopt it (Lee et al., 2012; Lee et al., 2015).

3.6 Conceptual Research Model and Hypotheses

In order to study and explain the BIM adoption in the Bahraini construction industry, a research model is created. This model identifies indicators affecting BIM adoption and analyzes relationships between the indicators. The evaluation results of BIM adoption indicators can also be used to develop a BIM adoption strategy that is suitable for the Kingdom of Bahrain situation.

The first step in formulating the model is to identify the primary constructs. In this research, there are seven main categories of indicators discussed in Sub-section 3.3.3. Each of these categories includes several indicators. The categories are used to study the adoption of BIM in the Bahraini construction industry. All indicators are given abbreviations for easy referencing, by taking the first two letters of each category with the indicator number in the list, for example, TE1 is for technology-related indicator 1, which is "Information format", and so on. Table (3.3) shows each indicator with its abbreviation in the final indicators set.

Table (3.3) Final Set of Indicators

Category	Code	Indicators
Technology	TE1	Information format
	TE2	Usefulness of digital transfer of data
	TE3	Security of confidential information on project data
	TE4	Visualization
	TE5	Technical competence of staff
	TE6	Technological capability of organization
	TE7	Automation
	TE8	Data richness/ Real-time data
	TE9	Hardware equipment/ Hardware upgrade
	TE10	Observability
	TE11	Uninterrupted power and a strong Internet
	TE12	Awareness of the technology among industry stakeholders
	TE13	BIM libraries
Process	PR1	Developing data exchange standards
	PR2	Companies' collaboration experience with project partners
	PR3	Standard and rules
	PR4	Collaboration (project) management tools
	PR5	Desire to speed up the design process
	PR6	Communication
	PR7	Shared norms and collective expectations diffused through information exchange activities
	PR8	Contractual sharing norm
	PR9	Leadership of senior management
	PR10	Shared liability between project participants
	PR11	Providing guidance on use of BIM
	PR12	Information availability and sharing
People	PE1	Process and workflow training
	PE2	Qualified cadres and experts to train BIM software
	PE3	Need for innovation, and diffusion of innovation
	PE4	Supporting individual characteristics
	PE5	Software and technology training
	PE6	Interest in learning BIM
	PE7	level of awareness of BIM and the knowledge about BIM
	PE8	Observable large productivity gain

Table (3.3) Final Set of Indicators (Continue)

Category	Code	Indicators
People	PE9	Professional development
	PE10	Project team expectations
Environment	EN1	Globalization and competitive strategies
	EN2	Market demands
	EN3	International flexibility/adaptability to market
	EN4	Competitive advantages in market (core/unique)
	EN5	Pressure from competitors
	EN6	Influence from partners who have adopted BIM
	EN7	Best practices for constructible implementation
	EN8	Comparative advantage
	EN9	BIM benefits
	EN10	Enabling environment
Organization	OR1	Top management support
	OR2	Performance measures and benchmarking for continuous improvement.
	OR3	Financial resources of organization
	OR4	BIM supporting organizational structure
Policy	PO1	Regulation and policy
	PO2	Industry standards
	PO3	Project delivery modes
	PO4	The increased demand of design and build
BIM Adoption	AD1	Self-efficacy

The research model is developed by setting six of the main categories as latent variables (components) working as exogenous variables, while BIM adoption is the only endogenous variable with only one indicator. Each of the six main constructs includes its indicators as observed variables as shown in Figure (3.1). Then according to this six hypothesizes are created as follows:

Hypothesis 1 (H1): Environment-related indicators will have a positive effect on BIM adoption.

Hypothesis 2 (H2): Process-related indicators will have a positive effect on BIM adoption.

Hypothesis 3 (H3): Technology-related indicators will have a positive effect on BIM adoption.

Hypothesis 4 (H4): Organization-related indicators will have a positive effect on BIM adoption.

Hypothesis 5 (H5): Policy-related indicators will have a positive effect on BIM adoption.

Hypothesis 6 (H6): People-related indicators will have a positive effect on BIM adoption.

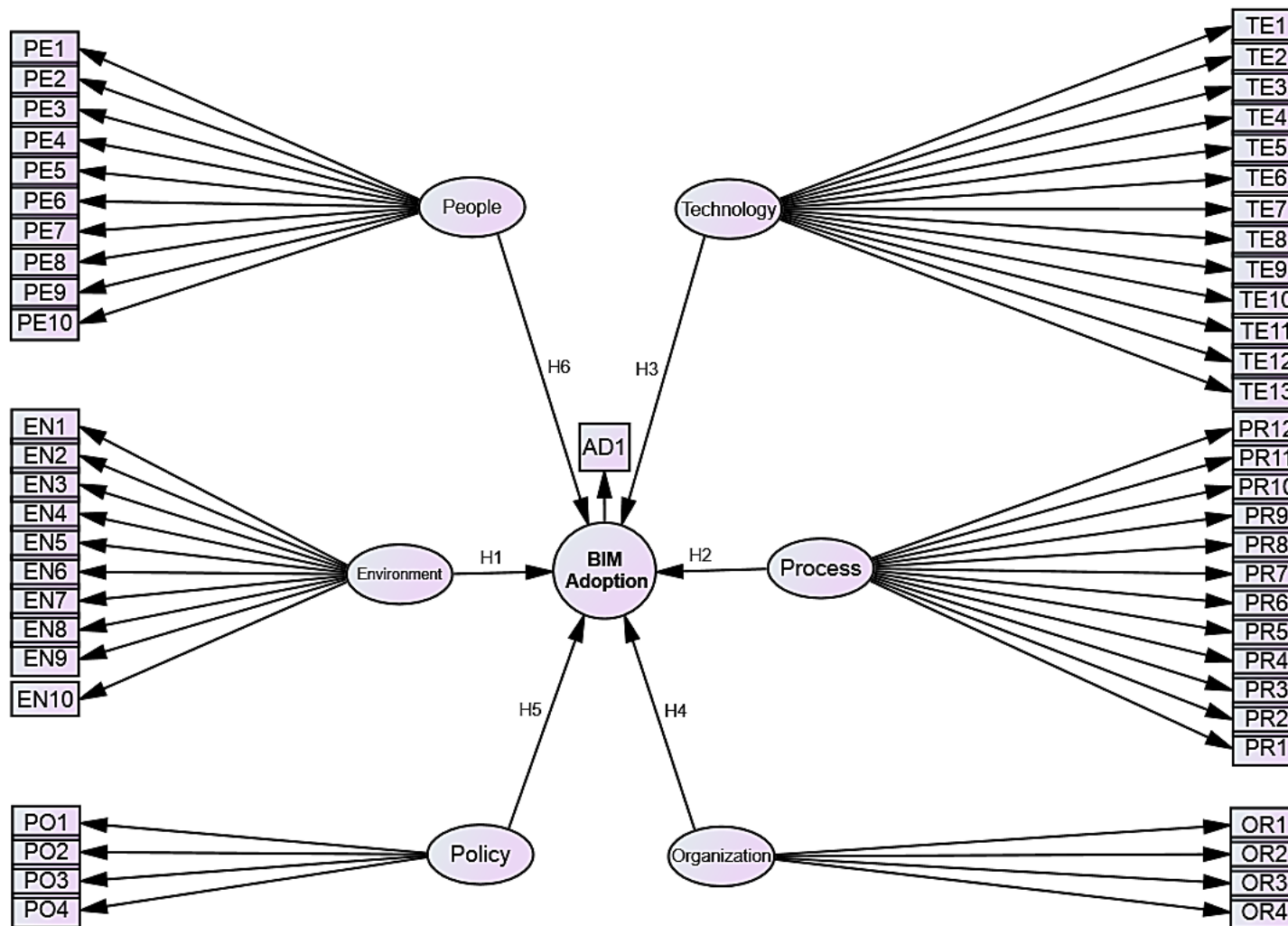


Figure 3.1: Research Model and Hypothesis

CHAPTER FOUR

DATA COLLECTION

4.1 Introduction

4.2 Questionnaire Targeted Group

4.3 Questionnaire Sample Size

4.4 Questionnaire Design and Distribution

4.5 Response Rate

CHAPTER FOUR

DATA COLLECTION

4.1 Introduction

Data performs a significant part in quantitative analysis researches. According to Yin (2009), the choice of the data collection methods depends on the level of assessment the researcher could have in obtaining information since some of them might be beyond the control of the researcher. In addition to the literature review and the Delphi method to identify the indicators that drive the BIM adoption, the third source of collecting data is through a quantitative data collection approach, in the form of a questionnaire to a portfolio of professionals of the Bahraini construction industry. Data collected reflect perception by the industry professionals of indicators driving for BIM adoption, which will provide valuable input into BIM adoption rates across different markets and will be used to build, calibrate and validate the research model.

Therefore, this chapter first will discuss the targeted group of respondents from the industry professionals, and the criteria for choosing them, then it will draw on the used data sampling methods, and the justification of choice. After that, it will explain the questionnaire design and forms of distribution. Finally, the review of the final rates of collected responses will be presented.

4.2 Questionnaire Targeted Group

The questionnaire targeted group includes industry professionals in both public and private sector. For the private sector the choice of the questionnaire's targeted group is done in two stages. First, the targeted categories of engineering offices are identified. Second, the targeted individuals of industry professionals are specified.

For engineering offices and according to The Council for Regulating the Practice of Engineering Professions (CRPEP), engineering offices in Bahrain are classified as shown in Table (4.1).

Table (4.1): Classification of Engineering Offices

Category	Description
A	Are offices that have the right of undertaking all engineering activities, regardless of the value.
B	Are offices that have the right of undertaking all engineering activities, each of which has a total value not exceeding four million Dinars.
C	Are offices that have the right of undertaking all engineering activities, each of which has a total value not exceeding one million Dinars.
D	Are entities, institutions and companies that have in-house engineering units for all engineering activities of their own engineering projects, regardless of the value thereof.
E	Are entities, institutions and companies that have in-house engineering units for all engineering activities, subject to the specific licensed area as determined by CRPEP.
F	Are engineering laboratories that have their own engineering personnel for the preparation of various studies.
K	Are offices that have the right of undertaking studies and providing expertise and advisory in engineering areas in specific field licensed by CRPEP.

According to the shown classification of the engineering offices, the researcher decides to target only offices with A, B, C, and D categories, and mainly focuses more on A and B category, as the size of the projects undertaken, and the number of engineers is larger, and hence, they will be more concerned about BIM.

Second, in the choice of the targeted individuals of the industry professionals, the survey of this study was not limited to BIM experts but includes the all industry professionals in order to investigate the overall BIM awareness, BIM usage, and influencing adoption indicators in the industry from all points of views. Hence, the targeted group is from all engineering disciplines.

4.3 Questionnaire Sample Size

The sample size must be adequate to represent the population of interest, and this may often be the overriding concern of the researcher. In scientific researches in general and in statistical researches in particular, there are two decisions, either to take all the population or sample of the population. Survey sampling requires the selection of a small sub-population that is representative of the whole population (Liu et al., 2015). In order to determine the required research sample, three methods are used:

a) Mathematical Equation:

The mathematical equation is used to calculate the research sample size. For that reason, the population size needs to be determined. Table (4.2) represents the population size for licensed engineers from both private and public sector according to CRPEP records.

Table (4.2): Total Number of Licensed Engineers from Private and Public Sectors

Numbers of Licensed Engineers in Private Sector							
	Architecture	Civil	Mechanical	Electrical	Project Management	Quantity surveying	Total
A	179	314	103	76	17	19	708
B	115	173	74	37	8	10	417
C	56	66	30	20	0	16	188
D	113	110	38	16	1	8	286
Total	463	663	245	149	26	53	1599
Numbers of Licensed Engineers in Public Sector							
Ministry of Works							406
Ministry of Municipalities							157
Total							563
Total number of licensed engineers from both sectors							2162

Equation (4.1) is used to calculate the sample size of the infinite population (Hogg and Tannis 2009).

$$SS = \frac{Z^2 * (p) * (1-p)}{C^2} \quad (4.1)$$

Where:

SS is the sample size for infinite population.

Z is the normal standard variate (Z=1.96 for 95% confidence level).

p is the (estimated) proportion of the population having the characteristic, it may be known from prior research or other sources; if it is unknown use p= 0.5 which assumes maximum heterogeneity (i.e. a 50/50 split) (Rose et al., 2014).

C is the margin of error (5%) (Rose et al., 2014).

Thus,

$$SS = \frac{1.96^2 \times 0.5(1 - 0.5)}{(0.05)^2} = 384.16 \approx 384$$

Correction for finite population:

$$SS \text{ finite} = \frac{SS}{1 + \frac{SS-1}{POP}} \quad (4.2)$$

Where POP is the population, which is equal to 2162 from Table (4.2).

$$SS \text{ finite} = \frac{384}{1 + \frac{384 - 1}{2162}} = 326.225 \approx 326$$

So, the sample size according to the use of mathematical equation is 326 for professionals from the decided four engineering offices classifications.

b) The Used Statistical Method (SEM):

CB-SEM is the statistical method that is going to be used in the data analysis process in order to identify indicators driving the BIM adoption. SEM is more sensitive to sample size than other multivariate approaches (Hair et al., 2014). As some of the statistical algorithms used by SEM programs are unreliable with small samples.

Referring to Chapter two, Table (2.3) shows that the minimum sample size required when using SEM, there is a consensus among researcher that for SEM the minimum sample size should not be less than 200. The larger sample size is always needed for a stronger model result.

c) The Review of Previous Studies:

The third method used to determine the sample size is by reviewing similar studies. By this method the researcher can get an idea about the minimum and the maximum size of the required sample.

The chosen studies revolve around BIM subject and at the same time use SEM as a data analysis statistical method. Table (4.3) represents the results of this method:

Table (4.3): Review of Previous Studies for Sample Size Determination

Year	Reference	Sample Size	Notes
2018	Acquah and Oteng, 2018	125	
2018	Pang and Zhai, 2018	192	
2017	Ngowtanasawan, 2017	278	
2016	Chen et al., 2016	249	A total of 2,050 professionals are identified
2016	Enegbuma et al., 2016	292	
2016	Hong et al., 2016	120	
2015	Enegbuma et al., 2015	352	
2015	Ding et al., 2015	218	
2015	Kim et al., 2015	310	
2015	Lee et al., 2015	114	
2014	Son et al., 2014	162	
2014	Chen et al., 2014	131	

As a result of reviewing the three methods, the researcher decides to use the sample size calculated by the mathematical equation, which is 326. However, the researcher has strived to get the maximum number of

responses and not to fall under 200 responses as recommended by the other two methods.

4.4 Questionnaire Design and Distribution

To meet the objectives of this research, primary data has to be collected from engineering field professionals in the Kingdom of Bahrain. A questionnaire survey is designed to collect primary data regarding the awareness, usage, and indicators driving for BIM adoption in the Bahraini construction industry. Survey questions are first examined and identified through a relevant literature review.

The questionnaire is designed in a way to match different levels of professional's knowledge about BIM. It contains four different sections explained as follows: The first section is to identify the respondents' and organization profile, e.g., their education level, specialization, position, years of experience in the construction industry, organization sector, grade, and type.

The second section of the questionnaire is focused on the first level of knowledge, which is the awareness about BIM, by asking the respondents directly whether they are aware or not about BIM. The third section of the questionnaire is focused on the level of knowledge about BIM software, definition and uses. Knowledge about BIM software is considered as a good indicator of BIM knowledge.

The last section of the questionnaire is focused on the respondent's opinion on the indicators that drive the adoption of BIM among construction industry professionals in Bahrain. The 54 indicators of BIM adoption and their seven respective categories are included in this section (Appendix 5). A Likert scale consisting of five points is utilized to judge the respondent's perception of the questions. With one being the lowest

and 5 is the highest rating (1: Strongly disagree, 2: Disagree, 3: Uncertain, 4: Agree, 5: Strongly Agree). The last question of this section asks the respondents to write any additional indicators they think it influences BIM adoption in the Bahraini construction industry.

4.5 Response Rate

The questionnaires are distributed in two forms: printed and online. For the private sector, A and B categories' offices were targeted first then followed by C and D categories offices, with a total of 300 printed copies delivered by hand and collected in the same manner with a time allowance of four weeks.

For the public sector, public relation departments in Ministry of Works and Ministry of Municipalities (4 municipalities) are contacted by more than one visit in order to send the questionnaire in an online format to all working engineers, as it forms the best way of connection for the public sector. The survey is left open for four weeks.

All received responses are valid with no missing data. The targeted survey sample size for this study was 326, and the received responses were 272 responses. The response rate is estimated to be approximately 83%. With 86% of the 272 from the private sector (234 responses) and only 14% (38 responses) from the public sector.

CHAPTER FIVE

DATA ANALYSIS

5.1 Introduction

5.2 Data Analysis Part 1: Descriptive Analysis of the Respondent's Attributes

5.3 Data Analysis Part 2: Multivariate Data Analysis

5.4 Data Analysis Part 3: Multivariate Analysis of Variance (MANOVA)

CHAPTER FIVE

DATA ANALYSIS

5.1 Introduction

The collected data from questionnaires (Appendix 6) distributed via printed and electronic forms are analyzed in order to answer the research questions. The data analysis is divided into two parts. The first part of data analysis using SPSS25 software is a descriptive analysis measuring the percentages of respondent's answers to the questionnaires first, second and third sections. It is mainly concerned with two goals: first is to collect some background information about the respondents. Second is to stand on the current situation of BIM adoption in the construction industry in the Kingdom of Bahrain.

The second part of data analysis tests the respondent's opinion about indicators drives the adoption of BIM in the Bahraini construction industry, which is the fourth section in the distributed questionnaire. The analysis of this part is by SEM technique using SPSS 25 and AMOS software.

In the third part, Multivariate Analysis of Variance (MANOVA) is used to assess the statistical significance of the effect of the attributes descriptive analysis on the indicators in each component (group) using SPSS 25 software.

5.2 Data Analysis Part 1: Descriptive Analysis of the Respondent's Attributes

5.2.1 Respondents education level

According to Figure (5.1), the results show the diversity of educational level among respondents. Respondents with a bachelor's degree are about 80%, then master's degree holders about 14% of, about other education levels diploma holders, form 2.97% of responses; finally, Ph.D. holders are about 0.7% of the total.

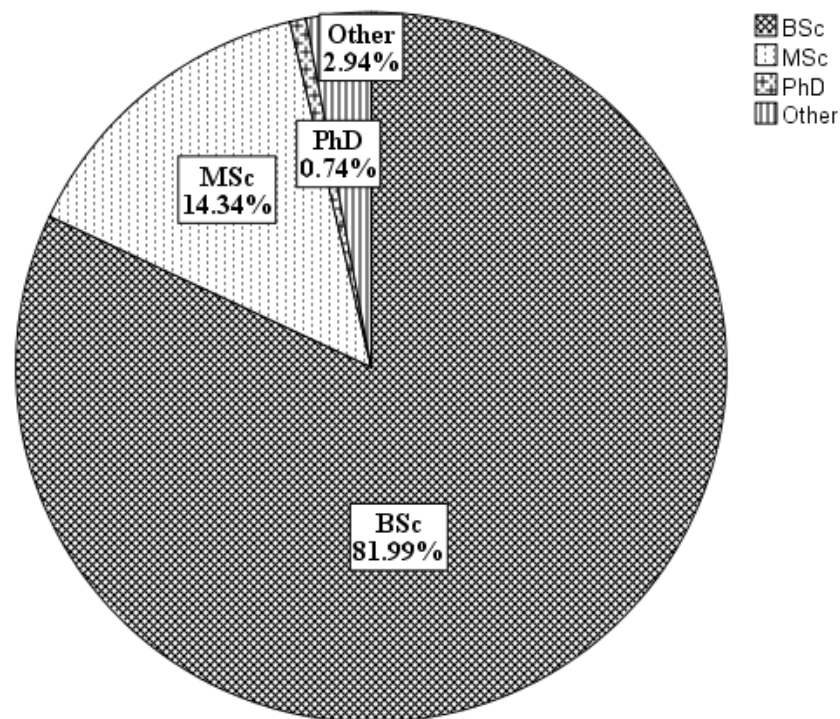


Figure 5.1: The Distribution of the Respondents According to their Level of Education

5.2.2 Respondents specialization

In total, about 46% of the respondents are specialized in architecture followed by 36 % specialized in civil engineering. This great present of architecture specialists is due to the nature of architecture work where the majority of architect's time is spent in offices, which helped in answering the questionnaire, while other engineers are mainly on site and it was more challenging to reach them. Following those mechanical engineers with 8.82%, electrical engineers with 3.68%, and others which varied between structural, interior and surveying engineers. Figure (5.2) represents the results of this question.

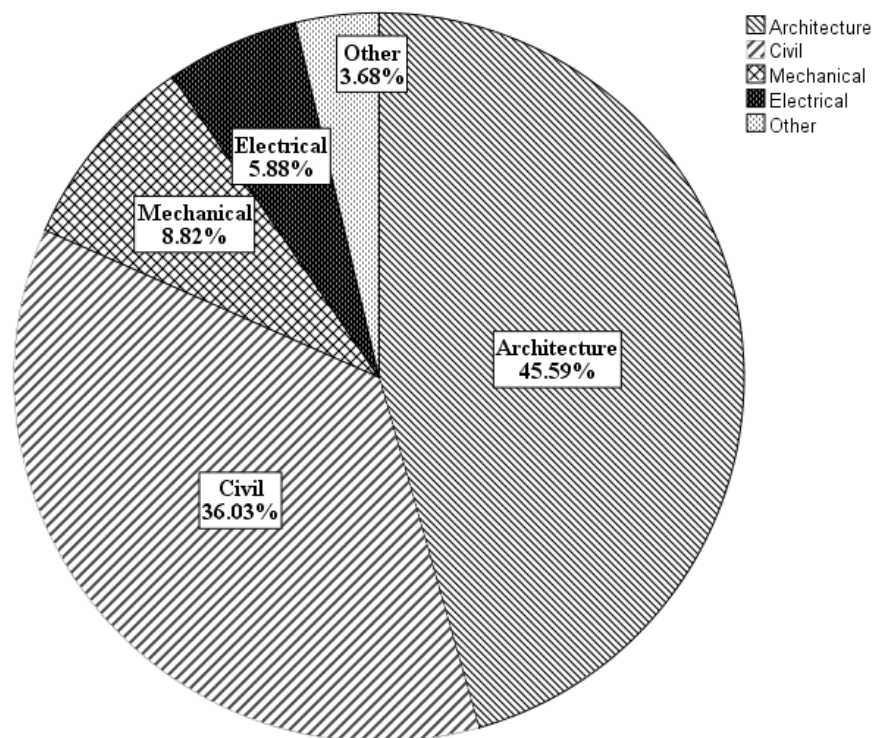


Figure 5.2: The Distribution of the Respondents According to their Specialization

5.2.3 Respondent's position

In first place comes respondents in architect position with 34.56%, then design engineers with 21.32%, project managers with 19.49%, construction engineers with 10.66%, other positions with 8.46%, and directors with only 4.41% of the total respondents. The answers for other positions varied between draft man, Mechanical Electrical Plumbing (MEP) coordinator, quantity surveyor, and maintenance engineer. From Figure (5.3) it is noted that BIM designer position forms only 1 %, which is three only of the respondents, while the results do not include the BIM manager position. This indicates that the concept of BIM is not profound in the organizations, especially with no existence of organization structure that defines BIM related positions.

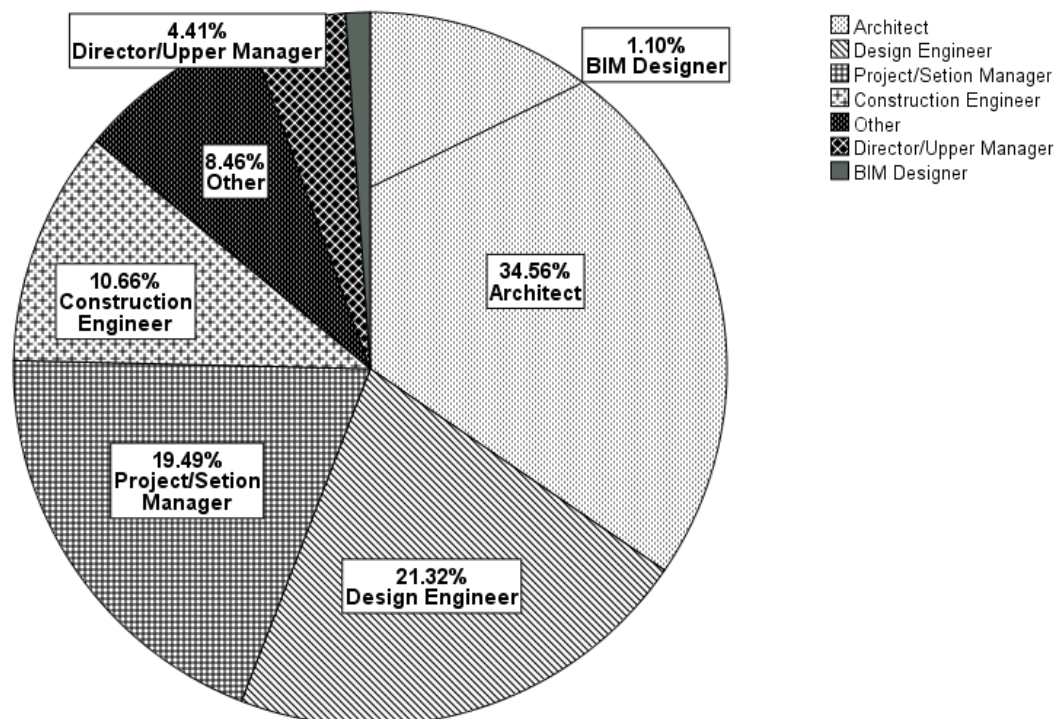


Figure 5.3: The Distribution of the Respondents According to their Positions

5.2.4 Respondent's years of experience

Figure (5.4) shows that 35.66% of the respondents have experience of less than five years. This is mainly due to the large number of new graduate engineers who have been employed to meet the increasing demand in the construction industry. In the second place comes respondents with 5 to 10 years of experience with 24.63%, then comes respondents with more than 20 years' experience with 18.75%, next respondents with experience from 11 to 15 years with 12.50%, finally, respondents with experience from 16 to 20 years with 8.46% of the total.

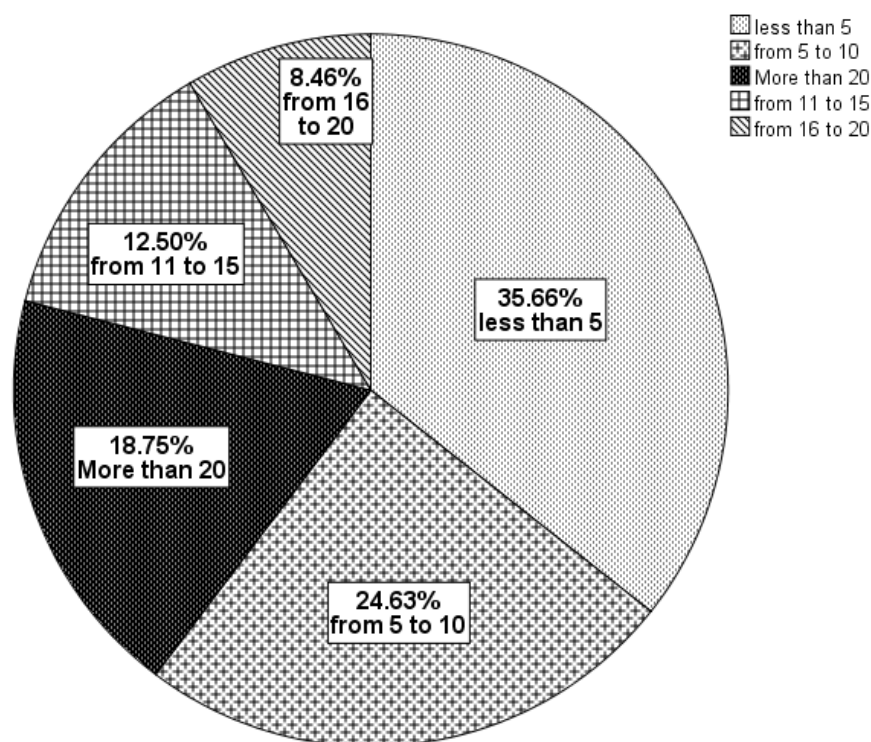


Figure 5.4: The Distribution of the Respondents According to their Years of Experience

5.2.5 Respondent's sector

The majority of the respondents are working in the private sector, with about 86 % of the total respondents. The small percentage of respondents from the public sector is due to the nature of the jobs given to some of the

respondents, which are mostly an administrative work away from real construction work; hence, the researcher chooses to have more respondents from the private sector in order to get more reliable results.

According to CRPEP, each engineering office is graded based on the number of working engineers, their grade, specialization, and the undertaken project values. The researcher mainly concentrates on having the majority of respondents from A, B, and C category companies, as they represent the majority of engineering offices in Bahrain.

The 235 respondents from the private sector show 57% working in grade A, 29% grade B, and about 13% from grade C as shown in Figure (5.5).

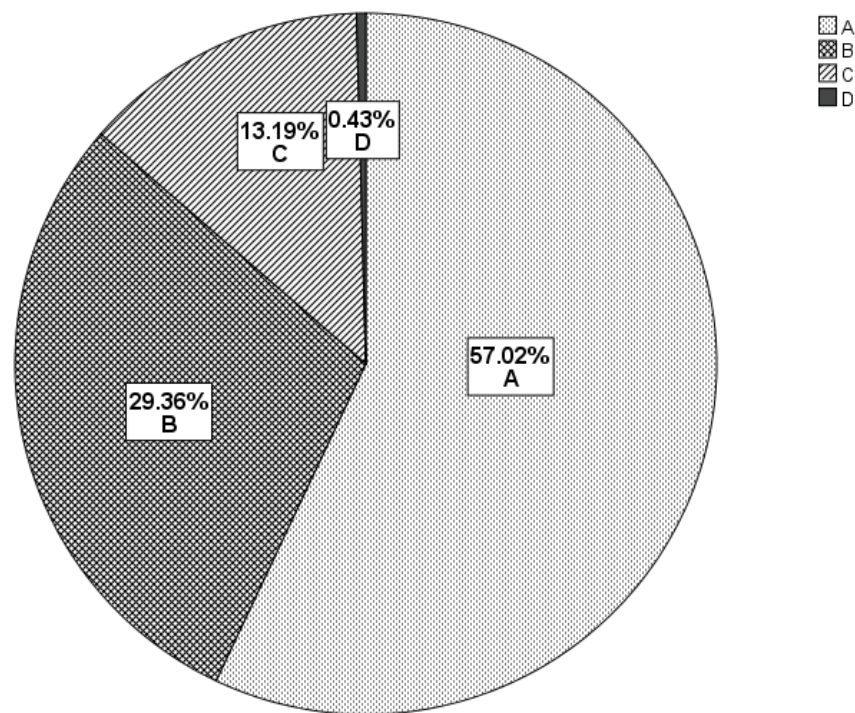


Figure 5.5: The Distribution of the Respondents According to their Company's Grade

These graded offices vary between consulting, design offices or general and sub-general contractors. The highest percentage is for consulting offices with about 37 %, then design offices with 33.82%, next

general and sub-contractors almost has a percentage of about 14% of the total Figure (5.6).

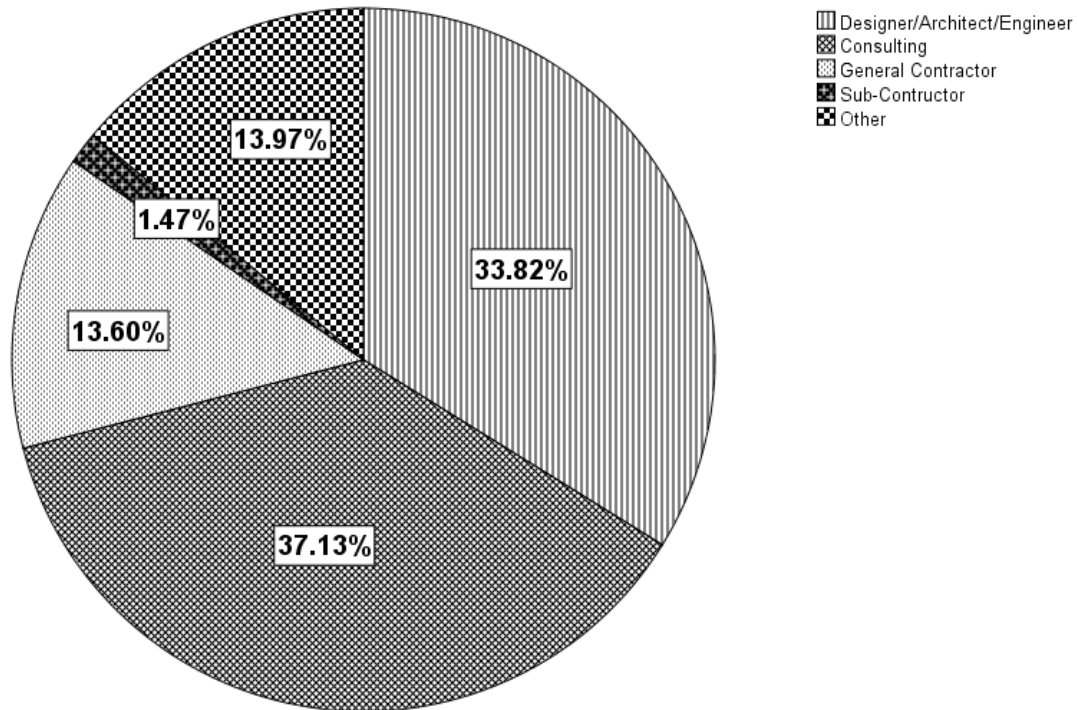


Figure 5.6: The Distribution of the Respondents According to their Company's Type

5.2.6 Respondent's awareness about BIM

The second section in the questionnaire mainly targets the awareness level of BIM between Bahraini construction industry professionals. The results are auspicious as 72% of respondents answer yes, that they are aware of BIM as shown in Figure (5.7). This high level of awareness facilitates the adoption of BIM in the industry at all levels and makes it easy to be implemented between industry professionals. Moreover, this high percentage of yes answers strengthens the results of the research and makes it more reliable as the respondents will give reliable answers based on prior knowledge about BIM.

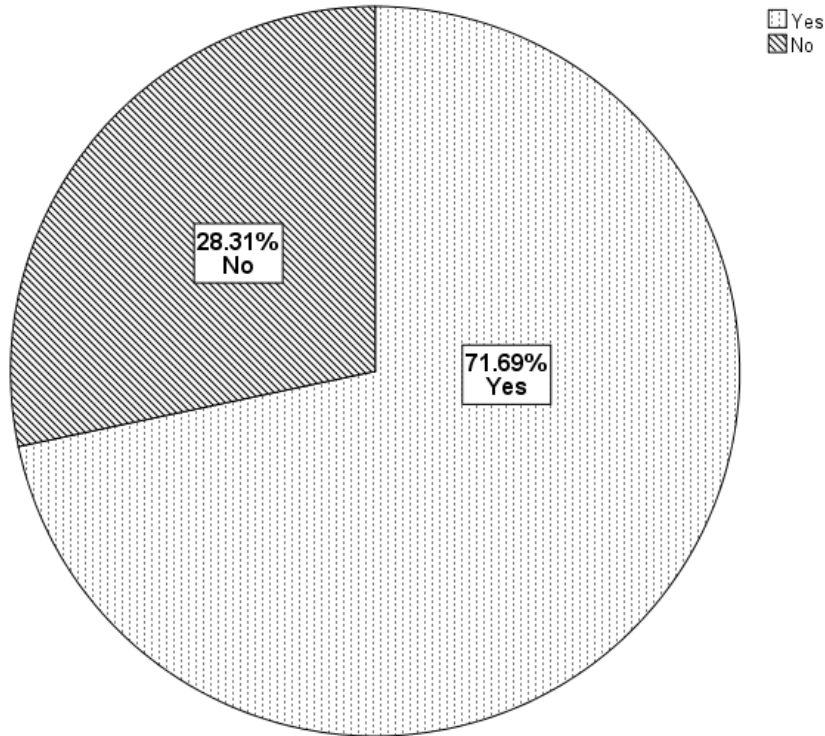


Figure 5.7: The Distribution of the Respondents According to their BIM Awareness

5.2.7 Respondent's knowledge about BIM

In order to test the respondent's level of knowledge, a list of the most popular engineering softwares is presented to choose the ones they use in their work as the use of any BIM software may be considered as the first stage of implementation in the industry.

The results in Figure (5.8) show that the highest two used softwares are Autodesk AutoCAD Architecture and Autodesk Revit with about 49 % and 21%, respectively. Both softwares are BIM tools, which give a good indication that the construction industry in Bahrain has the first stage of knowledge about BIM by using some of its tools, and this will facilitate the transition to next stages as explained in Chapter 2.

The third place was for other software, which varied between structure analysis softwares, such as STAAD pro and Etabs; design softwares, such as 3D max and SketchUp; or project management

softwares, such as MS Project and Primavera.

Next, respondents are asked to indicate the uses of these programs in their work. This helps in determining the stage of BIM implementation as the availability of such information introduces a tool to benchmark the stage of implementation.

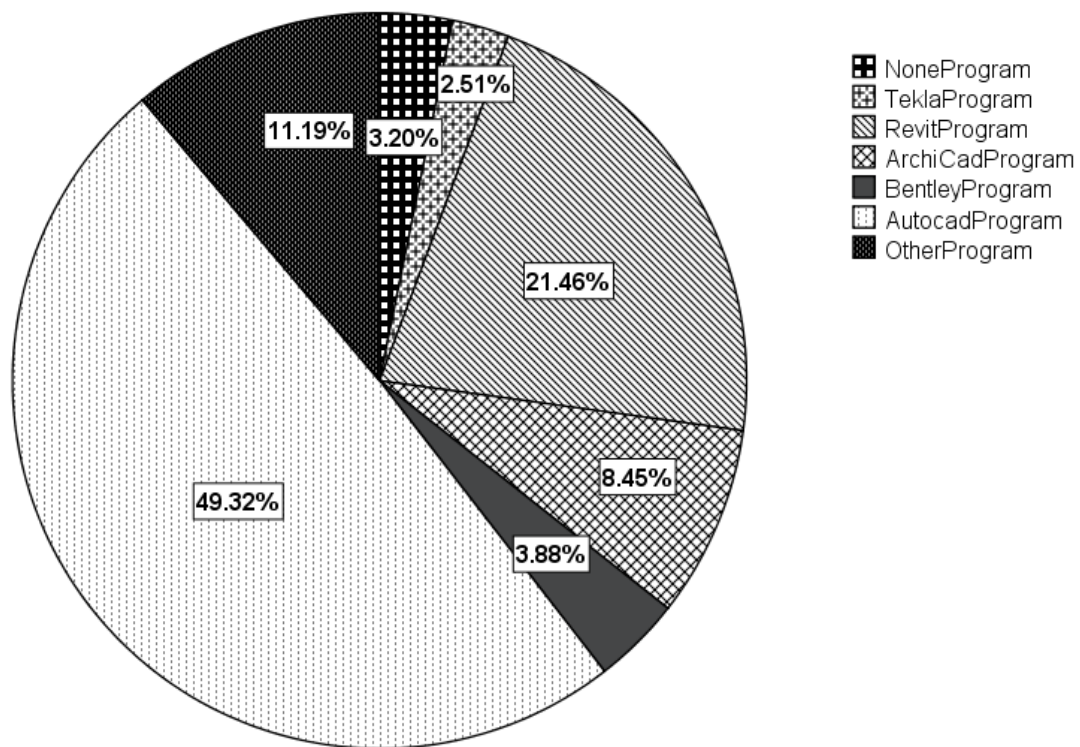


Figure 5.8: The Distribution of the Respondents According to Programs Used

According to Figure (5.9), the answers are highest for 2D use with 38.5% followed by 3D use with about 28.5%. These results place the Bahraini construction industry in BIM level 1. This level is characterized by using CAD in 2D or 3D format; however, without any model-based exchange between different disciplines as mentioned in Chapter 2. The other uses are for quantity surveying, cost estimation, project schedule, and structural design and analysis, respectively.

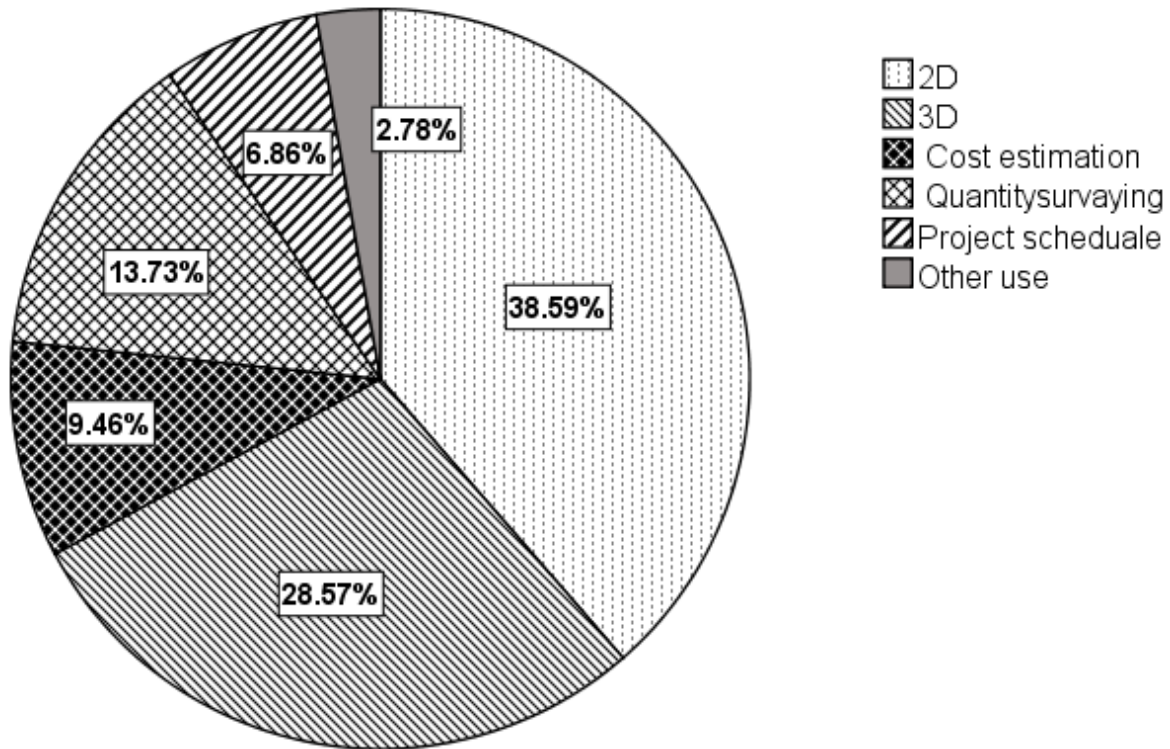


Figure 5.9: The Distribution of the Respondents According to Programs' Uses

5.2.8 Respondent's BIM usage

According to Figure (5.10), the results for BIM usage are disappointing with more than 60% of the respondent's answers that they do not use BIM in their work. This means that Bahrain construction industry professionals have an awareness of BIM and the knowledge of its software, but they are not using it in an optimized way in their work.

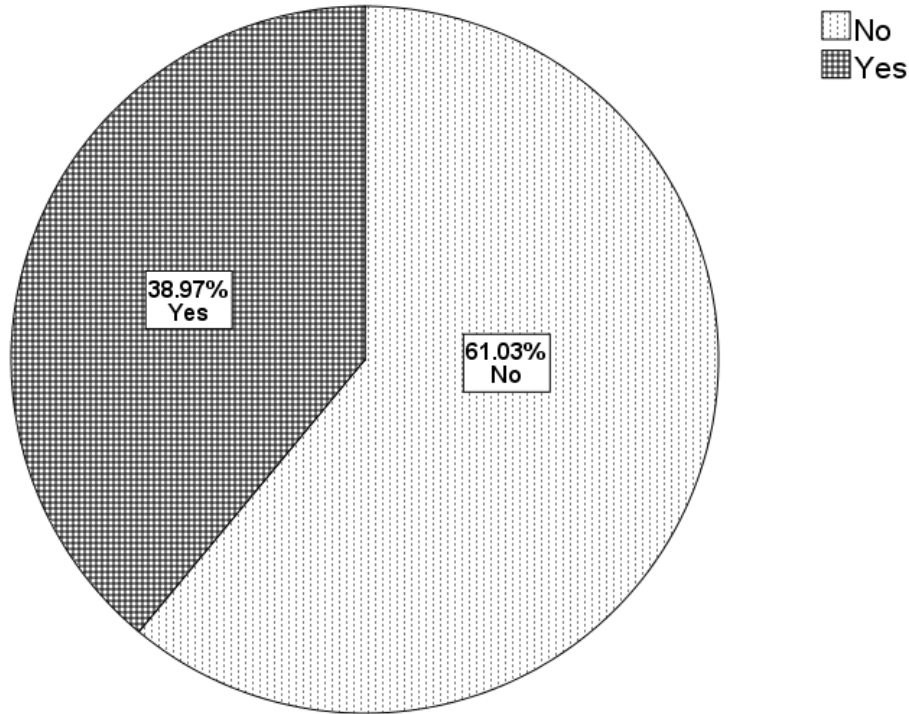


Figure 5.10: The Distribution of the Respondents According to BIM Usage

In order to profoundly investigate the level of BIM maturity in the Bahraini construction industry, the respondents who use BIM are asked to specify BIM using purposes. The answers in Figure (5.11) shows visualization and drawings production at the same position with a percentage of about 28%. On the other hand, the results show more advanced BIM usage purposes such as design analysis, interaction with professionals and model collaboration with lower percentages reaching only 7 % for model collaboration. For example, indicating that BIM usage still does not reach its optimum level in the industry and the level of knowledge among construction industry professionals can be described as shallow. Another option comes in the last place with answers like clash detection, decision making, and quantity take-off.

This confirms the previous results of Bahraini construction industry being at level 1 in BIM maturity levels, especially that the use of BIM is

only for visualization or drawing production and not reaching the interaction and collaboration use at level 2 and 3.

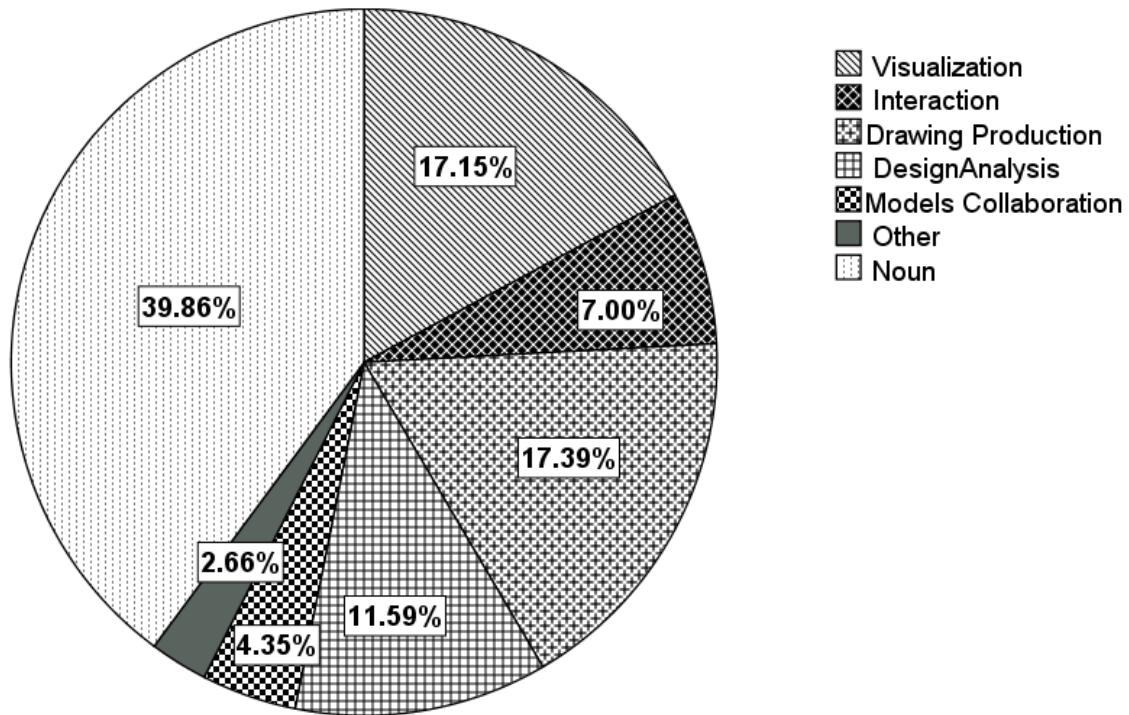


Figure 5.11: The Distribution of the Respondents According to BIM Usage Purposes

5.2.9 Respondent's BIM definition

According to the information mentioned in Chapter 2, BIM is a multidimensional concept that must be seen from different perspectives in order to reach its comprehensive definition. Figure (5.12) shows the distribution of respondents according to their definition of BIM. About 32.7% of the respondents define BIM as a visualization tool, 27.5% define it as new technology and techniques, 18% as a collaboration process. It can be noticed that the percentages of defining it as a visualization tool and new technology and techniques are close, and hence it can be stated that the Bahraini industry professionals see BIM as a new technology that is

used for visualization. These results confirm that their knowledge about BIM is shallow as they only know BIM from one perspective, and they do not have complete knowledge about it.

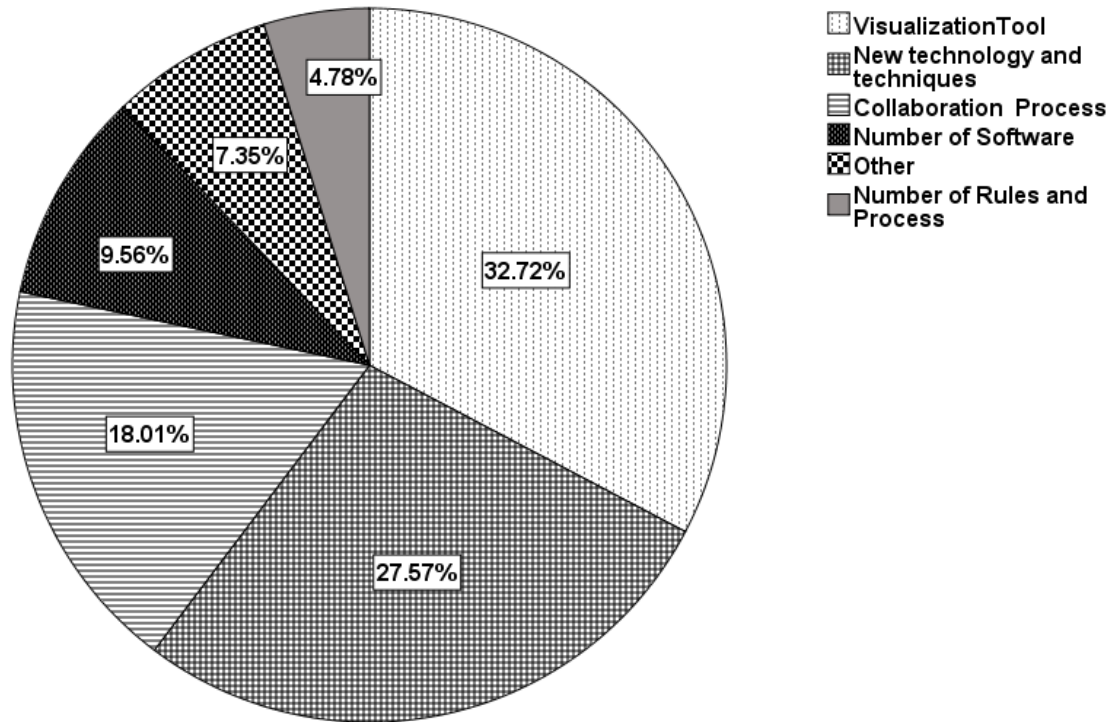


Figure 5.12: The Distribution of the Respondents According to their BIM Definition

5.3 Data Analysis Part 2: Multivariate Data Analysis

This research mainly aims to answer some critical questions, for example, what indicators determine technology component? How do technology-related indicators affect BIM adoption? The second part: multivariate data analysis through SEM is used to identify the indicators driving for BIM adoption in the Bahraini construction industry. Multivariate analysis is done through three procedural steps: Principal Component Factor Analysis (PCFA), also called Exploratory Factor Analysis (EFA); Confirmatory Factor Analysis (CFA); and SEM as shown in Figure (5.13).

A similar process is applied in developing: SEM for BIM maturity model (Chen et al., 2016;Chen et al., 2014); a Causal Model of BIM Adoption in the Thai Architectural and Engineering Design Industry (Ngowtanasawan, 2017); and Key factors for the BIM adoption by architects in a Chinese study (Ding et al., 2015).

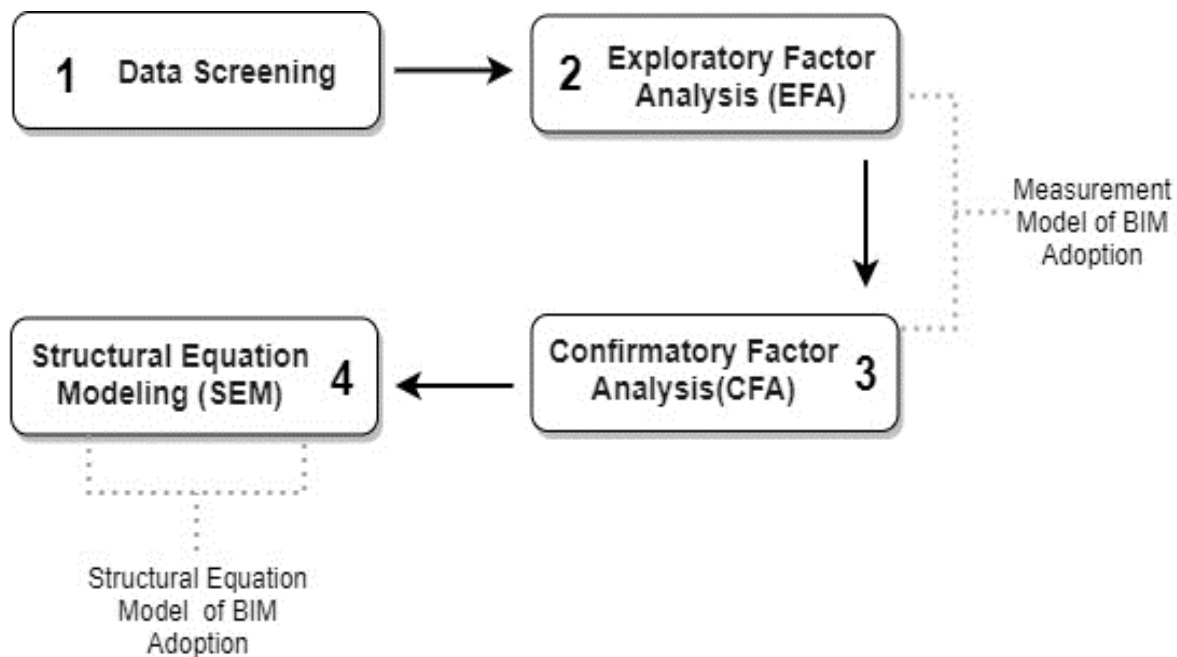


Figure 5.13: Multivariate Data Analysis Steps

5.3.1 Data screening

In order to produce a realistic and valid model, it is essential to perform a data screening phase before the data analysis in SEM. Data screening phase using SPSS 25 software is done in three steps: first checking of missing collected data; second testing the normality assumption in terms of Skewness Index (SI) and Kurtosis Index (KI) of each tested indicator; finally detecting multicollinearity in terms of bivariate correlation (r), the squared multiple correlations (R^2_{smc}), and the variance inflation factor (VIF) (Chen et al., 2016).

a) Missing data

The original data of the 272 responses are screened, and all valid responses are complete, and there is no missing value in the data set.

b) Normality assumption

The normality assessment is made by assessing the measure of Skewness Index (SI) and Kurtosis Index (KI) for every indicator. The absolute values of SI less than 3 and KI less than 10 indicate that the data is normally distributed (Chen et al., 2012; Hoyle, 2012; Chen et al., 2014; Chen et al., 2016). Table (5.1) presents the resulted SPSS 25 output for the normality assessment for every indicator in the model.

The values for SI are between -0.006 and -1.103, the absolute value of which is less than the recommended value 3. For KI the values are between -0.024 and 2.024 whose absolute value is less than the recommended value 10. Hence normality assumption of the distribution of all areas is not rejected.

Table (5.1): The Assessment of Normality Distribution for Indicators

Indicators	Skewness Index (SI)	Kurtosis Index (KI)
TE1	-0.780	1.462
TE2	-0.503	0.140
TE3	-0.356	-0.026
TE4	-0.586	0.581
TE5	-1.103	1.635
TE6	-0.627	0.642
TE7	-0.183	-0.578
TE8	-0.379	0.529
TE9	-0.707	0.426
TE10	-0.732	0.676
TE11	-0.006	-0.532
TE12	-0.538	0.162
TE13	-0.415	0.129
PR1	-0.387	0.571
PR2	-0.286	0.237
PR3	-0.504	0.379
PR4	-0.718	1.350
PR5	-0.656	0.324
PR6	-0.561	0.123
PR7	-0.342	0.487
PR8	-0.096	-0.104
PR9	-0.218	-0.491
PR10	-0.345	0.174
PR11	-0.637	0.779
PR12	-0.691	0.462
PE1	-1.073	2.024
PE2	-0.848	0.644
PE3	-0.616	0.672

**Table (5.1): The Assessment of Normality Distribution for Indicators
(Continue)**

Indicators	Skewness Index (SI)	Kurtosis Index (KI)
PE4	-0.530	0.520
PE5	-0.690	0.147
PE6	-0.802	0.600
PE7	-0.512	0.043
PE8	-0.766	0.912
PE9	-0.844	1.491
PE10	-0.265	-0.040
EN1	-0.752	1.098
EN2	-0.664	0.415
EN3	-0.576	0.586
EN4	-0.366	-0.164
EN5	-0.154	-0.147
EN6	-0.189	-0.035
EN7	-0.435	0.335
EN8	-0.365	-0.024
EN9	-0.590	0.832
EN10	0.111	-0.314
OR1	-0.912	1.454
OR2	-0.650	1.250
OR3	-0.627	0.232
OR4	-0.630	0.492
PO1	-0.367	0.056
PO2	-0.468	0.146
PO3	-0.087	-0.466
PO4	-0.348	-0.260
AD1	-0.645	1.068

c) Multicollinearity assessment

Bivariate correlation (r), the squared multiple correlation (R^2_{smc}), and the variance inflation factor (VIF) and tolerance are used to detect multicollinearity.

- **Bivariate Correlation (r)**

The Bivariate Correlations computes Pearson's correlation coefficient. Correlations measure how indicators are related. As a rule of thumb an ' r ' value more than 0.85 may indicate extreme collinearity, and hence, must be eliminated (Chen et al., 2016). The results show the majority of values between 0.2 and 0.5; all bivariate correlations are reasonably less than 0.85; therefore, no action is needed to eliminate or combine variables.

- **Squared Multiple Correlation (R^2_{smc})**

Squared multiple correlation is the percent variance explained in that indicator (David, 2007). Simply "r squared" multiplied by 100 gives the value of R^2_{smc} . If $R^2_{\text{smc}} > 0.90$ for a particular indicator this indicates extreme multivariate collinearity (Chen et al., 2014). Hence, R^2_{smc} between each indicator and all other indicators must be calculated to ensure that there is no any multivariate collinearity between variables. The output showing the R^2_{smc} for every indicator using SPSS 25 software is presented in Table (5.2). The table reported no indicator is > 0.9 , all indicators are between 0.155 and 0.665, and therefore no action was needed to eliminate or combine variables.

Table (5.2): Squared Multiple Correlations for the Indicators

Indicators	R²_{smc}	Indicators	R²_{smc}
PO1	0.630	PR4	0.433
PO2	0.665	PR5	0.283
PO3	0.355	PR6	0.423
PO4	0.155	PR7	0.377
EN1	0.430	PR8	0.260
EN2	0.489	PR9	0.231
EN3	0.426	PR10	0.286
EN4	0.466	PR11	0.332
EN5	0.209	PR12	0.380
EN6	0.242	TE13	0.223
EN7	0.290	TE12	0.223
EN8	0.402	TE11	0.122
EN9	0.293	TE10	0.152
EN10	0.204	TE9	0.274
PE1	0.478	TE8	0.355
PE2	0.499	TE7	0.257
PE3	0.408	TE6	0.235
PE4	0.318	TE5	0.419
PE5	0.476	TE4	0.363
PE6	0.366	TE3	0.239
PE7	0.320	TE2	0.261
PE8	0.274	TE1	0.217
PE9	0.385		
PE10	0.195		
OR4	0.492		
OR3	0.560		
OR2	0.546		
OR1	0.549		
PR1	0.297		
PR2	0.331		
PR3	0.447		

- **Variance Inflation Factor (VIF) and Tolerance Test**

Variance Inflation Factor (VIF) quantifies how much the indicator is inflated. If the VIF of an observed indicator exceeds 4 or 10, the indicator is considered highly collinear with other variables and poses a problem in regression analysis (Chen et al., 2016; Xu et al., 2014). For tolerance values, a value under 0.2 indicates that the indicator is correlating with other indicators and it should not be included (Acquah and Oteng, 2018). SPSS 25 software is used to calculate VIF by setting each indicator as a dependent variable and all other indicators as independent variables.

Appendix 7 shows the output of SPSS 25 software for VIF and tolerance values. Based on recommended cutoff values, all VIF values are less than 4, and all tolerance values are higher than 0.2. This indicates that multicollinearity is not a likely threat to the parameter estimates. Moreover, as a result, it can be generalized that this indicates sufficient construct validity for all indicators. Now all indicators are ready to the following step of testing construct validity using EFA.

5.3.2 Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis (EFA) is a data-driven approach, that is commonly used to identify the number and nature of indicators that are part of unified concepts, by grouping (categorizing) them. These groups can be used to represent relationships among sets of many interrelated indicators (Lee et al., 2015; Enshassi and AbuHamra, 2016).

The six initial categories with the 53 indicators that measure BIM adoption are explored by the Principal Component Factor Analysis (PCFA) with a varimax rotation using SPSS 25. PCFA is a statistical procedure seeks to calculate correlations and interactions among indicators to reduce a large set of indicators to a small set that still contains most of the

information in the large set, hence, identify only key indicators or groups of indicators that in this case drive the adoption of BIM in the Bahraini construction industry.

Mainly two key points need to be examined in deciding whether a data set is proper for factor analysis: the minimum sample size and the relationship between indicators. Guidelines for the minimum sample size needed for factor analysis suggest a minimum sample size of 100 to 200 responses (Boomsma, 1982; 1985), or at least 4 to 5 times the number of variables (Hair et al., 1998). In this research, the collected sample size is 272, which is more than the minimum of 100 to 200 and about five times larger than the number of variables, which is considered sufficient for factor analysis. On the other hand, in terms of the strength of the relationships among the variables, Bartlett's test of sphericity (Bartlett, 1954) and the Kaiser-Myer-Olkin (KMO) test (Kaiser, 1970) are recommended as the first step of factor analysis tests. These tests are conducted as follows.

a) Bartlett's Test of Sphericity

Bartlett's test of sphericity is a statistical test for the overall significance of all correlations within a correlation matrix. It tests if the correlation matrix is an identity matrix. In this case, it indicates that indicators are unrelated and therefore unsuitable for factor analysis test. For Bartlett's test of sphericity, a significant value of less than 0.05 ($p < 0.05$) is required (Bartlett, 1954; Lee et al., 2015).

The output of SPSS for the results of Bartlett's test of sphericity is shown in Table (5.3). The Bartlett test of Sphericity was 6596.387 and 1378 degrees of freedom. The associated significance level was small at $P = 0.000$ for all indicators. The probability value (Sig.) associated with

the Bartlett test is less than 0.01; hence, it can be said that there is some correlation between indicators of BIM adoption, and the correlation matrix is not an identity matrix. Therefore, it satisfies the factor analysis requirement.

Table (5.3): KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.895
Bartlett's Test of Sphericity	Approx. Chi-Square	6596.387
	df	1378
	Sig.	.000

b) Kaiser-Myer-Olkin (KMO) test

KMO measure of sampling adequacy is similar to testing of indicators' correlations. However, it has a different principle. It is known that the indicator's correlation can be measured. However, the correlation between any two indicators can be affected by other indicators. Due to this, partial correlation is used to measure the correlation between any two indicators after removing the effect of others. KMO measure varies between 0 and 1. If it is almost 1 (high), the PCFA can act effectively, but if the value is almost 0 (low), then it can be said that the PCFA is not the right test. An acceptable value for KMO must be greater than 0.5 (Kaiser, 1970). As shown in Table (5.3) the KMO value is 0.895 (close to 1). Then it can be considered acceptable because it exceeds the minimum requirement of 0.50.

The two tests indicate that the correlation matrix is not an identity matrix and all of the indicators are correlated. According to the results of these tests, the sample data of BIM adoption in the Bahraini construction industry are appropriate for factor analysis.

c) Principle Component Factor Analysis (PCFA)

Principle Component Factor Analysis (PCFA) is an eigenvector-based multivariate analysis, whose measure mainly reveals the internal structure of data in a way that best explains variance in that data (Ji et al., 2012). In other words, it can be said that it is used to form new variables that are linear composites of the original variables. Table (5.4) shows the output of SPSS 25 for initial and extraction communalities for the 53 indicators that influence the BIM adoption in the construction industry. Communalities represent the total amount of proportion of variance in the original variables (Enshassi and AbuHamra, 2016). Columns 2 and 5 of Table (5.4) show the initial communalities, each of which is equal to 1 because it estimates the variance in each indicator accounted for by all indicators. While the extraction communalities give the percent of variance for a given variable as shown in columns 3 and 6 of Table (5.4). The communality value for each indicator should be 0.50 or higher (Enshassi and AbuHamra, 2016).

The results for all indicators satisfy the minimum requirement of being higher than 0.50, so no indicators are excluded based on low communalities. The next step involves using eigenvalue measure in order to reduce the initial number of indicators. Table (5.5) shows the total variance derived from the principal component analysis before rotation.

Table (5.4): Initial and Extraction Communalities for the Indicators

Communalities					
BIM Adoption Indicators	Initial Communality	Extraction Communality	BIM Adoption Indicators	Initial Communality	Extraction Communality
TE1	1.000	0.616	PE3	1.000	0.715
TE2	1.000	0.675	PE4	1.000	0.672
TE3	1.000	0.655	PE5	1.000	0.714
TE4	1.000	0.651	PE6	1.000	0.626
TE5	1.000	0.661	PE7	1.000	0.649
TE6	1.000	0.653	PE8	1.000	0.662
TE7	1.000	0.672	PE9	1.000	0.692
TE8	1.000	0.588	PE10	1.000	0.619
TE9	1.000	0.637	EN1	1.000	0.712
TE10	1.000	0.573	EN2	1.000	0.752
TE11	1.000	0.636	EN3	1.000	0.694
TE12	1.000	0.553	EN4	1.000	0.636
TE13	1.000	0.715	EN5	1.000	0.667
PR1	1.000	0.578	EN6	1.000	0.560
PR2	1.000	0.538	EN7	1.000	0.670
PR3	1.000	0.654	EN8	1.000	0.653
PR4	1.000	0.585	EN9	1.000	0.660
PR5	1.000	0.580	EN10	1.000	0.640
PR6	1.000	0.657	OR1	1.000	0.708
PR7	1.000	0.684	OR2	1.000	0.691
PR8	1.000	0.675	OR3	1.000	0.713
PR9	1.000	0.663	OR4	1.000	0.725
PR10	1.000	0.570	PO1	1.000	0.721
PR11	1.000	0.699	PO2	1.000	0.771
PR12	1.000	0.623	PO3	1.000	0.679
PE1	1.000	0.693	PO4	1.000	0.566
PE2	1.000	0.704			

PCFA converts correlated indicators into a set of groups called principal components. The number of components is equal to the number of indicators; therefore 53 components are generated. PCFA generates two tables of scores, initial eigenvalues table, and extraction sums of squared

loadings table for each indicator. The eigenvalue for a particular component calculates the variance in all the components which is accounted for by that component thus, used to determine which component to keep in the solution. Column 2 in Table (5.5), shows the total variance explained for the given components, and it can be noticed that the first component has the highest eigenvalue as it accounts for the most variance in the analysis. For component two the variance is accounted as much variance leftover and as much as it could, and so on for the rest of the components. In Table (5.5), column 3 shows the percentage of the variance for each component, while column 4 shows the cumulative for these percentages. The components are listed in descending order of variance, for example, against component number three, an accumulative has a value of 36.249% is shown, this means that the three first components together count for this value.

The extraction sums of squared loadings table are similar to the initial eigenvalues table; however, it shows only components with eigenvalues equal to 1 or higher. This contributes to the determination of the number of rows for the extraction sums of squared loadings. In our case, 14 principal components that have eigenvalues higher than one are created. The computed percentage of the cumulative variance of the 14 components is equal to 65.571% as shown in column 7. Thus, it can be said that according to the calculations, the 53 indicators are grouped in 14 components, where those 14 components count for 65.571% of the total variance while the other components count for the remaining 34.429%.

Table (5.5) Total Variance Explained for the Indicators

Component (Groups)	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total Variance	% of Variance	Cumulative Variance %	Total Variance	% of Variance	Cumulative Variance %
1	14.064	26.535	26.535	14.064	26.535	26.535
2	2.900	5.472	32.007	2.900	5.472	32.007
3	2.248	4.242	36.249	2.248	4.242	36.249
4	1.937	3.655	39.905	1.937	3.655	39.905
5	1.763	3.326	43.230	1.763	3.326	43.230
6	1.692	3.192	46.423	1.692	3.192	46.423
7	1.548	2.921	49.344	1.548	2.921	49.344
8	1.488	2.808	52.152	1.488	2.808	52.152
9	1.403	2.647	54.799	1.403	2.647	54.799
10	1.335	2.520	57.319	1.335	2.520	57.319
11	1.176	2.218	59.537	1.176	2.218	59.537
12	1.131	2.135	61.672	1.131	2.135	61.672
13	1.057	1.994	63.665	1.057	1.994	63.665
14	1.010	1.906	65.571	1.010	1.906	65.571
15	0.930	1.755	67.326			
16	0.910	1.717	69.043			
17	0.865	1.633	70.676			
18	0.822	1.550	72.226			
19	0.759	1.433	73.658			
20	0.742	1.399	75.058			
21	0.731	1.379	76.437			
22	0.710	1.340	77.777			
23	0.657	1.240	79.017			
24	0.644	1.215	80.232			
25	0.596	1.124	81.356			
26	0.591	1.116	82.472			
27	0.573	1.080	83.552			
28	0.571	1.077	84.630			
29	0.522	0.984	85.614			
30	0.508	0.959	86.573			

Table (5.5) Total Variance Explained for the Indicators (Continue)

Component (Groups)	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total Variance	% of Variance	Cumulative Variance %	Total Variance	% of Variance	Cumulative Variance %
31	0.487	0.919	87.492			
32	0.471	0.888	88.380			
33	0.450	0.850	89.230			
34	0.410	0.774	90.004			
35	0.401	0.757	90.762			
36	0.385	0.727	91.488			
37	0.367	0.692	92.180			
38	0.353	0.666	92.845			
39	0.336	0.634	93.479			
40	0.333	0.628	94.107			
41	0.327	0.618	94.725			
42	0.303	0.572	95.297			
43	0.296	0.559	95.856			
44	0.288	0.544	96.400			
45	0.266	0.502	96.902			
46	0.257	0.485	97.387			
47	0.237	0.446	97.834			
48	0.225	0.425	98.259			
49	0.207	0.391	98.650			
50	0.201	0.380	99.030			
51	0.185	0.349	99.379			
52	0.173	0.327	99.706			
53	0.156	0.294	100.000			

d) Scree Plot

The scree plot is another method to decide the number of components that can be created from the data set. As shown in Figure (5.14), the scree plot shows eigenvalues in Y-axis, and it orders them from highest to lowest against all components in X-axis. The origin line is set to eigenvalue value 1, where 1 is the cutoff point for the selection of components number, as discussed before. The origin line at 1 shows 14 components according to

their eigenvalues; however, the main points of interest are two things: first the steep slope (elbow); second where the curve starts to flatten. It can be seen that between components one and two where the slope of the curve is clearly leveling off (the “elbow”) are the components that must be generated by the analysis while the curve starts to flatten between components 3 and 15 with an eigenvalue less than 1 for component 15.

Unluckily, both criteria, namely, total variance explained and scree plot, sometimes generate an unreasonably large quantity of components. In our case, a cut-off of an eigenvalue =1 gives a total of 14 components, while the scree plot suggests only two components due to the way the slope levels off. Hence, the decision of the number of components will be taken according to the strength of the relationships between components and indicators according to the factor rotation method in the next section.

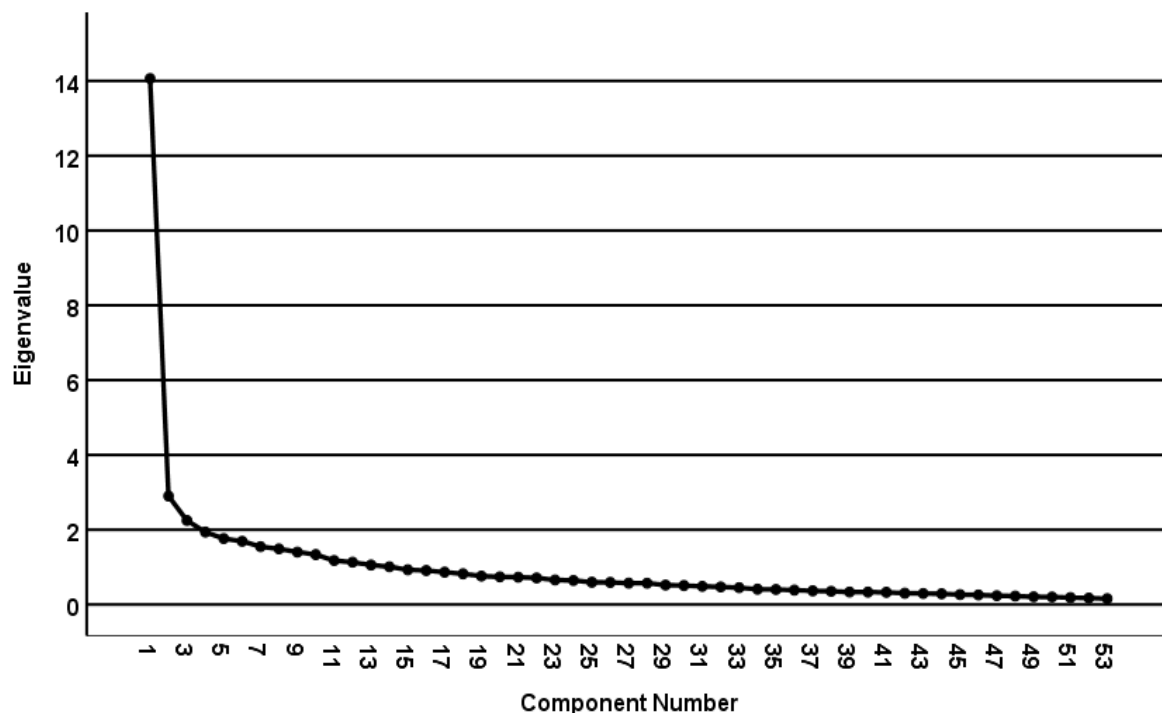


Figure 5.14: Scree Plot of BIM Adoption Components

e) Rotated Component Matrix

Table (5.6) shows the factor loading for each of the 53 indicators after rotation by the Varimax method. Varimax method is the most popular approach used by researchers, which gives the best parsimonious analytical solution (Harman, 1960). This minimizes the number of indicators by counting only indicators with high factor loadings in each component. The 53 indicators are distributed among 14 extracted components as supported previously by total variance explained test. The highest factor loading for each indicator is highlighted in bold in Table (5.6).

Table (5.6) Rotated Component Matrix for the Indicators

Indicator	Component													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TE1	.211	.042	.216	.227	.086	-.060	.613	.109	-.015	-.089	-.124	.215	.052	.025
TE2	.130	.016	.080	.075	.022	-.007	.668	.167	.094	-.120	.157	.305	.088	.148
TE3	.004	.164	.147	.059	.080	.193	.712	-.054	-.031	.213	-.011	-.044	-.017	-.029
TE4	.081	.145	.117	.119	.180	.208	.620	.018	.073	.220	.248	-.126	.041	.046
TE5	.191	.314	.025	.170	.046	.104	.286	.001	-.013	.104	.276	.519	-.046	.208
TE6	.184	.120	.016	.078	.077	.144	.109	.052	.025	.143	.065	.706	.165	-.080
TE7	.069	.267	.222	.071	-.114	.223	.188	-.033	.183	.588	-.102	.196	.036	.116
TE8	.141	.340	.086	.234	.148	.131	.257	-.015	.140	.438	.225	-.049	-.014	-.141
TE9	.120	.091	.072	.036	.043	.068	.249	.045	.165	.282	.632	.156	-.051	-.066
TE10	.024	.034	.026	.174	.102	.019	-.020	.156	-.082	.635	.223	.080	.099	.173
TE11	-.017	.041	.056	.065	.167	.176	.053	.022	.041	.145	.144	.113	.710	.063
TE12	.167	.206	.060	.108	.276	-.293	.122	.208	-.061	.310	.160	.299	.161	.081
TE13	.140	.219	.190	.059	.059	.024	.021	.067	-.025	-.005	.678	.013	.368	.049
PR1	.064	.546	.072	.281	.115	-.002	.120	.254	.003	.097	.192	.064	-.218	.038
PR2	.080	.539	.082	.030	.242	.095	.096	.268	.106	.080	.179	.038	-.174	-.051
PR3	.099	.678	.193	-.008	.149	.120	.007	.152	.037	.161	-.004	.180	.130	.107
PR4	.085	.580	.145	.000	.223	.232	.041	.100	.174	.187	.125	.149	.008	.033
PR5	.220	.237	.332	-.028	.290	.094	-.087	-.051	-.006	.059	.470	.171	-.046	.073
PR6	.272	.274	.157	.177	.483	.176	-.163	-.010	-.036	.087	.184	.313	-.032	.138
PR7	.162	.209	.204	.128	.714	.035	.060	.140	-.010	.119	.071	.028	.008	-.043
PR8	.090	.078	.061	.040	.744	.052	.149	.153	.196	.072	.034	.001	.079	-.046
PR9	.067	.227	-.167	-.010	.535	.087	.283	.053	.189	-.112	-.056	.101	.264	.266
PR10	.173	.351	-.012	.057	.499	.106	.052	-.004	-.149	-.121	.122	.000	.100	.297

Table (5.6) Rotated Component Matrix for the Indicators (Continue)

Indicator	Component													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PR11	.353	.542	.032	.323	.032	-.001	.123	-.056	.063	-.071	.087	-.038	.353	.117
PR12	.273	.654	.039	.089	.113	.057	.154	.035	.100	-.034	.019	.011	.241	.014
PE1	.582	.333	.014	.144	.107	.242	.128	-.024	-.045	-.059	.157	.222	-.041	.233
PE2	.689	.289	.093	-.038	-.039	.213	.100	.126	.074	-.095	.108	.081	.082	.153
PE3	.703	.083	.152	.102	.209	.055	-.053	.173	-.046	.276	.139	-.043	-.022	-.028
PE4	.605	-.049	.167	-.020	.294	.067	.102	.167	-.061	.346	.110	-.012	.059	-.081
PE5	.716	.139	-.027	.107	.073	.160	.163	.095	.258	-.001	.097	.100	-.059	.115
PE6	.573	.113	.265	-.020	.141	-.136	.092	.158	.292	-.006	-.035	.213	.099	-.024
PE7	.460	.208	.195	.009	.122	.116	.101	.116	.242	-.180	-.120	.209	.362	-.153
PE8	.097	.213	.646	.184	.065	.228	.237	.060	-.017	-.076	.163	.083	-.022	-.004
PE9	.210	.134	.608	.288	.148	.162	.082	.141	.016	.019	.246	.196	-.052	.018
PE10	.066	-.014	.627	.224	.217	.093	.144	.000	.061	.208	.058	-.014	.198	.072
EN1	.035	.070	.077	.745	.127	.116	.131	.140	.139	.121	.079	-.035	-.057	.184
EN2	.077	.075	.194	.778	.131	.166	.083	-.006	.114	.083	-.041	.103	.087	.080
EN3	-.003	.108	.251	.714	-.058	.078	.109	.157	.159	.100	.047	.070	.112	-.089
EN4	.072	.126	.221	.416	-.006	.266	.100	.058	.464	.045	.063	.276	.005	.109
EN5	.115	.101	.003	.200	.183	.037	.002	.003	.743	.069	.066	-.014	-.033	.077
EN6	.142	.111	.239	.199	-.071	.043	.032	.092	.547	-.105	.009	-.107	.286	.104
EN7	.100	.163	.566	.101	-.052	.023	.136	.083	.271	.157	-.021	-.310	.161	.232
EN8	.106	.058	.541	.119	.000	.168	.117	.047	.355	.158	.075	.064	-.115	.337
EN9	.241	.142	.464	.122	-.045	.123	.093	.173	.024	-.038	.100	-.047	.144	.512
EN10	.038	.052	.199	.122	.123	-.021	.055	.125	.192	.209	-.033	.007	.025	.682
OR1	.198	.141	.094	.373	.127	.643	.153	.086	.124	-.063	.048	.036	.063	.117
OR2	.099	.073	.259	.232	.176	.669	.106	.205	-.009	.134	.042	.003	-.009	.058
OR3	.145	.178	.143	.063	.046	.698	.114	.188	.040	.120	.118	.161	.202	-.041
OR4	.234	.237	.140	.007	-.060	.522	.047	.345	.202	.090	-.030	.122	.361	-.047
PO1	.192	.241	.057	.166	.133	.188	.134	.698	-.109	.039	-.004	.032	-.093	.116
PO2	.151	.156	.066	.112	.094	.081	.058	.810	.003	.098	-.024	-.032	.055	.136
PO3	.126	.038	.085	.024	.124	.245	-.045	.642	.334	-.005	.146	.116	.123	-.053
PO4	.255	-.077	.076	.163	.102	.232	-.010	.285	.226	.154	.299	-.282	.252	.103

The pattern of factor loadings is examined in order to identify indicators with high complex structure. So, all factor loadings (correlations) less than 0.5, or any indicator with two values of factor loadings in two components or more (cross loading) must be eliminated. As factor loadings of more than 0.5 are considered very significant and must be retained (Hair et al., 1998; Hong et al., 2016) with reference to explained information in Chapter two. Accordingly, it is necessary to

remove indicators (PE7, PR10, PR6, TE8, TE12, PR5, PO4) because their values for factor loadings are less than 0.5. More additional two indicators are removed, EN9 and EN4, as they are loaded under two components or what it can be called cross loading. As shown in Table (5.7), all remaining 44 indicators are loaded strongly on one component each and with factor loading above 0.5.

Table (5.7): Rotated Component Matrix After Modifications

indicator	Component													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PE5	.716													
PE3	0.703													
PE2	0.689													
PE4	0.605													
PE1	0.582													
PE6	0.573													
PE7	0.460													
PR3		0.678												
PR12		0.654												
PR4		0.580												
PR1		0.546												
PR11		0.542												
PR2		0.539												
PE8			0.646											
PE10			0.627											
PE9			0.608											
EN7			0.566											
EN8			0.541											
EN2				0.778										
EN1				0.745										
EN3				0.714										
PR8					0.744									
PR7					0.714									
PR9					0.535									
PR10					0.499									
PR6					0.483									
OR3						0.698								
OR2						0.669								
OR1						0.643								
OR4						0.522								
TE3							0.712							
TE2							0.668							

**Table (5.7): Rotated Component Matrix After Modifications
(Continue)**

Component														
indicator	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TE4							0.620							
TE1							0.613							
PO2								0.810						
PO1								0.698						
PO3								0.642						
EN5									0.743					
EN6									0.547					
EN4				0.416					0.464					
TE10										0.635				
TE7										0.588				
TE8										0.438				
TE12										0.310				
TE13											0.678			
TE9											0.632			
PR5											0.470			
PO4											0.299			
TE6												0.706		
TE5												0.519		
TE11													0.710	
EN10														0.682
EN9			0.464											0.512

By reviewing the 14 components (groups) in Table (5.7), it can be noticed that there are many components (9 components) with a very small number of indicators (one, two or three), this leads to a conclusion that there is no strong correlation between the 14 groups. Especially, when the usual rule of greater than 1.0 communities does not seem to work the best.

The researcher has suggested that in order to proceed to the next step which is the CFA using AMOS software the number of indicators should be at least three. To clarify more, with two indicators or less the model would be unidentified and generates a negative degree of freedom. While, in the case of three indicators per component, the model would be just

identified with a degree of freedom equal to zero. Such models may affect the testing of the theory and may face a low-reliability problem (Hair et al., 2014).

A better approach is to consider the minimum four indicators per component so that a solution can be found with a positive degree of freedom and corresponding chi-square and goodness of fit value. In this case, the researcher decides to force SPSS 25 software to distribute the 53 indicators to 6 components as they have been distributed before in Chapter three in order to increase the correlation between the components. Hence, further analysis of 6 components is done as follows.

f) Rotated Component Matrix For 6 Components (Groups)

Table (5.8) shows the factor loading for each of the 53 indicators after rotation by the Varimax method. The 53 indicators are now distributed on six extracted components as decided by the researcher. The highest factor loading for each indicator is highlighted in bold in Table (5.8).

The pattern of factor loadings is examined in order to identify indicators with high complex structure. So, all factor loadings less than 0.5 or any indicator with two values of factor loadings in two components or more is eliminated. According to that, it is necessary to remove several indicators because their value for factor loading is less than 0.5 (shown with an underline in Table (5.8)). Moreover, more additional two indicators are removed, PE9 and PR12, as they are loaded under two components. As shown in Table (5.8), now the 6 components are showing more strong correlations, and all remaining 33 indicators are loading strongly on one component each and with factor loading above 0.5.

Table (5.8) Rotated Component Matrix for Six Components

Components						
Indicator	1	2	3	4	5	6
EN7	.675	-.017	.023	.071	.144	.205
EN8	.612	-.029	.204	.095	.135	.277
EN6	.577	.019	-.017	.148	.343	-.119
EN2	.565	.211	.367	.193	-.049	-.047
PE10	.558	.070	.194	.065	.020	.354
EN1	.552	.264	.294	.229	-.159	-.010
EN3	.535	.077	.358	.262	-.081	-.019
EN9	.510	.044	.098	.140	.301	.251
EN10	.510	.226	.010	.016	.033	.134
EN4	.507	.079	.378	.260	.162	-.027
EN5	<u>.484</u>	.245	-.006	.088	.184	-.078
PR7	.158	.646	.044	.136	.030	.309
PR8	.166	.623	-.012	.145	.048	.134
PR9	.098	.615	.133	.062	.255	-.172
PR10	.036	.604	.072	.033	.193	.124
PR6	.089	.507	.152	.138	.181	.367
PR2	.028	<u>.469</u>	.202	.261	.083	.207
PR3	.084	<u>.450</u>	.255	.230	.233	.182
TE12	.038	<u>.445</u>	.176	-.010	.081	.354
PR1	.116	<u>.442</u>	.312	.196	-.006	.182
PR12	.101	<u>.442</u>	.257	.127	<u>.424</u>	.016
PR4	.101	<u>.433</u>	.283	.263	.168	.222
TE3	.132	.096	.608	.031	-.019	.080
TE5	.001	.267	.601	.046	.232	.238
TE2	.128	.106	.541	.012	.284	.001
TE4	.237	.204	<u>.499</u>	.108	.015	.220
TE1	.213	.130	<u>.497</u>	-.023	.256	-.037
TE6	-.137	.143	<u>.466</u>	.180	.271	.154

Table (5.8) Rotated Component Matrix for 6 Components (Continue)

Components						
Indicator	1	2	3	4	5	6
TE7	.255	.009	<u>.438</u>	.184	.017	.255
PE8	.393	.028	<u>.398</u>	.143	.158	.299
TE8	.198	.281	<u>.397</u>	.158	-.033	.332
OR4	.149	.019	.195	.665	.376	.054
PO3	.171	.156	-.072	.647	.196	.096
OR3	.076	.025	.373	.631	.194	.164
PO2	.151	.275	-.072	.629	.074	.121
PO1	.069	.318	.103	.601	.081	.135
OR2	.266	.075	.301	.591	-.003	.187
OR1	.315	.134	.367	.509	.190	-.026
PO4	.369	.075	-.123	<u>.411</u>	.131	.258
TE11	.166	.167	.125	<u>.207</u>	.147	.074
PE2	.066	.111	.138	.243	.698	.248
PE7	.145	.159	.114	.224	.655	-.013
PE5	.150	.171	.156	.203	.612	.209
PE6	.219	.172	.025	.055	.600	.237
PE1	.033	.278	.329	.144	.526	.246
PR11	.258	.375	.255	.049	<u>.446</u>	.005
PE4	.056	.176	.008	.211	.292	.565
PE3	.105	.203	-.043	.234	.363	.560
PR5	.102	.275	.134	.010	.188	.557
TE9	.061	.093	.368	.080	.032	<u>.499</u>
TE10	.135	.180	.136	.190	-.247	<u>.467</u>
TE13	.136	.174	.139	.086	.212	<u>.447</u>
PE9	<u>.414</u>	.106	.313	.193	.158	<u>.435</u>

g) Reliability and validity analysis

Using SPSS 25 the final set of indicators were tested for reliability using Cronbach's coefficient alpha. A value of 0.70 or above indicates a reliable correlation (Xu et al., 2014; Masood et al., 2014). All indicators displayed good reliability in terms of Cronbach's alpha values. The final set of indicators, components, factor loadings, and alpha are summarized in Table (5.9).

Table (5.9): Cronbach's Alpha Values for the Final Set of Indicators

Component	Code	Description	Factor Loading	Alpha
Component 1 (Environment)	EN7	Best practices for constructability implementation.	0.675	0.843
	EN8	Comparative advantage.	0.612	
	EN6	Influence from partners who have adopted BIM.	0.577	
	EN2	Market demand.	0.565	
	PE10	Project team expectations.	0.558	
	EN1	Globalization and competitive strategies.	0.552	
	EN3	International flexibility/adaptability to market.	0.535	
	EN9	BIM benefits.	0.510	
	EN10	Enabling environment.	0.510	
	EN4	Competitive advantages in market (core/unique).	0.507	
Component 2 (Process)	PR7	Shared norms and collective expectations diffused through information exchange activities.	0.646	0.845
	PR8	Contractual sharing norm.	0.623	
	PR9	Leadership of senior management.	0.615	
	PR10	Shared liability between project participants.	0.604	
	PR6	Communication.	0.507	

Table (5.9): Cronbach's Alpha Values for the Final Set of Indicators
(Continue)

Component	Code	Description	Factor Loading	Alpha
Component 3 (Technology)	TE3	Data richness.	0.608	0.796
	TE5	Hardware equipment/Hardware upgrade.	0.601	
	TE2	Technological capability of organization.	0.541	
Component 4 (Organization and Policy)	OR4	BIM supporting organizational structure	0.665	0.839
	PO3	Project delivery modes.	0.647	
	OR3	Financial resources of organization.	0.631	
	PO2	Industry standards.	0.629	
	PO1	Regulation and policy.	0.601	
	OR2	Performance measures and benchmarking for continuous improvement.	0.591	
	OR1	Top management support.	0.509	
Component 5 (People -1)	PE2	Qualified cadres and experts to train BIM software.	0.698	0.825
	PE7	Level of awareness of BIM and the knowledge about BIM.	0.655	
	PE5	Software and technology training.	0.612	
	PE6	Interest in learning BIM.	0.600	
	PE1	Process and workflow training.	0.526	
Component 6 (People -2)	PE4	Supporting individual characteristics.	0.565	0.756
	PE3	Need for innovation, and diffusion of innovation	0.560	
	PR5	Desire to speed up the design process.	0.557	
				0.945

It must be noticed that the SPSS software re-organized the indicators differently than the original organization done in Chapter three, and this according to the correlation between indicators. For example, component one shows all indicators of "Environment" (EN) component with the addition of one more indicator from "People" (PE) component which is PE10 (desire for professional development). Naming the components will be according to the majority of the indicators in each component as given before in Chapter three as most of them will be sharing the same background idea.

5.3.3 Confirmatory Factor Analysis (CFA)

The next step after the EFA is the confirmatory factor analysis (CFA). CFA main goal is to validate the research measurement model (Chen et al., 2016). The measurement model or sometimes it is called the outer model relates observed variables (indicators) to their latent variables (components or constructs). Within the measurement model, one observed variable can only be related to one latent variable. Each latent variable must contain at least one observed variable. The way latent and observed variables are related indicated by a single-headed arrow for one direction relation, this arrow can be either reflective (as in this research model) or formative. The graphical representation of structural equation models is explained before in Chapter two.

The CFA test is done in AMOS software by drawing the measurement model as shown in Figure (5.15). In this research, observed variables are the indicators of BIM adoption, which are 33 indicators resulted from EFA in the previous step. Rectangles represent indicators and associated with respective measurement errors. Measurement errors represent errors in the answer for every single respondent (unreliability), and it is added automatically by AMOS software with a default regression value of 1. Latent variables are the groups that those indicators are grouped in, which are the six groups resulted from EFA test. Ovals represent latent variables and related to respective indicators by single direction reflective arrow. In order for AMOS software to run, one relationship from each latent variable to any of its respective Indicators must have a restricted regression value of 1. A double-headed arrow indicates covariance relationships, is drawn between all latent variables.

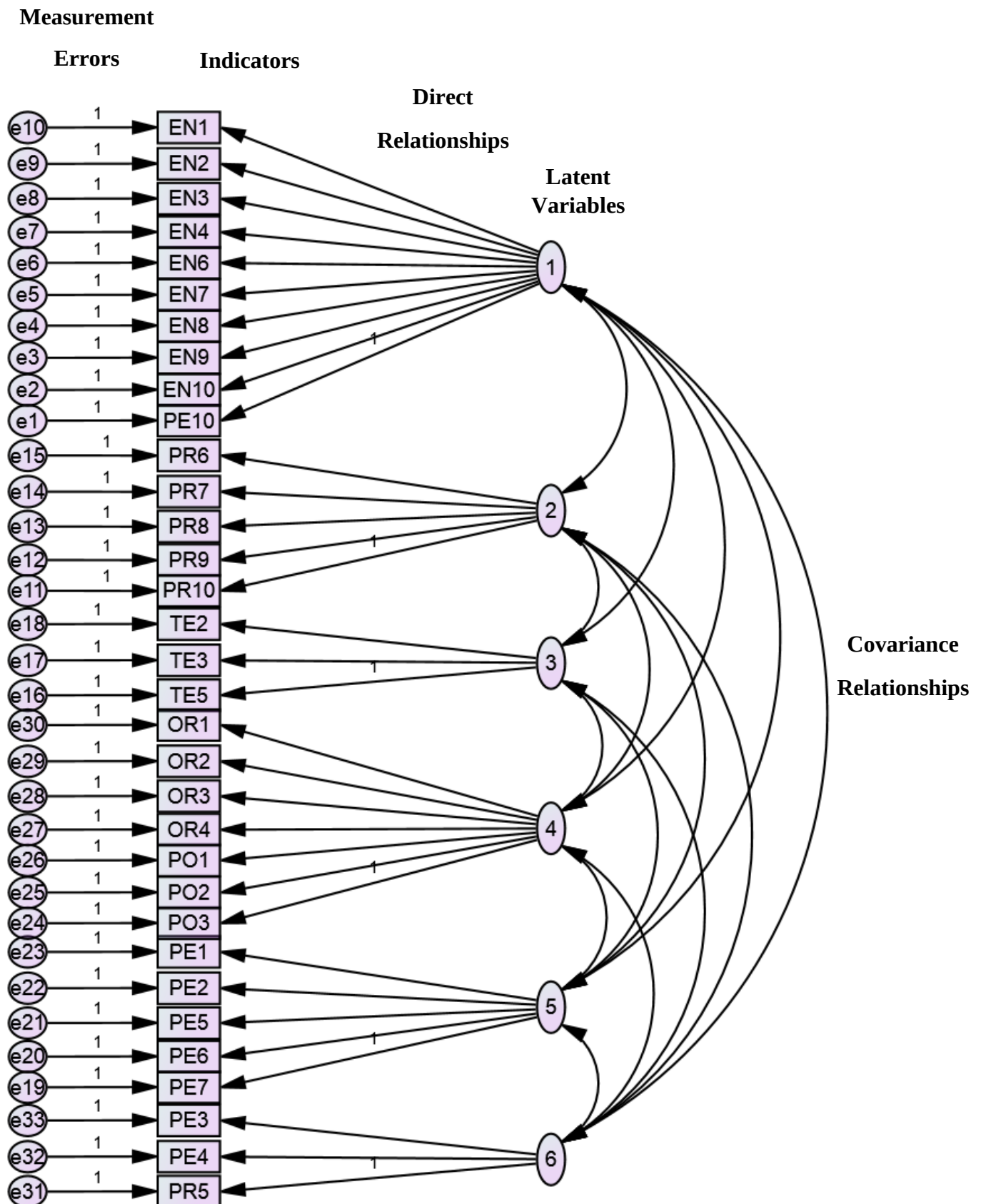


Figure 5.15: BIM Adoption Measurement Model

The next step is to run the AMOS software for the previously explained measurement model. The researcher instructs AMOS to calculate the standardized estimates (factor loadings) for all variables in the model. The output showing the factor loading for every indicator in the measurement model and it is presented in Figure (5.16). The factor loading for every indicator is shown near the arrow pointing it. Moreover, the values on double-headed arrows indicate estimates of correlations among latent variables.

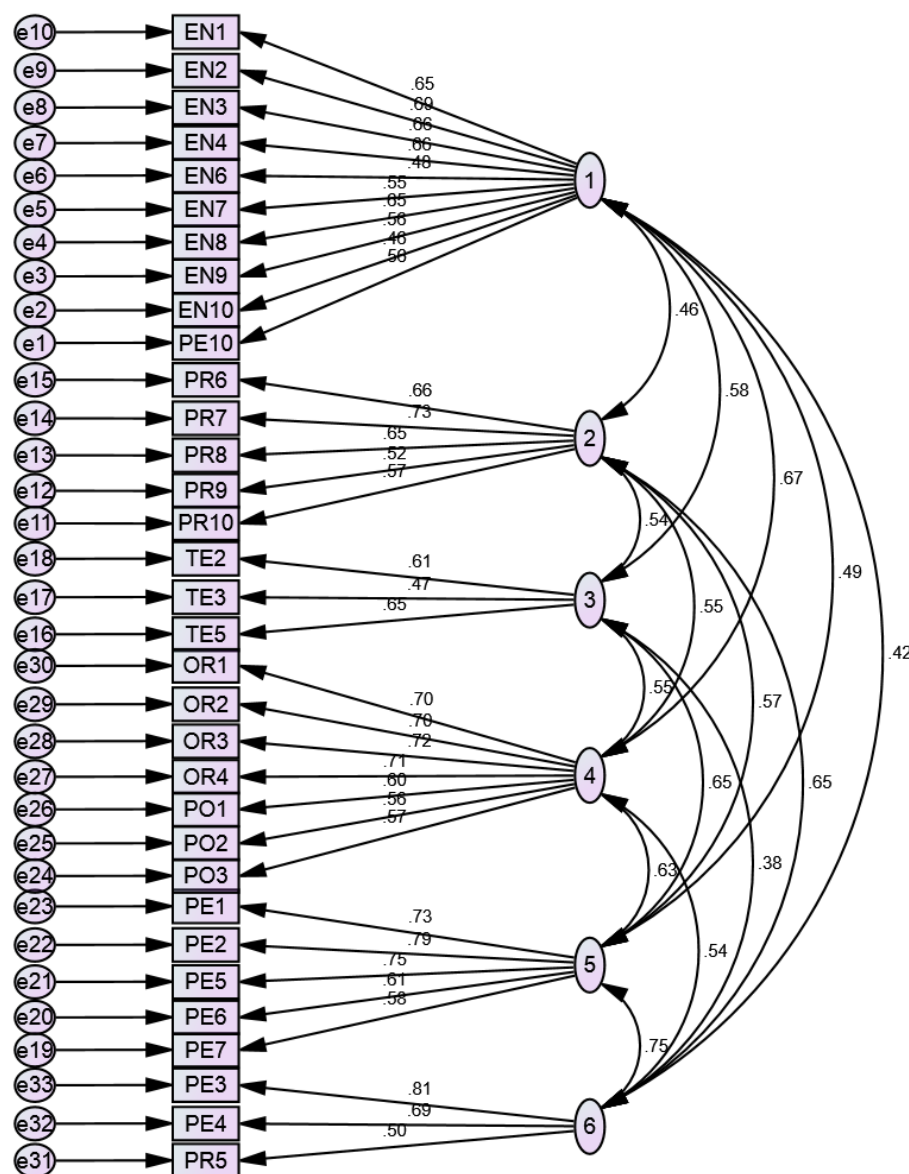


Figure 5.16: The Factor Loading for Every Indicator in the Measurement Model for BIM Adoption

Next is to check the fit indexes scored for the measurement model and to compare with the required cut-off points shown in Table (5.10). Table (5.11) shows a comparison between cutoff points and BIM adoption measurement model output of AMOS software.

Table (5.10): Fit Indexes Cutoff Points

Index Name	Full Index Name	Value	Sources
CMIN/DF	Minimum Discrepancy divided by its Degrees of Freedom	≤ 3.0	Hair et al., (2009)
GFI	Goodness of Fit Index	> 0.85	Maruish, (2004)
PGFI	Parsimony Goodness of Fit Index	≥ 0.5	Mulaik et al., (1989)
RMR	Root Mean Square Residual	≤ 0.1	Garson, (2014)
TLI	Tucker-Lewis coefficient	≥ 0.9	Bentler and Bonett, (1980)
RMSEA	Root Mean Square Error of Approximation	< 0.10	Steiger, (2007)
CFI	Incremental Measure of Comparative Fit Index	> 0.95	Hair et al., (2009)
AGFI	Adjusted Goodness of Fit Index	> 0.8	Maruish, (2004)

Table (5.11): Measurement Model Fit Results

Fit Index	Recommended Value	Measurement Model Value	Fit Index	Recommended Value	Measurement Model Value
CMIN/DF	≤ 3.0	2.501	TLI	≥ 0.9	0.770
GFI	> 0.85	0.778	RMSEA	< 0.10	0.074
PGFI	≥ 0.5	0.666	CFI	> 0.90	0.791
RMR	≤ 0.1	0.044	AGFI	> 0.8	0.741

From Table (5.11), it can be noticed that the indexes obtained by the research measurement model do not achieve the required level. In this case, the factor loading for every indicator is examined. Indicators with factor loadings less than 0.5 are eliminated since these indicators are considered

problematic in the model. The process of deleting indicators with factor loadings less than 0.5 must be done gradually, by deleting the lowest factor loading indicator one by one.

Appendix 8 presents the factor loadings of indicators after running the measurement model for the first time. As noticed the lowest factor loading is for the indicator (EN10); hence it must be deleted and rerun the new measurement model. The fit indexes are examined for the new measurement model.

As the model is still not achieving the model fitness stage, the process of deleting the indicators with factor loadings less than 0.5 is continued until the fitness indexes are achieved. In this research, the researcher runs four iterations for the measurement model until all indicators with factor loadings less than 0.5 are deleted. Appendix 8 presents the factor loadings of indicators for the four iterations. After those four iterations, four indicators were deleted (EN10, TE3, EN6, PR5). The fit indexes of the new measurement model are examined again, and the output presented in Table (5.12).

Table (5.12) Measurement Model Fit Results (after four iterations)

Fit Index	Recommended Value	Measurement Model Value	Fit Index	Recommended Value	Measurement Model Value
CMIN/DF	≤ 3.0	2.747	TLI	≥ 0.9	0.775
GFI	> 0.85	0.790	RMSEA	< 0.10	0.08
PGFI	≥ 0.5	0.658	CFI	> 0.90	0.799
RMR	≤ 0.1	0.044	AGFI	> 0.8	0.748

Results have seen a slight improvement in some of the fit index measurements; however, the model still not achieving the model fit requirements.

In this case, we look to the Modification Indices (MI) obtained by running the software for the last measurement model. MI are statistics that can be used to improve the model fit. Covariance values are the main targeted values in MI; it suggests covariance relations between measurement errors associated with indicators. The most crucial point is that the chosen covariances must be between two measurement errors categorized within the same latent variable.

Table (5.13) indicates the MI for pairs of correlated measurement errors, which reflect redundant items that exist in the model. The highest MI value is 93.01 which is greater than 15.0. The correlated measurement errors here are between e25 and e26. The associated indicators, the indicators are PO1 and PO2. The redundancies between these two items have caused the measurement model to have a poor fit. The solution of this is to covariance the e25 and e26 together with a double-headed arrow in order to remove this redundancy as shown in Figure (5.17).

Table (5.13): Modification Indices AMOS Output

Connected Errors			M.I.	Comment
e29	<-->	e30	25.897	MI > 15 indicates item OR1 and OR2 are redundant
e27	<-->	e28	22.332	MI > 15 indicates item OR3 and OR4 are redundant
e25	<-->	e30	16.048	MI > 15 indicates item PO2 and OR1 are redundant
e25	<-->	e28	20.845	MI > 15 indicates item PO2 and OR3 are redundant
e25	<-->	e26	93.010	MI > 15 indicates item PO1 and PO2 are redundant
e24	<-->	e25	16.851	MI > 15 indicates item PO2 and PO3 are redundant
e20	<-->	e23	15.229	MI > 15 indicates item PE6 and PE1 are redundant
e19	<-->	e20	28.241	MI > 15 indicates item PE6 and PE7 are redundant
e10	<-->	e27	17.722	Inapplicable (between different latent variables)
e9	<-->	e10	33.786	MI > 15 indicates item EN1 and EN2 are redundant
e4	<-->	e10	15.239	MI > 15 indicates item EN1 and EN8 are redundant
e4	<-->	e5	25.083	MI > 15 indicates item EN7 and EN8 are redundant
e3	<-->	e8	20.477	MI > 15 indicates item EN3 and EN9 are redundant

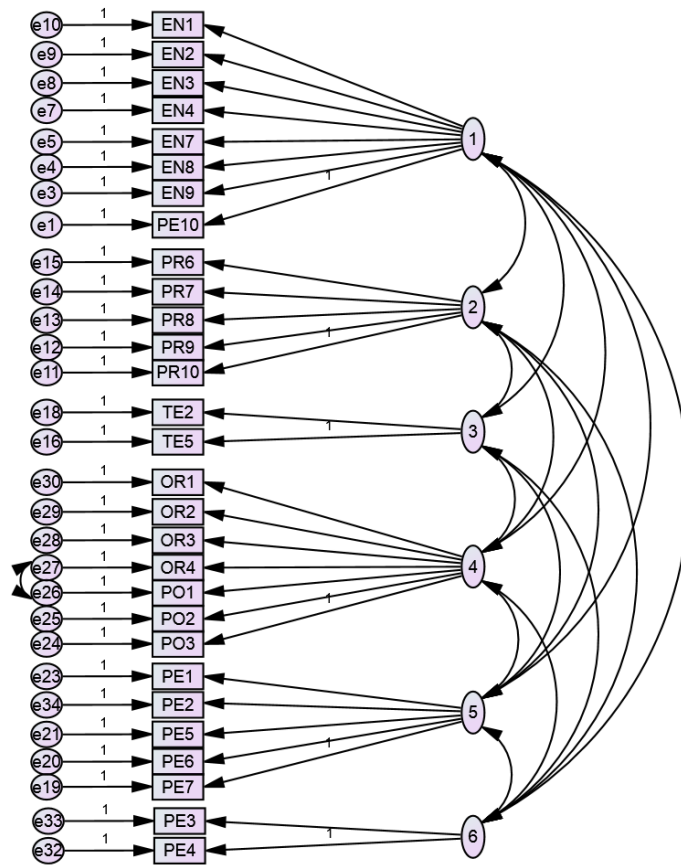


Figure 5.17: The New Measurement Model After e25 and e26 are Set as “Free Estimate”

The fitness indexes for the model are tested again and compared with the required minimum values. If the model is still not fit, the suggested MI in Table (5.13) are done one by one in descending order of their values. For BIM adoption measurement model tested for this research, all MI are done, and the model fit test shows the results in Table (5.14).

Table (5.14) Measurement Model Final Fit Results

Fit Index	Recommended Value	Measurement Model Value	Fit Index	Recommended Value	Measurement Model Value
CMIN/DF	≤ 3.0	1.691	TLI	≥ 0.9	0.910
GFI	> 0.85	0.881	RMSEA	< 0.10	0.051
PGFI	≥ 0.5	0.673	CFI	> 0.90	0.926
RMR	≤ 0.1	0.033	AGFI	> 0.8	0.845

The results of the final measurement model, shown in Figure (5.18), indicate that all fitness indexes values are meeting all goodness of fit recommended values. Hence, it can be said that the model is fit and ready to be used in the final stage which is the structural model stage.

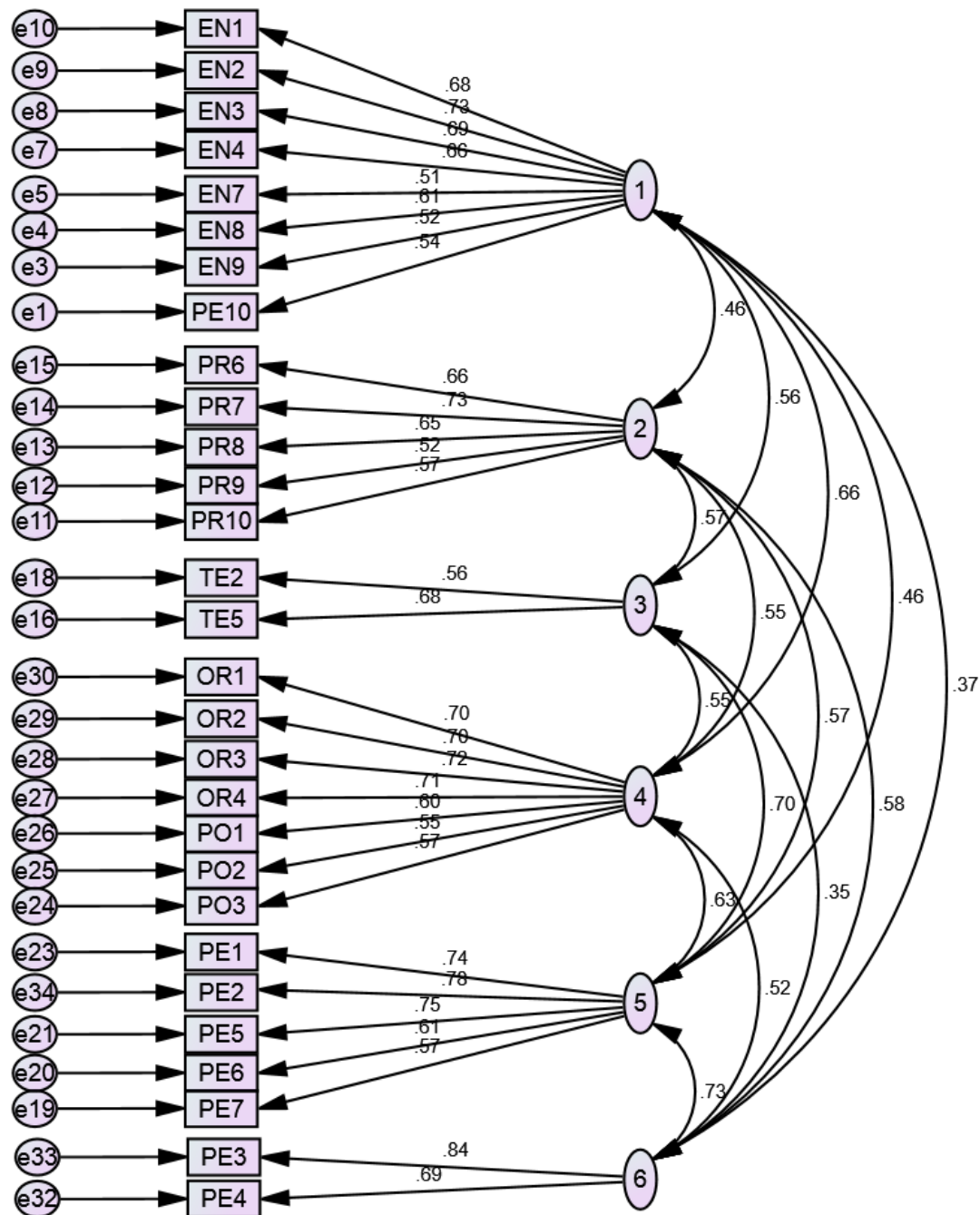
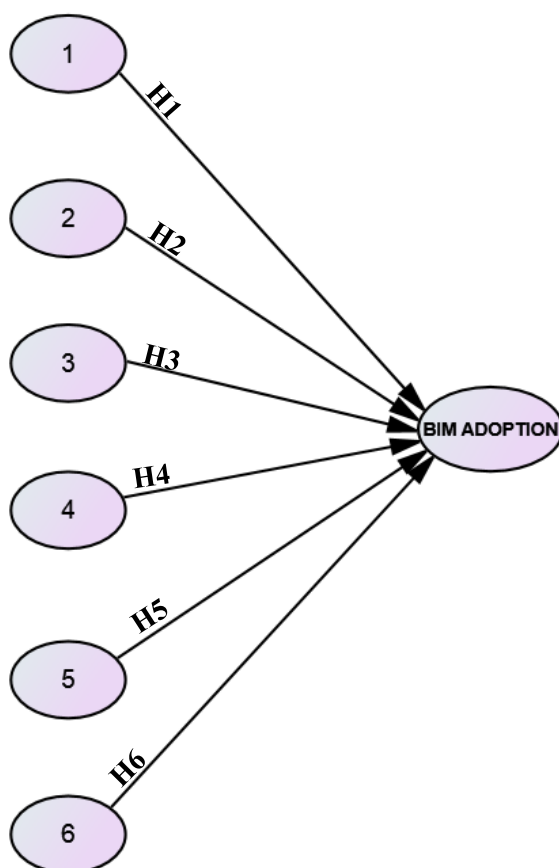


Figure 5.18: Final Measurement Model

5.3.4 Structural Model

Structural Model or called the inner model is a model to test and validate the relationships between latent variables only (Ngowtanasawan, 2017). In this research, after the measurement model was constructed and confirmed, a visual path diagram representing hypothesized relationships among exogenous and endogenous latent variables is presented in Figure (5.19). The path diagram shows six exogenous latent independent components related by straight single-head arrows with one endogenous latent dependent component, which is the BIM adoption in the Bahraini construction industry.



Hypothesis 1: Environment-related indicators will have a positive effect on BIM adoption.

Hypothesis 2: Process-related indicators will have a positive effect on BIM adoption.

Hypothesis 3: Technology-related indicators will have a positive effect on BIM adoption.

Hypothesis 4: Organization-related indicators will have a positive effect on BIM adoption.

Hypothesis 5: Policy-related indicators will have a positive effect on BIM adoption.

Hypothesis 6: People-related indicators will have a positive effect on BIM adoption.

Figure 5.19: Path Diagram of BIM Adoption Model

Six hypotheses are proposed according to the final path diagram shown in Figure (5.19) and explained in Table (5.15) below.

Table (5.15): Research Model Hypothesis

Hypothesis	Relationship	Indicators Included	Factor Name
H1	Factor 1 → BIM Adoption	EN1, EN2, EN3, EN4, EN7, EN8, EN9, PE10	Environment
H2	Factor 2 → BIM Adoption	PR6, PR7, PR8, PR9, PR10	Process
H3	Factor 3 → BIM Adoption	TE2, TE5	Technology
H4	Factor 4 → BIM Adoption	OR1,OR2,OR3,OR4, PO1, PO2, PO3	Organization and Policy
H5	Factor 5 → BIM Adoption	PE1,PE2,PE5,PE6, PE7	People (1)
H6	Factor 6 → BIM Adoption	PE3, PE4	People (2)

The next step is to draw the structure model in AMOS software. The structural model is similar to the measurement model with some modifications such as: removing all the covariances between latent components, adding an error to the endogenous latent component (BIM Adoption), and adding the only indicator to the BIM adoption component which is AD1. Based on the measurement model and the path diagram, an SEM of BIM adoption in the Bahraini construction industry is proposed and shown in Figure (5.20).

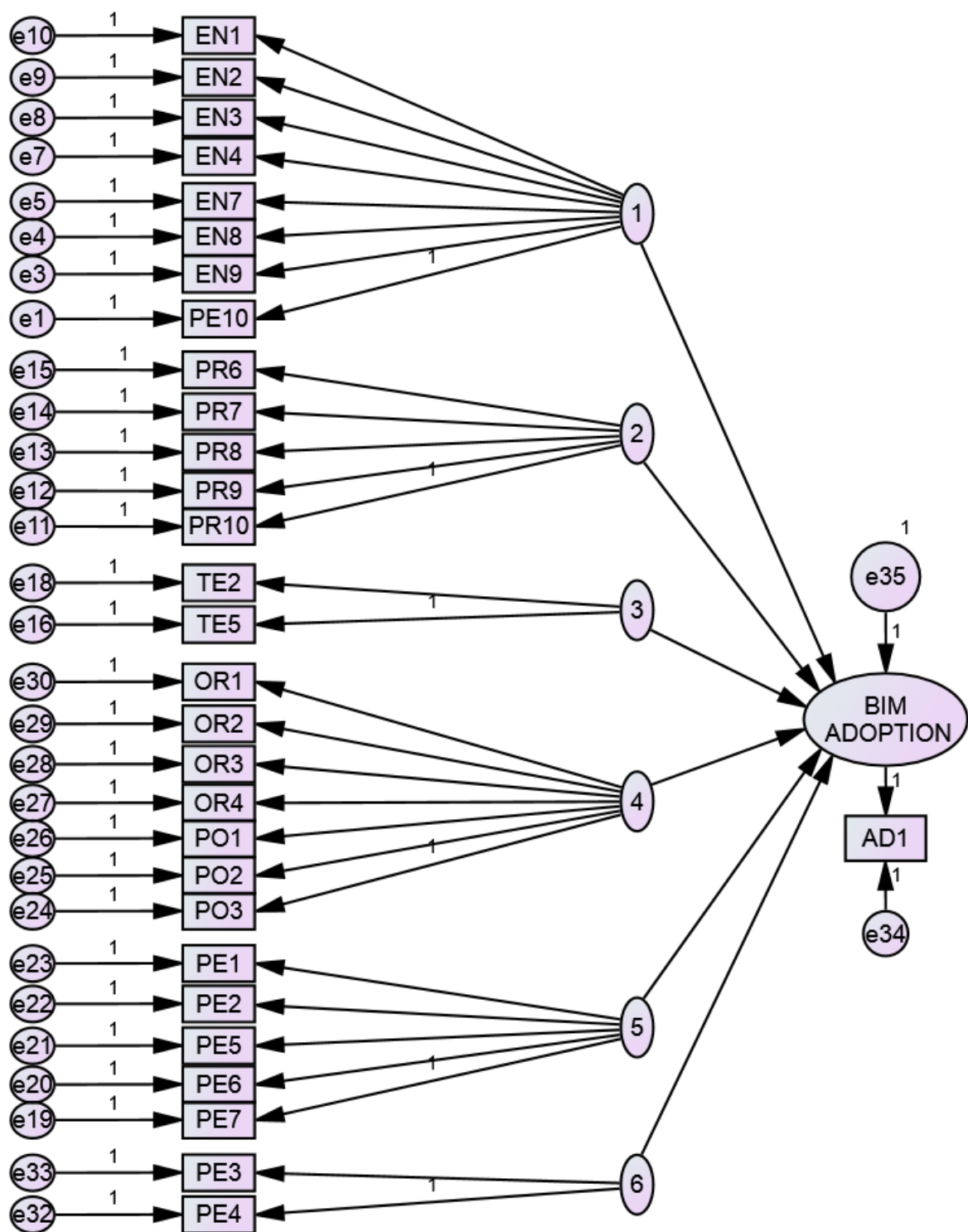


Figure 5.20: BIM Adoption Structural Model

The next step is assessing the strength of the relationships between latent components by testing the model hypotheses. The path coefficient is determined by the regression weights shown in Table (5.16). Constructs with a Critical Ratio (C.R) above 1.96 are considered to be statistically significant in the model (Hair et al., 2014; Enegbuma et al., 2015).

Out of the six hypotheses generated, two are found to be statistically significant while the remaining are found to be statistically insignificant in this model. The two significant hypotheses are environment and people (2) components, which have a positive impact on BIM adoption in the Bahraini construction industry with C.R. values of 2.478 and 3.623, respectively. The SEM hypotheses testing is shown in Figure (5.21) with the significant hypotheses (H1 and H6) shown in bold.

Table (5.16): Research Model Hypotheses Testing

Endogenous Component		Factor Name		Regression Estimate	S.E.	C.R.	P
BIM ADOPTION	<---	1	Environment	0.280	0.113	2.478	0.013
BIM ADOPTION	<---	2	Process	-0.050	0.112	-0.448	0.654
BIM ADOPTION	<---	3	Technology	0.230	0.133	1.731	0.083
BIM ADOPTION	<---	4	Organization and policy	0.177	0.091	1.954	0.051
BIM ADOPTION	<---	5	People (1)	0.135	0.102	1.327	0.185
BIM ADOPTION	<---	6	People (2)	0.332	0.092	3.623	<0.001

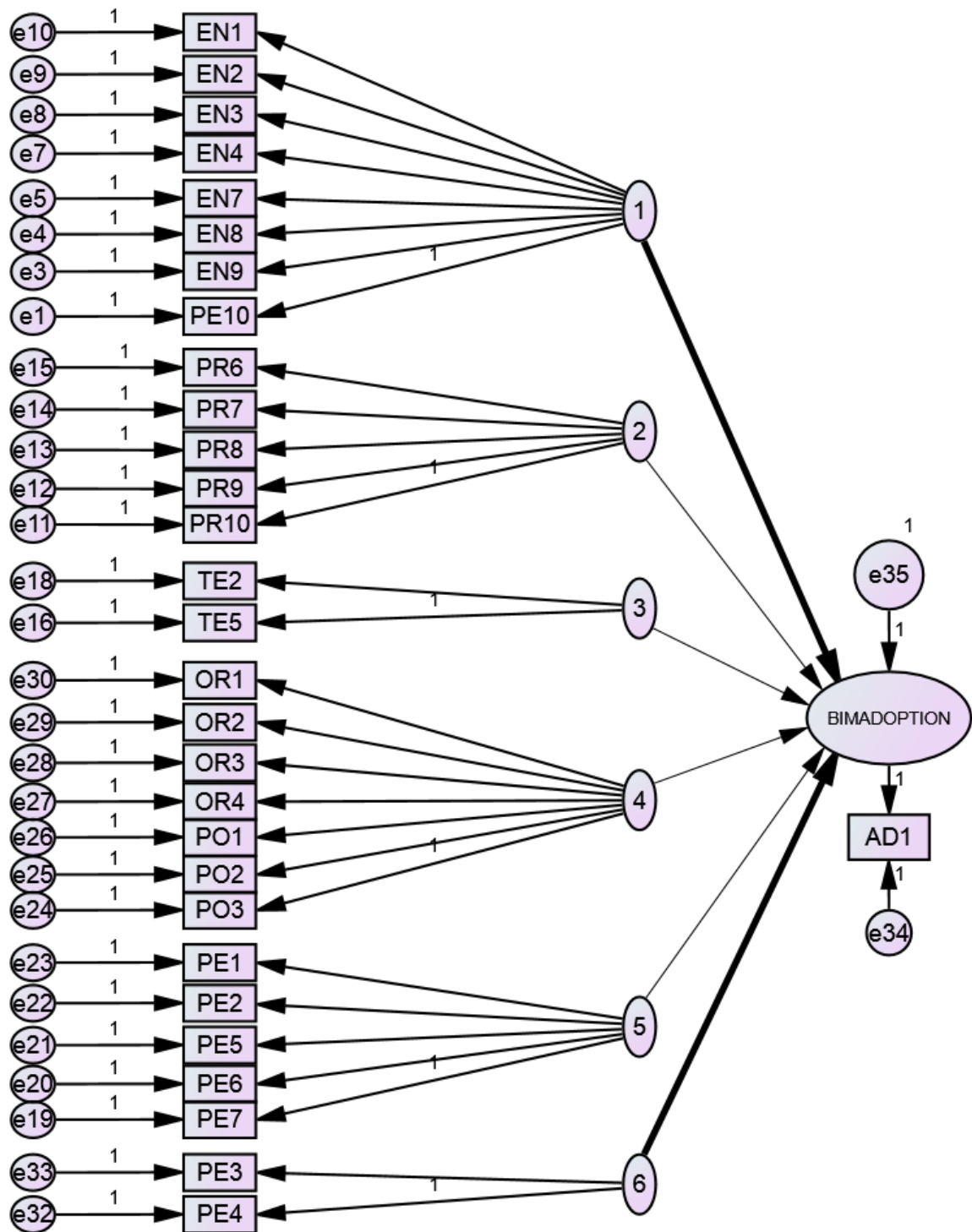


Figure 5.21: BIM Adoption Structural Model After Hypothesis Testing

According to the hypotheses results at Table (5.16) and Figure (15.21), it is found that the exogenous components "Processes", "Technology", "Organization", "Policy", and "People1" are not affecting BIM adoption in the model. The structural model is analyzed, and the output shows that the model is fit as shown in Table (5.17).

Table (5.17) Structural Model Fit Results

Fit Index	Recommended Value	Measurement Model Value	Fit Index	Recommended Value	Measurement Model Value
CMIN/DF	≤ 3.0	1.761	TLI	≥ 0.9	0.90
GFI	> 0.85	0.869	RMSEA	< 0.10	0.053
PGFI	≥ 0.5	0.673	CFI	> 0.90	0.915
RMR	≤ 0.1	0.037	AGFI	> 0.8	0.831

5.4 Data Analysis Part 3: Multivariate Analysis of Variance (MANOVA)

When a multivariate study design involves a single set of responses, along with one or more grouping of variables, then Multivariate Analysis of Variance (MANOVA) would be conducted (Huberty and Olejnik, 2006). MANOVA is merely an Analysis of variance (ANOVA) with several dependent variables. That is to say, ANOVA examines the statistical differences on one continuous dependent variable by an independent variable (French et al., 2008), while MANOVA assesses the statistical significance of the effect of one or more independent variables on a set of two or more dependent variables (Weinfurt, 1995). The advantage of the MANOVA, as opposed to ANOVA, lies in the fact that it considers correlations between variables which results in more productive use of the information contained in the data. Moreover, the combination of dependent variables may represent a variable that cannot be measured directly.

One of the main applications of the MANOVA is multivariate comparison testing where parameters for the various categories of a factor are tested to be significantly different or not. For example, we may conduct a study where we try to find a relationship between 'annual income' and 'position' together by 'level of education'. In that case, 'annual income' and 'position' are the two dependent variables, and we hypothesize that both together are affected by the 'level of education'.

There are many test-statistics for a MANOVA, SPSS 25 software displays the most common four tests of significance: Wilks Lambda test; Hotelling-Lawley's Trace test; Pillai's Trace test and Roy's greatest root test. Pillai's Trace test is considered to be the most powerful and robust

statistic for general use, Olson (1974) stated that Pillai's trace is more robust than the other statistics to violations of model assumptions. Pillai's Trace test is a positive valued statistic ranging from 0 to 1. Pillai's trace statistic, $V(s)$, is defined as follows (Pillai, 1955):

$$\text{Pillai's trace} = \text{trace}[H(H + E)^{-1}] = \sum_{i=1}^q \frac{\lambda_i}{1 + \lambda_i} \quad (5.1)$$

Where: **H** is the hypotheses matrix; **E** is the error matrix; **H+E** is the total amount of variance; λ_i is the eigenvalues for each variable.

In general, small p-values (below .05) mean that Pillai's returned a significant result (that there is a difference between the levels of the independent variable and the dependent variables) hence, the hypotheses is accepted; while, p-values higher than 0.05 will result rejecting the null hypothesis (Brown, 2011).

In this section, MANOVA is used to assess the effect of the collected results from the descriptive analysis (Section 5.2) on the indicators driving for BIM adoption in the Bahraini construction industry as shown in Figure (5.22).

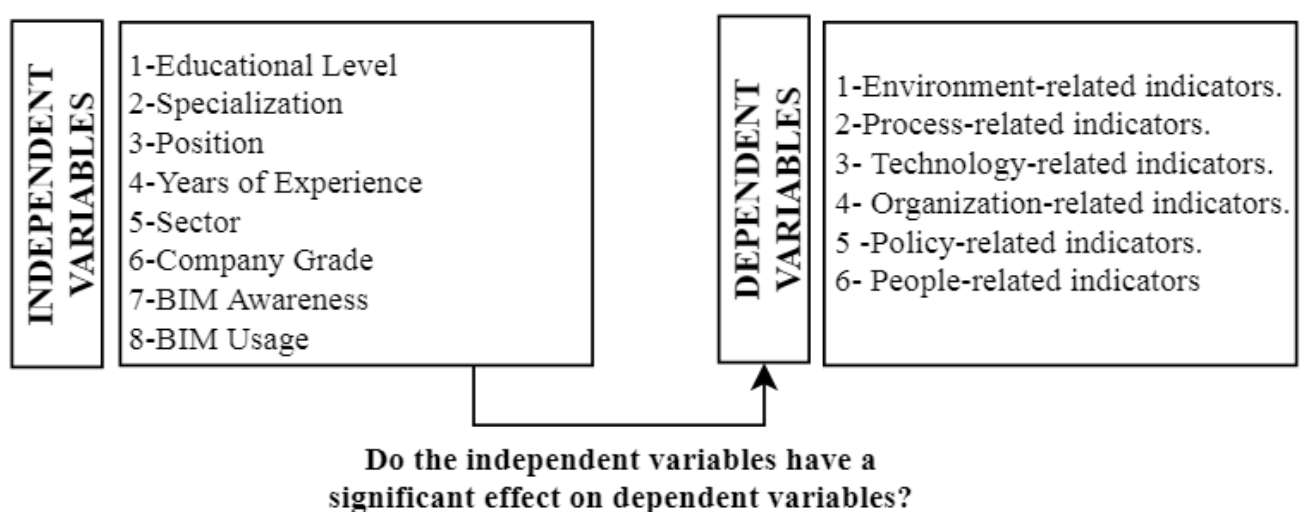


Figure 5.22: MANOVA Analysis Diagram

5.4.1 The effect of the educational level on BIM adoption components:

The MANOVA analysis is applied to test the effect of the "Educational level" on the six components of BIM adoption in the Bahraini construction industry. Table (5.18) shows the results of MANOVA analysis using SPSS 25 software.

Table 5.18: MANOVA Analysis for the Effect of the Educational Level on Components

Independent Variable	Dependent Variable	p-value (Sig.)	Decision (0.05)
Educational Level	Technology	0.859	Reject
	Process	0.179	Reject
	People	0.013	Accept
	Environment	0.712	Reject
	Organization	0.264	Reject
	Policy	0.355	Reject

Tests of the hypotheses show no significant effect for "Education level" on "Technology", "Process", "Environment", "Organization", and "Policy" as all p-values for these components are higher than the recommended p-value of 0.05. Hence, the null hypotheses of the significant effect of "Education level" on "Technology", "Process", "Environment", "Organization", and "Policy" are rejected. However, the null hypotheses that there is a significant effect of "Educational level" on "People related indicators" is accepted as the results of Table 5.18 shows that there is a significant interaction effect of "Educational level" on "People related indicators" with a p-value of 0.013.

Since the significant effect of "Educational level" on "People related indicators" is indicated, each of the ten indicators included in the "People component" will be examined to see if there is a significant impact on them separately. By the same criterion of p-value less than 0.05, the only significant result is for the effect of "Educational level" on indicator number eight which is "Observable large productivity gain" with a p-value of 0.042 (< 0.05).

5.4.2 The effect of the specialization on BIM adoption components

In this subsection, the MANOVA analysis is applied to test the effect of the "Specialization" on the six components of BIM adoption as shown in Table 5.19. Tests of the hypotheses show a significant effect for "Specialization" on the "Process", and "People" components only with p-values of 0.026 and 0.025, respectively. The p-values for these components are lower than the recommended p-value of 0.05. Hence, the null hypotheses of the significant effect of "Specialization" on the "Process", and "People" are accepted. Moreover, the null hypotheses that there is a significant effect of "Specialization" on "Technology", "Environment", "Organization", and "Policy" components are rejected as the results of Table (5.19) shows.

Table 5.19: MANOVA Analysis for the Effect of the Specialization on BIM Adoption Components

Independent Variable	Dependent Variable	p-value (Sig.)	Decision (0.05)
Specialization	Technology	0.770	Reject
	Process	0.026	Accept
	People	0.025	Accept

Table 5.19: MANOVA Analysis for the Effect of the Specialization on BIM Adoption Components (Continue)

Independent Variable	Dependent Variable	p-value (Sig.)	Decision (0.05)
Specialization	Environment	0.061	Reject
	Organization	0.345	Reject
	Policy	0.537	Reject

The indicators for "Process" and "People" components are examined to test the significant impact of "Specialization" on them separately. By the same criterion of p-value less than 0.05, Table (5.20) shows only the indicators with significant p-values. The indicators number 5,7, and 11 of the "Process" components have significant p-values 0.000, 0.015, 0.017, respectively. Moreover, the indicators number 1, 7, 9, and 10 of the "People" components, are significant with p-values 0.002, 0.010, 0.018, and 0.015, respectively.

Table 5.20: MANOVA Analysis for the Effect of the Specialization on Process and People Indicators

Component	Indicator Code	Indicator	p-value (Sig.)
Process	PR 5	Desire to speed up the design process.	0.000
	PR7	Shared norms and collective expectations diffused through information exchange activities.	0.015
	PR11	Providing guidance on use of BIM.	0.017

Table 5.20: MANOVA Analysis for the Effect of the Specialization on Process and People Indicators

Component	Indicator Code	Indicator	p-value (Sig.)
People	PE 1	Process and workflow training.	0.002
	PE 7	Level of awareness of BIM and the knowledge about BIM.	0.010
	PE 9	Professional development.	0.018
	PE 10	Project team expectations.	0.015

5.4.3 The effect of the position on BIM adoption components

To test the effect of the "Position" on BIM adoption indicators MANOVA test is applied using SPSS 25 software and the results are shown in Table (5.21). Tests of the hypotheses show a significant effect for respondents' "Position" on "People", and "Organization" components only. The p-values for these components are lower than the recommended p-value of 0.05 with p-values of 0.026 and 0.009, respectively. Hence, the null hypotheses of the significant effect of respondents' "Position" on the "People", and "Organization" are accepted. Moreover, the null hypotheses that there is a significant effect of respondents' "Position" on "Technology", "Process", "Environment", and "Policy" components are rejected.

Table 5.21: MANOVA Analysis for the Effect of the Position on BIM Adoption Components

Independent Variable	Dependent Variable	p-value	Decision (0.05)
Position	Technology	0.255	Reject
	Process	0.063	Reject
	People	0.026	Accept
	Environment	0.149	Reject
	Organization	0.009	Accept
	Policy	0.481	Reject

To determine which of the indicators of the "People" and "Organization" components are affected by respondents' "Position", MANOVA analysis is applied to them separately. Using the same criterion of p-value less than 0.05, Table (5.22) shows only the indicators with significant p-values. In the "People" component, indicators number 1, 4, 6, 7, 9, and 10 are significant with p-values 0.037, 0.048, 0.028, 0.007, 0.042 and 0.026, respectively. In the "Organization" component, two indicators only have significant p-values which are indicator 1 "Top management support", and 4 "An organizational structure that supports BIM" with p-values of 0.040 and 0.024, respectively.

**Table 5.22: MANOVA Analysis for the Effect of the Position on
People and Organization Indicators**

Component	Indicator Code	Indicator	p-value (Sig.)
People	PE 1	Process and workflow training.	0.037
	PE 4	Supporting individual characteristics.	0.048
	PE 6	Interest in learning BIM.	0.028
	PE 7	Level of awareness of BIM and the knowledge about BIM.	0.007
	PE 9	Professional development.	0.042
	PE 10	Project team expectations.	0.026
Organization	OR 1	Top management support.	0.040
	OR 4	BIM supporting organizational structure	0.024

5.4.4 The effect of the years of experience on BIM adoption components

The null hypothesis of the effect of the "Years of experience" is accepted for the "Environment" component only with a p-value of 0.038, while the other hypotheses are rejected for the rest of the components with p-values shown in Table (5.23). MANOVA analysis is applied to the "Environment" related indicators separately. Only one indicator has a significant p-value of 0.023 with respect to the criterion of p-value less than 0.05, which is indicator 10 "Enabling environment".

Table 5.23: MANOVA Analysis for the Effect of the Years of Experience on BIM Adoption Components

Independent Variable	Dependent Variable	p-value	Decision (0.05)
Years of Experience	Technology	0.688	Reject
	Process	0.596	Reject
	People	0.525	Reject
	Environment	0.038	Accept
	Organization	0.296	Reject
	Policy	0.845	Reject

5.4.5 The effect of the sector on BIM adoption components

The majority of the respondents are working in the private sector, with about 86 % of the total respondents (referring to Section 5.2.5). The MANOVA analysis is applied to test the effect of the "Sector" on the six components. Table (5.24) shows the results of MANOVA analysis using SPSS 25 software. All components show a significant p-value except the "Process" component which had a p-value of 0.492.

Since the significant effects of the "Sector" on "Technology", "People", "Environment", "Organization", and "Policy" components are shown, the indicators included in these components will be examined to see if there is a significant impact on each indicator or not. By the same criterion of p-value less than 0.05, Table (5.25) shows the results for MANOVA analysis on each of the indicators. The table shows that the "Sector" has a significant effect on all listed indicators of the five components.

Table 5.24: MANOVA Analysis for the Effect of the Sector on BIM Adoption Components

Independent Variable	Dependent Variable	p-value	Decision (0.05)
Sector	Technology	0.004	Accept
	Process	0.492	Reject
	People	0.005	Accept
	Environment	0.001	Accept
	Organization	0.007	Accept
	Policy	0.001	Accept

Table 5.25: MANOVA Analysis for the Effect of the Sector on Technology, People, Environment, Organization, and Policy Indicators

Component	Indicator Code	Indicator	p-value (Sig.)
Technology	TE 7	Automation	0.008
	TE 9	Hardware equipment/ Hardware upgrade	0.012
	TE 11	Uninterrupted power and a strong Internet	0.000
	TE 12	Awareness of the technology among industry stakeholders	0.024
People	PE 4	Supporting individual characteristics	0.010
	PE 6	Interest in learning BIM	0.000
	PE 7	level of awareness of BIM and the knowledge about BIM	0.080
	PE 10	Project team expectations	0.080

**Table 5.25: MANOVA Analysis for the Effect of the Sector on
Technology, People, Environment, Organization, and Policy
Indicators (Continue)**

Component	Indicator Code	Indicator	p-value (Sig.)
Environment	EN 4	Competitive advantages in market	0.001
	EN 5	Pressure from competitors	0.001
	EN 6	Influence from partners who have adopted BIM	0.002
	EN 7	Best practices for constructible implementation	0.004
	EN 8	Comparative advantage	0.001
Organization	OR 3	Financial resources of organization	0.016
	OR 4	BIM supporting organizational structure	0.002
Policy	PO 2	Industry standards	0.021
	PO 4	The increased demand of design and build	0.028

5.4.6 The effect of the company grade on BIM adoption components

Studying the effect of the "Company grade" on BIM adoption components using MANOVA analysis by SPSS 25 software shows the acceptance of the null hypotheses for "Technology", "Environment", and "Policy" components. The p-values for these components are 0.016, 0.003, and 0.048, respectively. While the null hypotheses of the effect of "Company grade" on the "Process", "People", and "Organization"

components are rejected with p- values higher than 0.05, as shown in Table (5.26).

The effect of the "Company grade" is studied on "Technology", "Environment", and "Policy" related indicators in order to identify which indicators are significantly affected. The SPSS output for this analysis is shown in Table (5.27), which shows significant effect of "Company grade" on all indicators related to the components.

Table 5.26: MANOVA Analysis for the Effect of the Company Grade on BIM Adoption Components

Independent Variable	Dependent Variable	p-value	Decision (0.05)
Company Grade	Technology	0.016	Accept
	Process	0.909	Reject
	People	0.065	Reject
	Environment	0.003	Accept
	Organization	0.051	Reject
	Policy	0.048	Accept

Table 5.27: MANOVA Analysis for the Effect of the Sector on Technology, and Environment Indicators

Component	Indicator Code	Indicator	p-value (Sig.)
Technology	TE 6	Technological capability of organization	0.016
	TE 11	Uninterrupted power and a strong Internet	0.004
	TE 12	Awareness of the technology among industry stakeholders	0.039

Table 5.27: MANOVA Analysis for the Effect of the Sector on Technology, and Environment Indicators (Continue)

Component	Indicator Code	Indicator	p-value (Sig.)
Environment	EN 4	Competitive advantages in market	0.019
	EN 5	Pressure from competitors	0.005
	EN 6	Influence from partners who have adopted BIM	0.001
	EN 7	Best practices for constructible implementation	0.026
	EN 8	Comparative advantage	0.005

5.4.7 The effect of the BIM awareness on BIM adoption components

The results referring to Subsection 5.2.6 shows that 72% of the respondents are aware of BIM. Table (5.28) shows MANOVA analysis results of the effect of "BIM awareness" on the six components

Tests of the hypotheses show significant effects of "BIM awareness" on the "Technology", "Process", and "Environment" components only with p-values of 0.001, 0.002, and 0.002, respectively. The p-values for these components are lower than the recommended p-value of 0.05. Hence, the null hypotheses of the significant effect of "BIM awareness" on the "Technology", "Process", and "Environment" components are accepted. Moreover, the null hypotheses of the effect of "People", "Organization", and "Policy" components are rejected.

Table 5.28: MANOVA Analysis for the Effect of BIM Awareness on BIM Adoption Components

Independent Variable	Dependent Variable	p-value	Decision (0.05)
BIM Awareness	Technology	0.001	Accept
	Process	0.002	Accept
	People	0.067	Reject
	Environment	0.002	Accept
	Organization	0.115	Reject
	Policy	0.269	Reject

The indicators for technology, process and environment components are examined to test the significant impact of BIM awareness on them separately. By the same criterion of p-value less than 0.05, Table (5.29) shows only the indicators with significant p-values.

Table 5.29: MANOVA Analysis for the Effect of the BIM Awareness on Technology, Process, and Environment Indicators

Component	Indicator Code	Indicator	p-value (Sig.)
Technology	TE 1	Information Format	0.010
	TE 2	Usefulness of digital transfer of data	0.002
	TE 4	Visualization	0.008
	TE 5	Technical competence of staff	0.001
	TE7	Automation	0.000
	TE 11	Uninterrupted power and a strong Internet	0.016

Table 5.29: MANOVA Analysis for the Effect of the BIM Awareness on Technology, Process, and Environment Indicators (Continue)

Component	Indicator Code	Indicator	p-value (Sig.)
Process	PR 1	Developing data exchange standards	0.025
	PR 2	Companies' collaboration experience with project partners	0.032
	PR 3	Standard and rules	0.007
	PR 4	Collaboration (project) management tools	0.005
	PR 5	Desire to speed up the design process	0.005
	PR 9	Leadership of senior management	0.004
	PR 11	Providing guidance on use of BIM	0.027
	PR 12	Information Availability and Sharing	0.000
Environment	EN 4	Competitive advantages in market	0.014
	EN 6	Influence from partners who have adopted BIM	0.001
	EN 7	Best practices for constructible implementation	0.005
	EN 8	Comparative advantage	0.003
	EN 9	BIM benefits	0.001

5.4.8 The effect of the BIM usage on BIM adoption components

To test the effect of the usage on "BIM adoption" components, MANOVA test is applied using SPSS 25 software, and the results are shown in Table (5.30). Tests of the hypotheses show significant effects of "BIM usage" on "Technology", "Process", "Environment" and "Policy" components only the p-values for these components are lower than the

recommended p-value of 0.05. Hence, the null hypotheses of the significant effect of "BIM usage" on "Technology", "Process", "Environment" and "Policy" are accepted. Moreover, the null hypotheses that there are significant effects of "BIM usage" on "People", and "Organization" components are rejected.

Table 5.30: MANOVA Analysis for the Effect of BIM Usage on BIM Adoption Components

Independent Variable	Dependent Variable	p-value	Decision (0.05)
BIM Usage	Technology	0.032	Accept
	Process	0.002	Accept
	People	0.054	Reject
	Environment	0.006	Accept
	Organization	0.063	Reject
	Policy	0.023	Accept

The indicators for "Technology", "Process", "Environment" and "Policy" components are examined to test the significant impact of "BIM usage" on them separately. By the same criterion of p-value less than 0.05, Table (5.31) shows only the indicators with significant p-values.

Table 5.31: MANOVA Analysis for the Effect of the BIM Usage on Technology, Process, Environment, and Policy Indicators

Component	Indicator Code	Indicator	p-value (Sig.)
Technology	TE 4	Visualization	0.026
	TE 5	Technical competence of staff	0.014
	TE 11	Uninterrupted power and a strong Internet	0.024
	TE 13	BIM libraries	0.003
Process	PR 4	Collaboration (project) management tools	0.008
	PR 5	Desire to speed up the design process	0.000
	PR 8	Contractual sharing norm	0.020
	PR 9	Leadership of senior management	0.034
	PR 11	Providing guidance on use of BIM	0.005
Environment	EN 4	Competitive advantages in market	0.023
	EN 5	Pressure from competitors	0.017
	EN 6	Influence from partners who have adopted BIM	0.001
	EN 7	Best practices for constructible implementation	0.018
	EN 8	Comparative advantage	0.000
	EN 9	BIM benefits	0.011
Policy	PO 3	Project delivery modes	0.006
	PO 4	The increased demand of design and build	0.009

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.1 BIM Awareness

6.2 BIM Knowledge

6.3 BIM Concept and Uses

6.4 Indicators Driving for BIM Adoption in the Bahraini Construction Industry

6.5 The Effect of Descriptive Analysis of the Respondent's Attributes Results on the BIM Adoption Components

CHAPTER SIX

RESULTS AND DISCUSSIONS

The research results together with the information got through the literature review provide a solid base for the researcher to discuss the approach and develop a discussion about the significant issues of the adoption of BIM in the Bahraini construction industry.

6.1 BIM Awareness

Awareness is an essential component at the early stages of any adoption process. The results from collected data, reveals the high awareness level of BIM among the industry professionals in the Kingdom of Bahrain, with a percentage of 72 % of total respondents (Subsection 5.2.6). This result is considered close to 80 % shown in Jordan (Al-btoush and Haron, 2017). This high percentage of awareness has positive effects on BIM adoption. It enables the engineering sector in Bahrain to overcome one of the most significant problems facing other countries in their efforts in adopting BIM. The lack of BIM awareness is considered the most significant barrier of BIM adoption in Malaysia (Gerges et al., 2017), and Nigeria (Zahrizan et al., 2014).

Moreover, BIM awareness is considered by the Construction Industry Development Board (CIDB) in Malaysia as one of the seven pillars for BIM adoption roadmap (Mohammad, Abdullah, Ismail, and Takim, 2018). It is one of the three main factors identified as critical factors that have been influencing the respondents' decision when considering to adopt or reject BIM (Hong et al., 2016).

6.2 BIM Knowledge

To evaluate BIM knowledge, the researcher considers the use of any of BIM tools (software) as the first stage of knowledge. The results show that the most used engineering software is AutoCAD Architecture software with a percentage of 49 % (Subsection 5.2.7). AutoCAD Architecture software is considered to be the predecessor of BIM technology. If AutoCAD is used right, it will create an interactive information sharing space. However, unfortunately, when the respondents are asked about the uses of the software, the majority of answers are 2D, and 3D uses with a percentage of 38.5 % and 28.5 %, respectively. This is clear evidence that "BIM use" is in stage 1 maturity level in the Bahraini construction industry. Stage 1 is only a modeling stage, where the BIM model is still produced separately for each disciplinary, and the output is much like CAD output. Even though the level of CAD use is high in the Kingdom of Bahrain, it lacks optimized usage with its full capabilities.

There is evidence of some BIM use at Stage 2 maturity level, where results show low percentages of uses for cost estimation, quantity surveying, and project scheduling as this stage may include 4D programmed data and 5D cost data creating a multidisciplinary model which enhances the collaboration between project stakeholders (Zakaria et al., 2013). On the other hand, none of BIM uses at Stage 3 maturity level is shown, even though more than 72 % of industry representatives have proper awareness about BIM, which incorporates critical challenges for its adoption.

In order to strengthen these results, respondents are merely asked if they use BIM or not, only 39 % have answered yes. The gap between awareness and usage form a barrier to further BIM adoption.

This gap appears not only in Bahrain, for example in Nigeria, although the level of BIM awareness is high, implementation of both process and technology are also considered to be low (Gerges et al., 2017). According to Hatem et al. (2018), this is mainly due to the resistance to change, the need for contracts organizing BIM implementation, and cost of training.

Similarly, the gap is evident in the UK, where the percentages of professionals who are aware and currently using BIM are 62% and 35% respectively (Ezcan et al., 2013). The percentages are close to those of this research. However, BIM level in the UK is more mature, and the BIM related experience and knowledge is higher.

6.3 BIM Concept and Uses

The results show that there are differences in the way professionals in the Bahraini construction industry perceive BIM. Where 32.7% defined BIM as a visualizing tool, while 27.5% defined it as new technology and techniques. These results indicate that construction professionals still lack comprehensive knowledge about BIM. The construction professionals see only the technological core of BIM and treat it as new technology and software. However, BIM is more than a new technology of visualization; it is a multidimensional concept.

These results are confirmed by the respondent's answers on the purposes of BIM usage, where visualization and drawing production purposes are ranked at the same position with about 28%. This is clear evidence that some respondents perceived that BIM is similar to any other drawing tool, which is a misunderstanding of what BIM is. This lack of understanding and knowledge of BIM are obstacles to improve BIM adoption level within the industry. Panuwatwanich and Peansupap (2013) reported that the misunderstanding of the BIM concept could lead to the

misalignment between BIM adoption and the company's business objectives. It also may have an impact on how clients look at the value of BIM, which will impact adoption. Moreover, it is found that the misconception of BIM leads to misinformed expectations regarding its benefits, and this results in the disappointment with BIM and its ensuing abandonment (Panuwatwanich and Peansupap, 2013).

To sum up, Bahrain's BIM maturity level is indicated by the level of practice, BIM understanding, and awareness as follows:

- BIM is only used as a tool to carry out specific tasks.
- BIM is not used as a collaboration tool.
- BIM is not used with a life-cycle approach.
- The use of BIM in the Kingdom of Bahrain is practically at Stage 1 maturity level. This indicates that the respondents' practical experience of BIM is mainly limited to the use of their traditional software as nobody has indicated any tool or technology for BIM implementation at Stage 2 or Stage 3 maturity levels.
- Despite the improved awareness of BIM and software developments, it has not yet been taken up in practice, and the BIM adoption in Bahrain is slow.

6.4 Indicators Driving for BIM Adoption in the Bahraini Construction Industry

This research systematically investigates which motivation indicators influence the adoption of BIM among professionals in the Bahraini construction industry. Subsequently, relevant indicators for driving BIM adoption are identified and studied for their impact mechanisms in BIM acceptance to suggest a more comprehensive model.

The research states that BIM adoption is possible when some indicators that drive the adoption are considered by individuals and organizations in the Bahraini construction industry. Thus, the BIM adoption model suggested by this research is composed of six main components (groups), including environment, technology, process, people, policy and organization, each of these components includes indicators that influence the adoption of BIM. The indications of the results of the research model are as follows.

The first hypothesis (H1) is not rejected. A significant and positive relationship is found between environment component and BIM adoption. This suggests that BIM adoption in the Kingdom of Bahrain can be achieved by considering some environment-related indicators. Per the research model, the environment component is measured by eight indicators: globalization and competitive strategies, market demand, international flexibility to market; gaining competitive advantages in the market; best practices for constructability implementation; comparative advantage; BIM benefits; and project team expectations. All previous indicators are revolving around drives coming from external forces, like international forces, markets, and partners impacting BIM adoption.

This result reflects the reality of Bahrain in the urban development matter. Bahrain is witnessing unprecedented urban growth and recognized globally as a real estate investment center. Moreover, it is the place where the headquarters of many international companies located. Hence, this makes the local construction industry looking for external factors and demands, especially with the increased demand of foreign companies who are working in Bahrain.

The second hypothesis (H2) is rejected. Process component has no significant impact on BIM adoption. Five indicators directly reflect it: shared norms and collective expectations diffused through information exchange activities; contractual sharing norm; leadership of senior management; shared liability between project participants; and communication. The result indicates that the management of the "Collaborative process" and "people" components will not influence the adoption of BIM. Moreover, the availability and the use of any BIM execution plan for BIM will have no effect in BIM adoption in Bahrain.

This result can be attributed to the failure of the Bahraini construction industry in managing a successful collaboration process especially with dealing with collective labor.

The third hypothesis (H3) that the technology component is not significantly correlated with BIM adoption. Technology component is directly reflected by two indicators: hardware equipment/ upgrade; and technological capability of the organization. The result indicates that the technological context does not influence the adoption of BIM. This result indicates clearly that the technological aspects in Bahrain is very strong. The ability of the organization to provide efficient hardware equipment's, and software packages are very strong. Bahrain is a very strong country

when it comes to the technology requirements and the availability of this requirements, enables bahrain to gain a very strong feature.

Fourth hypothesis (H4), which is the effect of the organization-related indicators, is rejected as a non-significant relationship is found between these indicators and BIM adoption. This hypothesis is modified by combining the organization and policy components as resulted by the statistical analysis method. So, the combined hypothesis is reflected by seven indicators: BIM supporting organizational structure; project delivery modes; financial resources of the organization; industry standards; regulation and policy; performance measures and benchmarks for continuous improvement; and top management support. As a result, the BIM adoption is not influenced by any indicators related to internal forces coming from the organization itself or any indicators focusing on regulation and contracts role in driving the adoption. This result can be attributed to the nonexistent of any rules and regulations that organize the delivery of the projects in the Kingdom of Bahrain. Moreover, the management style of the organizations seems to be not driven by the top management, hence it does not effect the BIM adoption.

Hypothesis number five (H5), which contains part one of people-related indicators, is found to be insignificant. Five indicators explain this hypothesis: qualified cadres and experts to train BIM software; level of awareness of BIM and the knowledge about BIM; software and technology training; interest in learning BIM; and process and workflow training. As a result, it is found that people-related indicators that revolve around practice, available experts and awareness have no influence on BIM adoption. This result is compatible to Bahrain situation, where the training is not a barrier especially with the availability of organizations like Tamkeen offering free training for Bahraini cadres. Additionally,

according to the research results the construction industry in Bahrain has a very high BIM awareness levels, that clearly the reason why BIM awareness does not affect BIM adoption in the Kingdom of Bahrain .

The last hypothesis (H6) contains the other part of people-related indicators with two indicators: supporting individual characteristics; and the need for innovation and the diffusion of innovation. This hypothesis is not rejected. A significant and positive relationship is found between these two indicators and BIM adoption in Bahrain. This means that the industry professionals' exposure to innovative technologies and the necessity to innovate ways to overcome the industry problems have a more significant potential to spark BIM among them. Moreover, BIM adoption in Bahrain is influenced by the personal characteristics that feature industry professionals.

These results are consistent with the findings by other independent researches. For example, with a survey of 352 construction professionals of the Malaysian construction industry, Enegbuma et al., (2015) found people-related indicators statistically insignificant, but, concluded that the direct impact on BIM adoption will be improved with future drive-in awareness and productivity gains by construction professionals (Enegbuma et al., 2015). Moreover, people-related indicators are cited by previous literature as the highest indicators driving for BIM adoption in the construction industry (Mohammad et al., 2018).

Based on a study by, Liu et al., (2010), the external forces are one of the main three factors that affect the AEC industry in adopting BIM in the USA. Also, for environment-related indicators, Wang et al., (2016) concluded that environment-related indicators are one of the five most essential kinds of factors affecting the adoption of BIM in Chania. Ahmed et al., (2017) found that external forces are considered one of the critical

factors that affect BIM adoption decisions. Additionally, based on frequencies, environment, and social factors are infrequently cited as influential factors (Monko et al., 2017).

6.5 The Effect of Descriptive Analysis of the Respondent's Attributes Results on the BIM Adoption Components

This section discusses the results of Section 5.4, to analyze the effect of the general characteristics of the industry professionals on the components and indicators of BIM adoption in the Kingdom of Bahrain.

The MANOVA analysis of the effect of the "Educational level" on the six components shows a significant impact on "People-related indicators". The "People" component is mainly revolving around the human interaction with the BIM system using the available skills and competencies. Hence, different education levels will affect the users' interaction with BIM and its adoption. The effect is specifically on the indicator number eight: "Observable large productivity gain". This result confirms the decisive role of education level on workers productivity, as the more informed people are about the professional aspects of their jobs, the more productive they will be.

For the study of the effect of the "Specialization" on the six components, MANOVA analysis of the hypotheses show a significant effect of the "Specialization" on the "Process" and the "People" components only. For the "Process" component, three significant indicators are describing the management of the collaboration process to achieve BIM requirements and benefits between construction stakeholders. So, the different specializations of construction process stakeholders affect collaboration process management, information sharing activities, and BIM execution plans. Moreover, for the "People" component, four

indicators are significantly affected by "Specialization", these are process and workflow training, level of awareness of BIM and knowledge, professional development, and project team expectations. The effect of "Specialization" is apparent when it comes to the "People" component, as stakeholders with different specializations (such as architecture, civil engineering, etc.) will affect BIM training and the level of awareness and knowledge. Furthermore, developing the skills to build and sustain professional relationships and networks in the workplace is affected by specialization of each of the stakeholders.

Position of the industry professionals will affect "People", and "Organization" components only. Different professionals' positions will determine the needed level of BIM process and workflow training, and hence the expectations for the BIM scope of work for each team member within the project. Also, the position of each stakeholder will affect the interest in learning BIM and the level of awareness and the knowledge about BIM. So that what explains the effect of the "Position" on people-related indicators. Organization-related indicators describe everything related to the internal forces coming from the organization itself, including leadership, and structure. Therefore, the "Position" of the industry professionals will influence the organizational structure in such a way that supports BIM adoption. For example, by introducing a specialized department for projects using BIM. It also will influence the top management to take all measures and procedures in the way of BIM adoption.

The effect of the "Years of experience" on BIM adoption components is significant for the "Environment" component only with reference to Sub-section 5.4.4. The "Years of experience" for the professionals will affect their perception of all external forces on the adoption of BIM

(environmental context), including government role, client requirements, global changes and requirements, industry characteristics and competition.

The MANOVA analysis is applied to test the effect of the sector on the six components of BIM adoption. The results show a significant effect on "Technology", "People", "Environment", "Organization", and "Policy" components. The increasing attention and demand by the public and private organizations for the delivery of their construction projects in the most successful way have influenced many areas. For technology, for example, each sector is looking for suitable ways to enhance its automation level, by looking for reliable internet and hardware resources. At the same time, the focus on people is critical; each sector creates initiatives to increase the awareness and knowledge among professionals by the organization of training courses, enhancing the individual characteristics and elevating the interest of learning BIM among workers. Moreover, the efforts to identify the external and internal forces that work as motivators and barriers for BIM adoption by both sectors.

Engineering companies in the Kingdom of Bahrain in the private sector are divided into grades; the grade of companies found to affect "Technology", "Environment", and "Policy" components. According to the "Company grade", the technological capability of the organization will differ and hence the awareness of the technology among the workers. Moreover, external forces on the adoption of BIM change according to the grade, for example, the pressure and influence from competitors.

The MANOVA analysis is applied to test the effect of "BIM awareness" on the six components, and the results show an effect on three components only, "Technology", "Process", and "Environment". The level of awareness will affect technology-related indicators in many ways, such as it will determine the information format used in any project. People with

awareness will choose BIM for the digital data transfer, visualization, and for the features that are provided by automation. For the "Process" component, the awareness level will help in driving the top management to develop data exchange standards and rules to enhance the collaboration experience among project partners. Moreover, with high awareness, the industry professionals gain many advantages besides the BIM benefits like the "Competitive" and "Comparative" advantages in the market especially with the increasing demand on using BIM.

"Technology", "Process", "Environment", and "Policy" are the only components affected by the level of "BIM usage". BIM usage will enhance the technical competence of the staff and will affect the visualization of the project. Moreover, it will affect the collaboration process among stakeholders, and hence, this process will be organized by contract rules and guidelines. Also, the level of usage will enhance the "Competitive" and "Comparative" advantages of the companies in the market and, hence, will form a pressure on competitors to gain BIM benefits. Finally, the increasing level of BIM usage will increase the demand for design and build contracts and, hence, will change the project delivery modes.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

7.2 Recommendations

7.3 Research Limitations

7.4 Future Research

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

The study investigated indicators influencing the adoption of BIM in the Bahraini construction industry. This chapter provides a sum up to the research, some recommendations for the construction industry professionals regarding BIM adoption, and presents some suggestions for further research.

7.1 Conclusion

Several related BIM theoretical models from previous studies were analyzed. The results of analyzing the theoretical models showed limitations in two areas, limitations regarding BIM nature and limitations regarding the Bahraini construction industry. Regarding BIM nature, the limitations include the lack of a model which study BIM from all its related aspects considering: its multidimensional nature; the different levels of BIM maturity in each country; inclusion of external factors; and flexibility. Regarding the Bahraini construction industry, the adoption of BIM is not that much apparent especially with the lack of published studies regarding this issue. Hence, this imposed the need for a specific model that will meet the situation of the Bahrain construction industry. For that, a comprehensive literature review is done to determine all related indicators. Initially, a list of 155 indicators is identified, then these indicators are reduced to 128 indicators. The 128 indicators are classified initially in seven components (groups): technology, people, process, policy, organization, environment, and BIM related indicators. The indicators are validated by the Delphi technique to identify the ones that are most suitable

to the situation of the Bahraini construction industry. The final result of the Delphi technique is a final list consisting of 54 indicators used to formulate the conceptual research model.

Next, a questionnaire, with a sample size of 326, is designed for collecting primary data on the awareness, usage, and indicators driving for the BIM adoption in the Bahraini construction industry. The response rate is approximately 83% (272 out of the 326), with 86% of the 272 from the private sector (234 responses) and only 14% (38 responses) from the public sector. The collected data are analyzed in three parts: first, a descriptive analysis using SPSS25 software, second a structural equation modeling technique using SPSS 25 and AMOS software. Several statistical tests are conducted until the model has reached the fitness stage then the hypothesis is tested in the form of a structural equation model. Third, MANOVA analysis is applied to test the relationships between the results of the descriptive analysis and the six components of BIM adoption.

The results of the questionnaire indicate that more than 72% of the respondents are aware of BIM. However, only 39% are using it in their work, which forms an obstacle for the BIM adoption in the Kingdom of Bahrain. To enhance this adoption to higher levels, the respondents determine environment-related indicators including the following: globalization and competitive strategies; market demand; international flexibility to market; gaining competitive advantages in the market; best practices for constructability implementation; comparative advantage; BIM benefits; and project team expectations.

Furthermore, the respondents determine people-related indicators including: "Supporting individual characteristics"; and "The need to innovate and the diffusion of innovation" as the primary indicators influencing the adoption of BIM in the Bahraini construction industry.

MANOVA analysis studied the effect of collected results from the descriptive analysis on the indicators driving for BIM adoption in the Bahraini construction industry. The results show that the "Technology" component is affected by the "Sector", the "Company grade", the "BIM awareness", and the "BIM usage". Process component shows that it is affected by the "Specialization", the "BIM awareness" and the "BIM usage". Moreover, the "People" component is affected by the "Educational level", the "Specialization", the "Position", the "Sector" of the respondents. While the "Environment" component is affected by the "Years of experience", the "Sector", the "Company grade", the "BIM awareness", and the "BIM usage". Finally, the "Policy" component is affected by the "Sector", the "Company grade", and the "BIM usage".

7.2 Recommendations

This section presents recommendations for how the industry can adopt BIM and integrates it within the construction industry's all processes.

Awareness:

- Seminars, workshops, conferences increasingly raise awareness levels of BIM, these all are carried out by various bodies and in consultation with the experts in the field of construction projects.
- There is an excellent provision to introduce BIM education at the university level so that when these students are graduated, it will be easy for them to adopt BIM on projects.
- Organizations must hold awareness sessions and train their employees to take this change slowly to avoid resistance and actively embrace BIM.
- Developing and supporting academic projects as well as encouraging researcher in the centers and institutions, to facilitate the transfer of expertise and information from the world.
- Increase customers' awareness of the importance of using BIM for all project phases, which encourage them to use BIM for their projects.

Adoption:

- The government must play a vital role by studying the successful experiences of other leading countries in this area such as Finland, Norway, and the UK, and what solutions these countries have developed to facilitate its adoption. Promotion of these success stories will help in increasing the adoption among industry stakeholders.

- Cooperation with the leading countries in BIM field, to provide specialists with practical training and to improve joint ventures.
- The need for an effective national implementation strategy, roadmap, and framework that meet the challenges and offer guidelines for organizations to leverage BIM at Stage 2 and Stage 3 maturity levels.
- Mandating BIM for the public sector.
- The government must initiate the establishment of a National Committee of Building Information Modeling (BIM), which will work as a BIM reference center.
- Incentivize for BIM implementation program by the government.
- Induction of experts from all levels will enhance the adoption of this technology.
- Adopting a policy to increase comparative and competitive advantages on all levels by measuring progress, insisting on accountability and remaining open to process innovation.
- Have a single point of access to all information relevant to the industry, and thus helps to develop a portal as a source of information to encourage knowledge sharing.
- The prime responsibility is of the employer, who can induct requirement from architects, consultants, and contractor to adopt BIM for design and planning. It is important also to identify their own organization's BIM goals as BIM planning is the key to effective implementation.
- Organizations need to take an essential point into account, that BIM experience increases BIM benefits, so they should raise the usage of BIM in their projects to improve the benefits.

- Using examples to increase BIM adoption, where stakeholders can study the data of an already executed buildings using BIM, this helps in learning the complexities and motivates the application of BIM on future projects.

7.3 Research Limitations

This research faced some limitations as explained below.

7.3.1 Model limitations

The major limitation that faced the model is being a new model, not examined before in any other study. Hence, the need for further confirmation by testing it on different countries with situations similar to the ones of the Kingdom of Bahrain.

7.3.2 Data collection limitations

First, the researcher faced challenges during the collection of the data phase. Issues like confidentiality of the data collected despite assurances that there will be utmost confidentiality.

Second, reluctant respond, some respondents either delayed their responses or never responded to the questionnaires, even with frequent visits, emails, and phone calls especially with daily engineering work.

Third, the shortage of BIM experts knowledgeable in BIM approach to design was a fundamental limitation.

7.3.3 Generalization limitation

The research is confined to the study of the construction industry in the Kingdom of Bahrain. Since BIM maturity level can be specific to geographical areas, caution is required when comparing the data and results in another situation.

7.4 Future Research

The questionnaire that is carried out for this research evaluates the Bahraini construction professional's knowledge about BIM. This work can be completed by studying the experience of architects, contractors, and client to establish a strategy to inform professionals about BIM. Moreover, the impacts of BIM during the utilization and maintenance phases and the clients' perceptions of BIM can be analyzed in further work. Also, the Bahrain situation could be very suitable to study how to convert nonadopters into adopters, and opinions related to BIM between adopters and nonadopters.

Additionally, further research must look into the obstacles that prevent the construction industry in the Kingdom of Bahrain from adopting BIM. It also may re-study the BIM awareness and adoption levels after the implementation of some initiatives from the government and private sector organizations and on project before and after implementing BIM.

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APPENDIX 1

INITIAL INDICATORS LIST

	Indicator	Reference
1.	Involvement stage	Lam et al., 2017
2.	Project value	Lam et al., 2017
3.	Top management support	Son et al., 2014; Enegbuma et al., 2015; Ahmed et al., 2017; Ahmen et al., 2017; Enegbuma et al., 2015; Ahuja et al., 2016; Zakaria et al., 2013; Son et al., 2014; Kim et al., 2015; Lee et al., 2015; Jin et al., 2017
4.	Technical support	Son et al., 2014; Zahrizan et al., 2014; Enegbuma et al., 2015; Kim et al., 2015; Panuwatwanich and Peansupap, 2013
5.	Standard and rules	Soon et al., 2013; Yaakob et al., 2016; Hatem et al., 2018; Zahrizan et al., 2014; Ahmen et al., 2017; Chen et al., 2016; Sunil, 2017
6.	Communication	Soon et al., 2013; Yaakob et al., 2016; Hatem et al., 2018
7.	Process and workflow training	Al-btoush and Haron, 2017; Yaakob et al., 2016; Hatem et al., 2018; Zahrizan et al., 2014; Won and Lee, 2010; Chan, 2014; Enegbuma et al., 2015; Kim et al., 2015; Panuwatwanich and Peansupap, 2013; Arayici et al., 2011; Lee et al., 2015; Jin et al., 2017; Sunil et al., 2017
8.	Software and technology training	Al-btoush and Haron, 2017; Ahmed et al., 2017; Zahrizan et al., 2014; Chan, 2014; Enegbuma et al., 2015; Kim et al., 2015; Panuwatwanich and Peansupap, 2013; Arayici et al., 2011; Lee et al., 2015; Jin et al., 2017; Sunil et al., 2017
9.	Realizing the value from financial perspective	Al-btoush and Haron, 2017; Hatem et al., 2018
10.	Perceived Usefulness	Ahmed et al., 2017; Xu et al., 2014; Hatem et al., 2018; Hong et al., 2016; Lee et al., 2012; Liu et al., 2010; Peansupap and Walker, 2005
11.	Perceived Ease of Use	Ahmed et al., 2017; Xu et al., 2014
12.	Compatibility	Ahmed et al., 2017; Enegbuma et al., 2015; Wang et al., 2016; Ahuja et al., 2016; Lee et al., 2012; Lee et al., 2015
13.	Complexity	Ahmed et al., 2017; Wang et al., 2016; Ahuja et al., 2016; Jin et al., 2017

14.	Trial ability	Ahmed et al., 2017; Ahuja et al., 2016
15.	Client's willingness to adopt new technology	Ahmed et al., 2017; Zahrizan et al., 2014
16.	Pressure from competitors	Ahmed et al., 2017
17.	Push from governments	Ahmed et al., 2017; Zahrizan et al., 2014
18.	Clients/owners support	Ahmed et al., 2017
19.	BIM mandate	Ahmed et al., 2017
20.	Government promotion	Ahmed et al., 2017
21.	Government financial support and subsidy	Ahmed et al., 2017
22.	Regulation, policy and industry standards	Ahmed et al., 2017
23.	Government support and policy through legislation Influence	Ahmed et al., 2017; Hatem et al., 2018; Zakaria et al., 2013; Abubakar et al., 2014; Jin et al., 2017
24.	Influence from partners who have adopted BIM	Ahmed et al., 2017
25.	Formal and informal pressures exerted on organizations by other organizations or governments	Ahmed et al., 2017
26.	Best practices for Constructability Implementation	Ahmed et al., 2017
27.	Availability of BIM professionals	Ahmed et al., 2017; Abubakar et al., 2014 ; Jin et al., 2017
28.	Awareness of the technology among industry stakeholders	Ahmed et al., 2017; Yaakob et al., 2016; Ahuja et al., 2016; Abubakar et al., 2014; Hong et al., 2016
29.	Strength of culture (e.g., shared identity, norms, values, and assumptions)	Ahmed et al., 2017; Yaakob et al., 2016; Arayici et al., 2011; Abubakar et al., 2014
30.	Shared norms and collective expectations diffused through information exchange activities	Ahmed et al., 2017; Zahrizan et al., 2014
31.	Performance measures and	Ahmed et al., 2017

	benchmarking for continuous improvement.	
32.	Globalization and competitive strategies	Ahmed et al., 2017; Wang et al., 2016
33.	Contractual sharing norm	Ahmed et al., 2017
34.	Market demands	Ahmed et al., 2017; Silva et al., 2016
35.	Economic demand in the AEC industry	Ahmed et al., 2017
36.	Collaborative Procurement methods	Ahmed et al., 2017; Abubakar et al., 2014
37.	The increase of design and Build, and Demand for BIM Industry	Ahmed et al., 2017; Zakaria et al., 2013
38.	Demographic factors	Ahmed et al., 2017
39.	Outsourcing	Ahmed et al., 2017
40.	Financial resources of organization	Ahmed et al., 2017
41.	Human capability/resources	Ahmed et al., 2017
42.	Organizational learning capability	Ahmed et al., 2017
43.	Technical competence of staff	Ahmed et al., 2017; Zahrizan et al., 2014; Zakaria et al., 2013
44.	Technological capability of organization	Ahmed et al., 2017; Wang et al., 2016
45.	Research and development capability of organization	Ahmed et al., 2017
46.	Managing people resistance to BIM change; and Socioeconomic conditions	Ahmed et al., 2017; Zakaria et al., 2013; Sunil et al., 2017; Zakaria et al., 2013; Panuwatwanich and Peansupap, 2013; Arayici et al., 2011
47.	Perceptions and attitudes	Ahmed et al., 2017
48.	Subjective norm	Ahmed et al., 2017
49.	Attitude towards the type of innovation (IT)	Ahmed et al., 2017
50.	Social influence	Ahmed et al., 2017
51.	Social network	Ahmed et al., 2017

52.	International flexibility/adaptability to market	Ahmed et al., 2017
53.	An organizational structure that supports BIM	Ahmed et al., 2017; Zahrizan et al., 2014; Won and Lee, 2010; Sunil et al., 2017
54.	Corporate management style (family owned or public owned)	Ahmed et al., 2017
55.	Business interest	Ahmed et al., 2017
56.	Interest in learning BIM	Ahmed et al., 2017
57.	Need to innovate, the innovation, and the diffusion of innovation	Ahmed et al., 2017
58.	Incentives; and Enjoyment with innovation	Ahmed et al., 2017
59.	Competitive advantages in market (core/unique)	Ahmed et al., 2017
60.	Organization size	Ahmed et al., 2017; Poirier et al., 2015
61.	Problems faced in the current 2D drafting practices	Silva et al., 2016; Hatem et al., 2018; Zakaria et al., 2013
62.	Ready pool of skilled BIM manpower	Silva et al., 2016; Zakaria et al., 2013; Hatem et al., 2018; Zahrizan et al., 2014
63.	Interoperability	Yaakob et al., 2016; Hatem et al., 2018; Jin et al., 2017; Sunil et al., 2017
64.	Security of confidential information on project data	Yaakob et al., 2016; Hatem et al., 2018
65.	Leadership of senior management	Yaakob et al., 2016; Zahrizan et al., 2014; Won and Lee, 2010; Sunil et al., 2017
66.	Ownership	Yaakob et al., 2016
67.	Owner request	Hatem et al., 2018; Zahrizan et al., 2014; Ahuja et al., 2016; Panuwatwanich and Peansupap, 2013; Jin et al., 2017; Abubakar et al., 2014; Jin et al., 2017
68.	Cooperation nature of engineering work	Hatem et al., 2018; Abubakar et al., 2014; Wang et al., 2016; Deutsch, 2011; Monko et al. 2017; Lee et al., 2012; Sunil et al., 2017

69.	Formulation of BIM contracts	Hatem et al., 2018; Zahrizan et al., 2014; Jin et al., 2017; Poirier et al.2015
70.	Qualified cadres and experts to train BIM software	Hatem et al., 2018
71.	Uninterrupted power and a strong Internet	Hatem et al., 2018
72.	knowledge about BIM	Zahrizan et al., 2014; Ahuja et al., 2016; Sunil et al., 2017; Zakaria et al., 2013; Panuwatwanich and Peansupap, 2013; Lee et al., 2015
73.	BIM is required by other team members	Zahrizan et al., 2014
74.	Hiring BIM specialists	Zahrizan et al., 2014; Ahuja et al., 2016
75.	Collaboration with universities	Zahrizan et al., 2014
76.	Development of BIM department within an organization to monitor the application of BIM	Zahrizan et al., 2014; Nikas, et al., 2007; Monko et al,2017
77.	Continuous investment in BIM	Zahrizan et al., 2014; Won and Lee, 2010
78.	Information sharing protocols	Zahrizan et al., 2014
79.	Clients' satisfaction with BIM projects	Zahrizan et al., 2014
80.	Shared liability between project participants	Zahrizan et al., 2014
81.	Collaboration (project) management tools	Zahrizan et al., 2014; Arayici et al., 2011; Lee et al.,2015
82.	BIM libraries	Zahrizan et al., 2014
83.	Incentive programs for using BIM	Zahrizan et al., 2014
84.	Providing guidance on use of BIM	Chan, 2014
85.	Defining levels of BIM working for reference in professional services agreements	Chan, 2014; Poirier et al., 2015
86.	Developing data exchange standards	Chan, 2014
87.	Comparative advantage	Wang et al., 2016
88.	Testability	Wang et al., 2016
89.	Observability	Wang et al., 2016

90.	Enterprise Scale	Wang et al., 2016; Jin et al., 2017
91.	Top Management Sustain	Wang et al., 2016
92.	Organizational Motivations	Wang et al., 2016
93.	Adopters' Affect	Wang et al., 2016
94.	BIM Benefits	Wang et al., 2016
95.	BIM process is very reliable	Ahuja et al., 2016
96.	BIM related Performance	Ahuja et al., 2016
97.	Managing risk	Zakaria et al., 2013
98.	level of awareness of BIM	Zakaria et al., 2013
99.	Education	Zakaria et al., 2013; Lee et al., 2015
100.	Software applications Interoperability	Chen et al., 2016
101.	Hardware equipment/ Hardware upgrade	Chen et al., 2016; Lee et al., 2015; Jin et al., 2017
102.	Information delivery method Information assurance	Chen et al., 2016
103.	Data richness/ Real-time data	Chen et al., 2016
104.	Documentation and modeling standards /Quality control Specifications	Chen et al., 2016
105.	BIM quality	Lee et al., 2012; Lee et al., 2015
106.	Self-efficacy	Lee et al., 2012; Lee et al., 2015
107.	Resource facilitating condition	Lee et al., 2012
108.	Technology facilitating condition	Lee et al., 2012
109.	External forces	Liu et al., 2010
110.	Internal readiness	Liu et al., 2010
111.	Other project team members decide to move to BIM	Panuwatwanich and Peansupap, 2013
112.	Observable large productivity gain	Panuwatwanich and Peansupap, 2013
113.	understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently	Arayici et al., 2011

114.	clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers	Arayici et al., 2009; Eastman et al., 2008; Lee et al., 2015
115.	BIM Software availability and affordability	Abubakar et al., 2014; Lee et al., 2015
116.	Enabling environment	Abubakar et al., 2014
117.	Proof of cost savings by its adoption	Abubakar et al., 2014
118.	Professional development	Peansupap and Walker, 2005
119.	Supporting individual characteristics	Peansupap and Walker, 2005
120.	Supporting technology characteristics	Peansupap and Walker, 2005
121.	Supporting supervisor and organization	Peansupap and Walker, 2005
122.	Supporting open discussion environment	Peansupap and Walker, 2005
123.	supporting rewards	Peansupap and Walker, 2005; Chen et al., 2016
124.	colleagues help	Peansupap and Walker, 2005
125.	project delivery modes	Poirier et al., 2015
126.	project team expectations	Poirier et al., 2015
127.	collective efficacy	Lee et al., 2015
128.	organizational innovativeness	Lee et al., 2015; Hong et al., 2016
129.	personal innovativeness	Lee et al., 2015
130.	internal pressure	Lee et al., 2015
131.	external pressure	Lee et al., 2015
132.	sufficient legal framework for integrating owners' view in design and construction	Lee et al., 2015
133.	Number of employees (over 100)	Nikas et al., 2007; Monko et al., 2017
134.	New set of skills required	Oluwole, 2011; Monko et al., 2017
135.	Usefulness digital transfer of data/information	Nikas et al., 2007; Monko et al., 2017

136.	Loss of data	Ashcraft, 2008
137.	Companies' collaboration experience with project partners	Jin et al., 2017
138.	BIM technology consultants in the project team	Jin et al., 2017
139.	Project nature	Jin et al., 2017
140.	Project schedule	Jin et al., 2017
141.	Number of BIM-knowledgeable companies in the project	Jin et al., 2017
142.	Project budget	Jin et al., 2017
143.	Project geographic location	Jin et al., 2017
144.	Staff from different companies working in the same location	Jin et al., 2017; Hong et al., 2016
145.	sufficient evaluation of BIM	Jin et al., 2017
146.	Acceptance of BIM from middle management	Jin et al., 2017
147.	Decision Making Support	Sunil et al., 2017
148.	Information Availability and Sharing	Sunil et al., 2017
149.	Information Format	Sunil et al., 2017
150.	Visualisation	Sunil et al., 2017
151.	Automation	Sunil et al., 2017
152.	Subjective Norms	Hong et al., 2016
153.	Ease of Implementation	Hong et al., 2016
154.	Desire to speed up the design process	
155.	Reduction of errors	Hong et al., 2016

APPENDIX 2

INDICATORS CATEGORIZATION

	Number	Indicator
Technology	1.	Information Format
	2.	Visualization
	3.	Automation
	4.	Usefulness digital transfer of data/information
	5.	Loss of data
	6.	Supporting technology characteristics
	7.	BIM Software availability and affordability
	8.	Understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently
	9.	Technology facilitating condition
	10.	Data richness/ Real-time data
	11.	Software applications Interoperability
	12.	Hardware equipment/ Hardware upgrade
	13.	Testability
	14.	Observability
	15.	Uninterrupted power and a strong Internet
	16.	Security of confidential information on project data
	17.	Problems faced in the current 2D drafting practices
	18.	Technical competence of staff
	19.	Technological capability of organization
	20.	Awareness of the technology among industry stakeholders
	21.	Compatibility
	22.	Complexity
	23.	BIM libraries
	24.	Technical support
People	25.	Process and workflow training
	26.	Software and technology training
	27.	Perceived Usefulness
	28.	Perceived Ease of Use
	29.	Strength of culture (e.g., shared identity, norms, values, and assumptions)
	30.	Human capability/resources
	31.	Organizational learning capability
	32.	Managing people resistance to BIM change; and Socioeconomic conditions
	33.	Perceptions and attitudes

	34.	Subjective norm
	35.	Social influence
	36.	Interest in learning BIM
	37.	Incentives; and Enjoyment with innovation
	38.	Qualified cadres and experts to train BIM software
	39.	Need to innovate, the innovation, and the diffusion of innovation
	40.	level of awareness of BIM and the knowledge about BIM
	41.	Education
	42.	Observable large productivity gain
	43.	Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers
	44.	Professional development
	45.	Supporting individual characteristics
	46.	Supporting open discussion environment
	47.	Colleagues help
	48.	Project team expectations
	49.	New set of skills required
	50.	Staff from different companies working in the same location
process	51.	Standard & rules
	52.	Communication
	53.	Shared norms and collective expectations diffused through information exchange activities
	54.	Contractual sharing norm
	55.	Collaborative Procurement methods
	56.	Social network
	57.	Corporate management style (family owned or public owned)
	58.	Leadership of senior management
	59.	Ownership
	60.	Collaboration with universities
	61.	Shared liability between project participants
	62.	Collaboration (project) management tools
	63.	Providing guidance on use of BIM
	64.	Developing data exchange standards
	65.	Companies' collaboration experience with project partners
	66.	Project schedule
	67.	Decision Making Support
	68.	Information Availability and Sharing

	69.	Desire to speed up the design process
Policy	70.	Regulation, policy & industry standards
	71.	The increased demand for design and Build contracts
	72.	Formulation of BIM contracts
	73.	Defining levels of BIM working for reference in professional services agreements
	74.	Managing risk
	75.	Information delivery method
	76.	Project delivery models
	77.	sufficient legal framework for integrating owners' view in design and construction
	78.	BIM mandate
	79.	Information sharing protocols
Organization	80.	Top management support
	81.	Realizing the value from financial perspective
	82.	Availability of BIM professionals
	83.	Performance measures and benchmarking for continuous improvement.
	84.	Financial resources of organization
	85.	Research and development capability of organization
	86.	An organizational structure that supports BIM
	87.	Business interest
	88.	Organization size
	89.	Hiring BIM specialists
	90.	Development of BIM department within an organization to monitor the application of BIM
	91.	Project budget
	92.	Continuous investment in BIM
	93.	Top Management Sustain
	94.	Organizational Motivations
	95.	Organizational innovativeness
	96.	Internal pressure
	97.	Number of employees (over 100)
	98.	Project nature
	99.	Project value
	100.	Acceptance of BIM from middle management
	101.	Internal readiness
En	102.	Client's willingness to adopt new technology

	103.	Pressure from competitors
	104.	Push from governments
	105.	Clients/owners support
	106.	Government financial support and subsidy
	107.	Government support and policy through legislation Influence
	108.	Influence from partners who have adopted BIM
	109.	Best practices for Constructability Implementation
	110.	Globalization and competitive strategies
	111.	Market demands
	112.	Economic demand in the AEC industry
	113.	International flexibility/adaptability to market
	114.	Competitive advantages in market (core/unique)
	115.	Client request
	116.	Demographic factors
	117.	BIM is required by other team members
	118.	Clients' satisfaction with BIM projects
	119.	Incentive programs for using BIM
	120.	Comparative advantage
	121.	BIM benefits
	122.	Other project team members decide to move to BIM
	123.	Enabling environment
	124.	Proof of cost savings by its adoption
	125.	External pressure
	126.	Number of BIM-knowledgeable companies in the project
	127.	Ease of Implementation
BIM	128.	BIM Self-efficacy

APPENDIX 3

Delphi Technique Questionnaire

Definitions:

BIM: “BIM is a digital representation of physical and functional characteristics of a facility. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder.” (NIBS, 2007)

Privacy Protection

All responses are kept strictly confidential and is only used for academic purposes.

Section 1: Personal profile

Name:

Position Title:

Company Name

How long have you been working in the Bahraini architecture, engineering and construction industry (AEC)?	Less than a year	1-5 years	6-10 years	11-15 years	More than 20 years	
Are you aware of Building Information Modeling (BIM)?	Yes	No				
Do you use Building Information Modeling (BIM)?	Yes	No				
Please indicate the BIM software product(s) that your firm uses: (select all that apply)	Autodesk Revit	Bentley Architecture	Rhino 3d	Tekla Structures	Archi CAD	AutoCAD Architecture

Section 2: BIM adoption in Bahrain

The following is a set of factors that help in the adoption of BIM technology in Bahrain’s construction industry. Please select the most appropriate answer by ticking one of the boxes for each criterion based on the current state of practice in Bahrain construction industry, where 1- Very inapplicable 2- Not applicable 3- Neutral 4-Applicable 5-Highlyapplicable

Category	Factor		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO.	Description	1	2	3	4	5
Technology	1	Information Format					
	2	Visualization					
	3	Automation					
	4	Usefulness digital transfer of data/information					
	5	Loss of data					

Category	Factor		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO.	Description	1	2	3	4	5
Technology	6	BIM Software availability and affordability					
	7	Understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently					
	8	Technology facilitating condition					
	9	Data richness/ Real-time data					
	10	Software applications Interoperability					
	11	Hardware equipment/ Hardware upgrade					
	12	Testability					
	13	Observability					
	14	Uninterrupted power and a strong Internet					
	15	Security of confidential information on project data					
	16	Problems faced in the current 2D drafting practices					
	17	Technical competence of staff					
	18	Technological capability of organization					
	19	Awareness of the technology among industry stakeholders					
	20	Compatibility					
	21	Complexity					
	22	BIM libraries					
	23	Technical support					
People	24	Process and workflow training					
	25	Software and technology training					
	26	Perceived Usefulness					
	27	Perceived Ease of Use					
	28	Strength of culture (eg, shared identity, norms, values, and assumptions)					
	29	Human capability/resources					
	30	Organizational learning capability					

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
People	31	Managing people resistance to BIM change; and Socioeconomic conditions					
	32	Perceptions and attitudes					
	33	Subjective norm					
	34	Social influence					
	35	Interest in learning BIM					
	36	Incentives; and Enjoyment with innovation					
	37	Qualified cadres and experts to train BIM software					
	38	Need to innovate, the innovation, and the diffusion of innovation					
	39	level of awareness of BIM and the knowledge about BIM					
	40	Education					
	41	Observable large productivity gain					
	42	Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers					
	43	Professional development					
	44	Supporting individual characteristics					
	45	Supporting open discussion environment					
	46	Colleagues help					
	47	Project team expectations					
	48	Subjective Norms					
	49	New set of skills required					
	50	Staff from different companies working in the same location					
process	51	Standard & rules					
	52	Communication					
	53	Shared norms and collective expectations diffused through information exchange activities					
	54	Contractual sharing norm					

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
process	55	Collaborative Procurement methods					
	56	Social network					
	57	Corporate management style (family owned or public owned)					
	58	Leadership of senior management					
	59	Ownership					
	60	Collaboration with universities					
	61	Shared liability between project participants					
	62	Collaboration (project) management tools					
	63	Providing guidance on use of BIM					
	64	Developing data exchange standards					
	65	Companies' collaboration experience with project partners					
	66	Project schedule					
	67	Decision Making Support					
	68	Information Availability and Sharing					
	69	Desire to speed up the design process					
Policy	70	Regulation, policy & industry standards					
	71	The increased demand for design and Build contracts					
	72	Formulation of BIM contracts					
	73	Defining levels of BIM working for reference in professional services agreements					
	74	Managing risk					
	75	Information delivery method					
	76	Project delivery models					
	77	Sufficient legal framework for integrating owners' view in design and construction					
	78	BIM mandate					
	79	Information sharing protocols					

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
Organization	80	Top management support					
	81	Realizing the value from financial perspective					
	82	Availability of BIM professionals					
	83	Performance measures and benchmarking for continuous improvement					
	84	Financial resources of organization					
	85	Research and development capability of organization					
	86	An organizational structure that supports BIM					
	87	Business interest					
	88	Organization size					
	89	Hiring BIM specialists					
	90	Development of BIM department within an organization to monitor the application of BIM					
	91	Project budget					
	92	Continuous investment in BIM					
	93	Top Management Sustain					
	94	Organizational Motivations					
	95	Organizational innovativeness					
	96	Internal pressure					
	97	Number of employees (over 100)					
	98	Project nature					
	99	Project value					
	100	Acceptance of BIM from middle management					
	101	Internal readiness					
Environment	102	Client's willingness to adopt new technology					
	103	Pressure from competitors					
	104	Push from governments					
	105	Clients/owners support					

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
BIM	106	Government financial support and subsidy					
	107	Government support and policy through legislation Influence					
	108	Influence from partners who have adopted BIM					
	109	Best practices for Constructability Implementation					
	110	Globalization and competitive strategies					
	111	Market demands					
	112	Economic demand in the AEC industry					
	113	International flexibility/adaptability to market					
	114	Competitive advantages in market (core/unique)					
	115	Client request					
	116	Demographic factors					
	117	BIM is required by other team members					
	118	Clients' satisfaction with BIM projects					
	119	Incentive programs for using BIM					
	120	Comparative advantage					
	121	BIM benefits					
	122	Other project team members decide to move to BIM					
	123	Enabling environment					
	124	Proof of cost savings by its adoption					
	125	External pressure					
	126	Number of BIM-knowledgeable companies in the project					
	127	Ease of Implementation					
BIM	128	Self-efficacy					

Please rank the following categories from most to least influential to the adoption of BIM in Bahraini construction industry

Category	People	Process	Policy	Organization	Technology	Environment
Rank						

APPENDIX 4

Delphi Technique Questionnaire Results Analysis

Definitions:

BIM: “BIM is a digital representation of physical and functional characteristics of a facility. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder.” (NIBS, 2007)

Privacy Protection

All responses are kept strictly confidential and is only used for academic purposes.

Section 1: Personal profile

Name:

Position Title:

Company Name

How long have you been working in the Bahraini architecture, engineering and construction industry (AEC)?	Less than a year	1-5 years	6-10 years	11-15 years	More than 20 years	
Are you aware of Building Information Modeling (BIM)?	Yes	No				
Do you use Building Information Modeling (BIM)?	Yes	No				
Please indicate the BIM software product(s) that your firm uses: (select all that apply)	Autodesk Revit	Bentley Architecture	Rhino 3d	Tekla Structures	Archi CAD	AutoCAD Architecture

Section 2: BIM adoption in Bahrain

The following is a set of factors that help in the adoption of BIM technology in Bahrain’s construction industry.

Please select the most appropriate answer by ticking one of the boxes for each criterion based on the current state of practice in

Bahrain construction industry, where **1- Very inapplicable** **2- Not applicable** **3- Neutral** **4-Applicable** **5-Highly applicable**

Category	Factor		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO.	Description	1	2	3	4	5
Technology	1	Information Format	0	0	2	5	4
	2	Visualization	0	0	3	3	5
	3	Automation	0	0	4	3	4
	4	Usefulness digital transfer of data/information	0	1	1	5	4
	5	Loss of data	1	0	7	2	1

Category	Factor		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO.	Description	1	2	3	4	5
Technology	6	BIM Software availability and affordability	0	2	6	1	2
	7	Understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently	0	1	5	4	1
	8	Technology facilitating condition	0	0	5	5	1
	9	Data richness/ Real-time data	0	1	3	2	5
	10	Software applications Interoperability	2	0	3	2	4
	11	Hardware equipment/ Hardware upgrade	1	0	3	2	5
	12	Testability	0	2	4	4	1
	13	Observability	0	1	3	5	2
	14	Uninterrupted power and a strong Internet	0	0	4	5	2
	15	Security of confidential information on project data	0	1	1	6	3
	16	Problems faced in the current 2D drafting practices	0	3	4	1	3
	17	Technical competence of staff	0	0	3	6	2
	18	Technological capability of organization	0	0	3	6	2
	19	Awareness of the technology among industry stakeholders	0	1	3	5	2
	20	Compatibility	0	0	5	5	1
	21	Complexity	0	0	7	4	0
	22	BIM libraries	1	1	2	3	4
	23	Technical support	0	2	3	2	4
People	24	Process and workflow training	0	1	1	6	3
	25	Software and technology training	0	2	1	3	5
	26	Perceived Usefulness	1	0	3	4	3
	27	Perceived Ease of Use	0	1	4	4	2
	28	Strength of culture (eg, shared identity, norms, values, and assumptions)	1	2	3	4	1
	29	Human capability/resources	0	0	5	3	3
	30	Organizational learning capability	0	0	4	4	3

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
People	31	Managing people resistance to BIM change; and Socioeconomic conditions	0	1	6	3	1
	32	Perceptions and attitudes	0	0	5	5	1
	33	Subjective norm	0	0	9	2	0
	34	Social influence	0	2	5	4	0
	35	Interest in learning BIM	0	0	3	5	3
	36	Incentives; and Enjoyment with innovation	0	1	4	2	4
	37	Qualified cadres and experts to train BIM software	0	0	2	5	4
	38	Need to innovate, the innovation, and the diffusion of innovation	0	2	0	5	4
	39	level of awareness of BIM and the knowledge about BIM	1	0	2	6	2
	40	Education	0	0	5	5	1
	41	Observable large productivity gain	0	1	2	7	1
	42	Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers	0	2	5	3	1
	43	Professional development	0	1	2	4	4
	44	Supporting individual characteristics	0	1	1	6	3
	45	Supporting open discussion environment	0	1	3	5	2
	46	Colleagues help	0	0	4	6	1
	47	Project team expectations	0	0	3	4	4
	48	Subjective Norms	0	0	4	5	2
	49	New set of skills required	3	1	1	5	1
	50	Staff from different companies working in the same location	0	1	2	7	1
process	51	Standard & rules	0	0	2	5	4
	52	Communication	0	1	2	5	3
	53	Shared norms and collective expectations diffused through information exchange activities	0	1	2	5	3
	54	Contractual sharing norm	0	0	3	7	1

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
process	55	Collaborative Procurement methods	0	1	4	5	1
	56	Social network	0	2	6	3	0
	57	Corporate management style (family owned or public owned)	0	0	7	2	2
	58	Leadership of senior management	0	1	2	4	4
	59	Ownership	0	1	3	5	2
	60	Collaboration with universities	0	1	4	3	3
	61	Shared liability between project participants	0	1	2	6	2
	62	Collaboration (project) management tools	0	1	1	6	3
	63	Providing guidance on use of BIM	1	1	1	6	2
	64	Developing data exchange standards	0	1	0	6	4
	65	Companies' collaboration experience with project partners	0	0	1	8	2
	66	Project schedule	0	0	4	4	3
	67	Decision Making Support	0	1	3	5	2
	68	Information Availability and Sharing	0	0	3	8	0
	69	Desire to speed up the design process	0	0	2	4	5
Policy	70	Regulation, policy & industry standards	0	1	2	6	2
	71	The increased demand for design and Build contracts	0	1	4	4	2
	72	Formulation of BIM contracts	0	1	5	2	3
	73	Defining levels of BIM working for reference in professional services agreements	0	1	5	3	2
	74	Managing risk	2	0	3	4	2
	75	Information delivery method	0	0	4	5	2
	76	Project delivery models	0	0	4	5	2
	77	Sufficient legal framework for integrating owners' view in design and construction	0	0	5	5	1
	78	BIM mandate	1	0	7	3	0
	79	Information sharing protocols	0	0	4	5	2

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
Organization	80	Top management support	0	1	2	3	5
	81	Realizing the value from financial perspective	0	1	3	3	4
	82	Availability of BIM professionals	1	0	4	5	1
	83	Performance measures and benchmarking for continuous improvement	0	1	2	6	2
	84	Financial resources of organization	0	1	2	8	0
	85	Research and development capability of organization	0	1	5	5	0
	86	An organizational structure that supports BIM	0	0	3	7	1
	87	Business interest	0	0	4	5	2
	88	Organization size	2	1	3	4	1
	89	Hiring BIM specialists	1	1	2	5	2
	90	Development of BIM department within an organization to monitor the application of BIM	1	0	5	3	2
	91	Project budget	0	1	5	4	1
	92	Continuous investment in BIM	1	1	4	5	0
	93	Top Management Sustain	0	0	6	5	0
	94	Organizational Motivations	0	0	4	7	0
	95	Organizational innovativeness	0	0	4	7	0
	96	Internal pressure	0	1	4	6	0
	97	Number of employees (over 100)	2	1	2	6	0
	98	Project nature	2	1	2	3	3
	99	Project value	2	1	2	4	2
	100	Acceptance of BIM from middle management	0	1	4	3	3
	101	Internal readiness	0	0	7	1	3
Environment	102	Client's willingness to adopt new technology	0	2	2	3	4
	103	Pressure from competitors	1	2	0	5	3
	104	Push from governments	0	3	3	3	2
	105	Clients/owners support	0	2	5	3	1

Category	Indicator		Very inapplicable	Not applicable	Neutral	Applicable	Highly applicable
	NO	Description	1	2	3	4	5
BIM	106	Government financial support and subsidy	0	2	5	3	1
	107	Government support and policy through legislation Influence	1	1	1	6	2
	108	Influence from partners who have adopted BIM	0	0	3	5	3
	109	Best practices for Constructability Implementation	0	0	2	7	2
	110	Globalization and competitive strategies	0	1	1	7	2
	111	Market demands	0	0	4	6	1
	112	Economic demand in the AEC industry	0	1	1	8	1
	113	International flexibility/adaptability to market	0	0	2	7	2
	114	Competitive advantages in market (core/unique)	1	0	5	3	2
	115	Client request	1	1	6	1	2
	116	Demographic factors	1	0	5	2	3
	117	BIM is required by other team members	1	1	4	2	3
	118	Clients' satisfaction with BIM projects	1	0	5	3	2
	119	Incentive programs for using BIM	0	0	3	5	3
	120	Comparative advantage	0	1	2	5	3
	121	BIM benefits	1	0	3	5	2
	122	Other project team members decide to move to BIM	1	0	2	6	2
	123	Enabling environment	0	0	4	2	5
	124	Proof of cost savings by its adoption	1	0	4	5	1
	125	External pressure	0	1	5	3	2
	126	Number of BIM-knowledgeable companies in the project	0	1	4	5	1
	127	Ease of Implementation	0	2	5	3	1
BIM	128	Self-efficacy	0	0	3	7	1

Please rank the following categories from most to least influential to the adoption of BIM in Bahraini construction industry:

Category	People	Process	Policy	Organization	Technology	Environment
Rank						

Respondents	People	Process	Policy	Organization	Technology	Environment
1"	6	2	1	5	4	3
2"	3	2	6	4	1	5
3"	1	5	2	3	4	6
4"	3	2	5	6	4	1
5"	3	4	5	1	2	6
6"	3	2	6	5	1	4
7"	2	3	6	5	1	4
8"	5	2	6	4	3	1
9"	6	2	3	5	1	4
10"	6	5	2	1	3	4
11"	1	4	6	2	5	3
According to most ranked	People	Process	Policy	Organization	Technology	Environment
	3	2	6	5	1	4

APPENDIX 5

Questionnaire Format

Section 1: General Information	القسم 1: معلومات عامة
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Please mark one answer of the following:

Name(optional)	الاسم(اختياري):
What is your education level? ☐ BSc ☐ MSc ☐ PhD ☐ Other :	ما هو مستواك التعليمي؟ ☐ البكالوريوس ☐ ماجستير ☐ دكتوراه ☐ أخرى:
What is your specialization? ☐ Architecture ☐ Civil Engineering ☐ Mechanical Engineering ☐ Electrical Engineering ☐ Other :	ما هو تخصصك؟ ☐ العمارة ☐ الهندسة المدنية ☐ الهندسة الميكانيكية ☐ الهندسة الكهربائية ☐ أخرى:
What is your position in your company? ☐ Director /Upper Manager ☐ Project/Section Manager ☐ Architect ☐ Design Engineer ☐ Construction Engineer ☐ BIM Manager ☐ BIM Designer ☐ Other :	ما هو منصبك في شركتك؟ ☐ مدير / المدير الأعلى ☐ مدير مشروع / قسم ☐ مهندس المعماري ☐ مهندس تصميم ☐ مهندس بناء ☐ مدير BIM ☐ مصمم BIM ☐ أخرى:
Years of experience in construction industry? ☐ Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐ More than 20 years	سنوات الخبرة في صناعة البناء والتشييد؟ ☐ أقل من 5 سنوات ☐ من 5 إلى 10 سنوات ☐ من 11-15 سنة ☐ من 16-20 سنة ☐ أكثر من 20 عامًا
What is your company name? (Optional)	ما هو اسم شركتك؟ (اختياري)
What is your organization sector? ☐ Public ☐ Private	الى أي قطاع تنتمي مؤسستك؟ ☐ القطاع العام ☐ القطاع الخاص
What is your company grade? ☐ A ☐ B ☐ C ☐ D ☐ F	ما هو تصنيف شركتك؟ ☐ أ ☐ ب ☐ ج ☐ د ☐ هـ
Which of the following best describes your company type? ☐ Designer /Architect /Engineer ☐ Consulting ☐ General Contractor ☐ Sub-Contractor ☐ Other:	أي مما يلي بشكل أفضل وصف لشركتك؟ مصمم/مهندس معماري/مهندس استشارات مقاول عام مقاول فرعي أخرى:

Section 2: Building Information Modeling Awareness	القسم 2 : الوعي بنمذجة معلومات البناء
--	---------------------------------------

Building Information Modeling (BIM) is defined as “a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle (NIBS, 2007).

Are you aware of Building Information Modeling (BIM)? ☐ Yes ☐ No	هل أنت على علم بنمذجة معلومات البناء؟ ☐ نعم ☐ لا
---	---

According to the previous definition, please mark one answer of the following:

Section 3: Building Information Modeling Knowledge	القسم 3 : معرفة نمذجة معلومات البناء
Any of the following programs you use in your work? (please select all that apply) ☐ None ☐ Tekla structures ☐ Autodesk Revit (Architecture -Structure -MEP) ☐ ArchiCAD ☐ Bentley systems architecture ☐ Autodesk AutoCAD Architecture ☐ Other :	أي من البرامج التالية تستخدمها في عملك الهندسي؟ (يرجى اختيار كل ما ينطبق) ☐ لا شيء ☐ Tekla structures ☐ Autodesk Revit (Architecture -Structure -MEP) ☐ ArchiCAD ☐ Bentley systems architecture ☐ Autodesk AutoCAD Architecture ☐ أخرى:
What are the uses of your chosen programs in your projects? (please select all that apply) ☐ Designing in 2D ☐ Designing in 3D ☐ Cost estimation ☐ Quantity surveying ☐ Project schedule ☐ Other :	ما هي استخدامات البرامج التي اخترتها في مشاريعك؟ (يرجى اختيار كل ما ينطبق) ☐ تصميم ثنائي الأبعاد ☐ تصميم ثلاثي الأبعاد ☐ تقدير التكلفة ☐ المسح الكمي ☐ جدول المشروع ☐ أخرى:
Have you ever used BIM in your work? ☐ Yes ☐ No	هل سبق لك استخدام نمذجة معلومات البناء (BIM) في عملك؟ ☐ نعم ☐ لا
If yes, for what purposes? (please select all that apply) ☐ Visualization ☐ Interaction with professionals ☐ Drawing production ☐ Design analysis ☐ Models collaboration across project life cycle ☐ Other :	إذا كانت الإجابة بنعم ، لأي أغراض؟ (يرجى اختيار كل ما ينطبق) ☐ التصور ☐ التفاعل مع المهنيين ☐ إنتاج الرسومات ☐ تحليل التصميم ☐ نماذج التعاون عن طريق النماذج عبر دورة حياة المشروع ☐ أخرى:
How do you define BIM through your own understanding? ☐ Visualization tool ☐ Collaborative process ☐ Number of software ☐ Number of rules and process ☐ New technology and techniques ☐ Other :	كيف تعرف BIM من خلال فهمك الخاص؟ ☐ أداة للتصور ☐ عملية تعاونية ☐ عدد من البرامج ☐ عدد القواعد والعمليات ☐ تكنولوجيا وتقنية جديدة ☐ أخرى:

Section 4: Factors influencing the adoption of BIM	القسم 4: العوامل التي تؤثر على تبني BIM
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Based on your experience and using this scale from 1 to 5 in the table below, indicate by ticking your opinion regarding the following statements about factors influencing the adoption of BIM. If you are not aware about BIM, please answer as factors influencing the adoption for any new technology in the Bahraini construction industry.

	Factor	Strongly disagree لا أوافق بشدة	Disagree لا أوافق	Uncertain غير محدد	Agree أوافق	Strongly Agree أوافق بشدة	العامل
		1	2	3	4	5	
Technology related factors / العوامل المتعلقة بالتكنولوجيا							
1	The technical competence of staff.						الكفاءة الفنية للموظفين.

	Factor	Strongly disagree لا أوافق بشدة (1)	Disagree لا أوافق (2)	Uncertain غير محدد (3)	Agree أوافق (4)	Strongly Agree أوافق بشدة (5)	العامل
2	The technological capability of organization.						القدرة التكنولوجية للمنظمة.
3	Available data richness.						غنى أو ثراء البيانات المتاحة .
4	Work automation.						أوتوماتيكية العمل.
5	The availability of supporting resources such as computer hardware equipment.						توفر الموارد الداعمة مثل أجهزة الكمبيوتر.
6	Awareness of the technology among industry stakeholders.						الوعي بأهمية التكنولوجيا بين أصحاب المصلحة.
7	Standardization of data format.						توحيد شكل البيانات.
8	Usefulness digital transfer of data.						فائدة النقل الرقمي للمعلومات.
9	The availability of 3D model visualization.						توفير التصور الثلاثي للابعاد.
10	The availability of security of confidential information on project data.						توفير الأمن المعلوماتي للبيانات.
11	The availability of BIM libraries to facilitate the work.						توفر مكتبات BIM (المجسمات الجاهزة) لتسهيل العمل.
12	Uninterrupted power and a strong Internet.						توفر الإنترنت بكفاءة.
13	The effortless observability of results in BIM.						قلة الجهد المطلوب لرؤية النتائج .
Process related factors / العوامل المتعلقة بالعملية							
1	Developing data exchange standards.						وضع معايير لتبادل البيانات.
2	Companies' collaboration experience with project partners.						التعاون بين الشركات وشركاء المشروع.
3	The availability of BIM standards & rules.						توافر المعايير والقواعد الخاصة به .
4	The need of collaboration management tools.						الحاجة إلى أدوات لإدارة التعاون.
5	Desire to speed up the design process.						الرغبة في تسريع عملية التصميم.
6	The need of communication among team members.						الحاجة للتواصل بين أعضاء الفريق.
7	The availability of shared norms and collective expectations diffused through information exchange activities.						وجود معايير وتوقعات مشتركة لتبادل المعلومات.
8	Contractual sharing norm between team members.						المشاركة التعاقدية بين أعضاء الفريق.
9	Leadership of senior management.						قيادة الإدارة العليا.
10	Shared liability between project participants.						المسؤولية المشتركة بين المشاركين في المشروع .
11	Providing guidance on use of BIM.						توافر التوجيه المساعد على استخدامه.
12	Information availability and sharing features of BIM.						توافر المعلومات ومشاركتها.
People related factors / العوامل المتعلقة بالأشخاص							
1	Providing process and workflow training.						توفير التدريب على العملية وسير العمل .

	Factor	Strongly disagree لا أوافق بشدة (1)	Disagree لا أوافق (2)	Uncertain غير محدد (3)	Agree أوافق (4)	Strongly Agree أوافق بشدة (5)	العامل
2	Qualified cadres and experts to train BIM software.						توافر الكوادر والخبراء للتدريب على برامجه.
3	Need to innovate, and the diffusion of innovation.						الحاجة إلى الابتكار وانتشاره.
4	Supporting individual characteristics.						دعم الخصائص الفردية.
5	Providing software and technology training.						توافر التدريب على البرامج والتكنولوجيا.
6	Interest in learning BIM.						الاهتمام بتعلمه.
7	Level of awareness and knowledge about BIM.						مستوى الوعي والمعرفة به.
8	Observable large productivity gain after using BIM.						الزيادة الملحوظة في الإنتاجية بعد استخدامه.
9	Desire of Professional development.						الرغبة في التطور المهني.
10	Project team expectations about results.						توقعات فريق المشروع حول النتائج.
Environment related factors / العوامل المتعلقة بالبيئة							
1	Globalization and competitive strategies.						العولمة والاستراتيجيات التنافسية.
2	Market demands.						التكيف مع متطلبات السوق.
3	International flexibility/adaptability to market.						المرونة والقدرة على التكيف للسوق الدولي.
4	Gaining competitive advantages in market.						اكتساب المزايا التنافسية في السوق.
5	Pressure from competitors.						ضغوط المنافسين للمنظمة.
6	Influence from partners who have adopted BIM.						تأثير الشركاء الذين اعتمدوه.
7	Best practices for constructible implementation.						يعد أفضل الممارسات لتنفيذ البناء.
8	Gaining Comparative advantage.						اكتساب المنظمة ميزة نسبية.
9	The benefits of using BIM.						فوائد استخدامه.
10	Enabling environment.						البيئة المواتية.
Organization related factors / العوامل المتعلقة بالمنظمة							
1	Top management support.						توافر دعم الإدارة العليا.
2	Performance measures and benchmarking for continuous improvement.						قياس الأداء والتحسين المستمر.
3	Financial resources of organization.						توافر الموارد المالية اللازمة.
4	The availability of organizational structure that supports BIM.						توافر الهيكل التنظيمي الداعم له.
Policy related factors / العوامل المتعلقة بسياسة العمل							
1	The availability of regulation & policy.						توافر اللوائح والسياسات التنظيمية.
2	The availability of industry standards.						توافر معايير الصناعة.
3	Required project delivery modes.						التوافق مع الطرق المطلوبة لتسليم المشاريع.
4	The increased demand for design and Build contracts.						زيادة الطلب على عقود التصميم والبناء.

BIM adoption related factors/ عوامل متعلقة بتبني البيم							
1	BIM self-efficacy.						الكفاءة الذاتية لـ BIM

برأيك ما هي العوامل الأخرى التي تؤثر على اعتماد BIM في صناعة البناء
البحرينية (اختياري) ؟
In your opinion what are other factors that influence the adoption of BIM in Bahraini construction industry (optional)?

	Suggested Factors	Strongly disagree لا أوافق بشدة	Disagree لا أوافق	Uncertain غير محدد	Agree أوافق	Strongly Agree أوافق بشدة	العوامل المقترحة
		1	2	3	4	5	
1							
2							

APPENDIX 6

Questionnaire Data

Section 1: General Information	القسم 1: معلومات عامة
Name(optional)	الاسم(اختياري):
What is your education level? ☐ BSc ☐ MSc ☐ PhD ☐ Other :	ما هو مستواك التعليمي؟ ☐ البكالوريوس ☐ ماجستير ☐ دكتوراه ☐ أخرى:
What is your specialization? ☐ Architecture ☐ Civil Engineering ☐ Mechanical Engineering ☐ Electrical Engineering ☐ Other :	ما هو تخصصك؟ ☐ العمارة 124 ☐ الهندسة المدنية 98 ☐ الهندسة الميكانيكية 24 ☐ الهندسة الكهربائية 16 ☐ أخرى 10:
What is your position in your company? ☐ Director /Upper Manager ☐ Project/Section Manager ☐ Architect ☐ Design Engineer ☐ Construction Engineer ☐ BIM Manager ☐ BIM Designer ☐ Other :	ما هو منصبك في شركتك؟ ☐ مدير / المدير الأعلى 12 ☐ مدير مشروع / قسم 53 ☐ مهندس المعماري 94 ☐ مهندس تصميم 58 ☐ مهندس بناء 29 ☐ مدير BIM ☐ مصمم BIM 3 ☐ أخرى 23:
Years of experience in construction industry? ☐ Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐ More than 20 years	سنوات الخبرة في صناعة البناء والتشييد؟ ☐ أقل من 5 سنوات 97 ☐ من 5 إلى 10 سنوات 67 ☐ من 11-15 سنة 34 ☐ من 16-20 سنة 23 ☐ أكثر من 20 عامًا 51
What is your company name? (Optional)	ما هو اسم شركتك؟ (اختياري)
What is your organization sector? ☐ Public ☐ Private	الى أي قطاع تنتمي مؤسستك؟ ☐ القطاع العام 37 ☐ القطاع الخاص 235
What is your company grade? ☐ A ☐ B ☐ C ☐ D ☐ F	ما هو تصنيف شركتك؟ ☐ أ 134 ☐ ب 69 ☐ ج 31 ☐ د 1 ☐ هـ 37
Which of the following best describes your company type? ☐ Designer /Architect /Engineer ☐ Consulting ☐ General Contractor ☐ Sub-Contractor ☐ Other:	أي مما يلي يشكل أفضل وصف لشركتك؟ مصمم/مهندس معماري/مهندس 92 استشارات 101 مقاول عام 37 مقاول فرعي 4 أخرى: 38:
Section 2: Building Information Modeling Awareness	القسم 2 : الوعي بنمذجة معلومات البناء

Building Information Modeling (BIM) is defined as “a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle (NIBS, 2007).

According to the previous definition, please mark one answer of the following:

Are you aware of Building Information Modeling (BIM)? ☐ Yes ☐ No	هل أنت على علم بنمذجة معلومات البناء؟ ☐ نعم 195 ☐ لا 77
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Section 3: Building Information Modeling Knowledge

القسم 3 : معرفة نمذجة معلومات البناء

Any of the following programs you use in your work? (please select all that apply)	أي من البرامج التالية تستخدمها في عملك الهندسي؟ (يرجى اختيار كل ما ينطبق)
☐ None	☐ لا شيء 14
☐ Tekla structures	☐ 11 Tekla structures
☐ Autodesk Revit (Architecture -Structure -MEP)	☐ 94 Autodesk Revit (Architecture -Structure -MEP)
☐ ArchiCAD	☐ 37 ArchiCAD
☐ Bentley systems architecture	☐ 17 Bentley systems architecture
☐ Autodesk AutoCAD Architecture	☐ 216 Autodesk AutoCAD Architecture
☐ Other :	☐ أخرى 49
What are the uses of your chosen programs in your projects? (please select all that apply)	ما هي استخدامات البرامج التي اخترتها في مشاريعك؟ (يرجى اختيار كل ما ينطبق)
☐ Designing in 2D	☐ تصميم ثنائي الأبعاد 208
☐ Designing in 3D	☐ تصميم ثلاثي الأبعاد 154
☐ Cost estimation	☐ تقدير التكلفة 51
☐ Quantity surveying	☐ المسح الكمي 74
☐ Project schedule	☐ جدول المشروع 37
☐ Other :	☐ أخرى 15: ...
Have you ever used BIM in your work?	هل سبق لك استخدام نمذجة معلومات البناء (BIM) في عملك؟
☐ Yes ☐ No	☐ لا ☐ نعم 106
If yes, for what purposes? (please select all that apply)	إذا كانت الإجابة بنعم ، لأي أغراض؟ (يرجى اختيار كل ما ينطبق)
☐ Visualization	☐ التصور 71
☐ Interaction with professionals	☐ التفاعل مع المهنيين 29
☐ Drawing production	☐ إنتاج الرسومات 72
☐ Design analysis	☐ تحليل التصميم 48
☐ Models collaboration across project life cycle	☐ نماذج التعاون عن طريق النماذج عبر دورة حياة المشروع 18
☐ Other :	☐ أخرى 11: .
How do you define BIM through your own understanding?	كيف تعرف BIM من خلال فهمك الخاص؟
☐ Visualization tool	☐ أداة للتصور 89
☐ Collaborative process	☐ عملية تعاونية 49
☐ Number of software	☐ عدد من البرامج 26
☐ Number of rules and process	☐ عدد القواعد والعمليات 13
☐ New technology and techniques	☐ تكنولوجيا وتقنية جديدة 75
☐ Other :	☐ أخرى 20

Section 4: Factors influencing the adoption of BIM

القسم 4: العوامل التي تؤثر على تبني BIM

Based on your experience and using this scale from 1 to 5 in the table below, indicate by ticking your opinion regarding the following statements about factors influencing the adoption of BIM. **If you are not aware about BIM, please answer as factors influencing the adoption for any new technology in the Bahraini construction industry.**

	Factor	Strongly disagree لا أوافق بشدة 1	Disagree لا أوافق 2	Uncertain غير محدد 3	Agree أوافق 4	Strongly Agree أوافق بشدة 5	العامل
Technology related factors / العوامل المتعلقة بالتكنولوجيا							
1	The technical competence of staff.	2	4	41	148	77	الكفاءة الفنية للموظفين.
2	The technological capability of organization.		7	43	147	75	القدرة التكنولوجية للمنظمة.
3	Available data richness.	1	12	74	133	52	غنى أو ثراء البيانات المتاحة .
4	Work automation.	2	10	61	141	58	أوتوماتيكية العمل.

	Factor	Strongly disagree لا أوافق بشدة (1)	Disagree لا أوافق (2)	Uncertain غير محدد (3)	Agree أوافق (4)	Strongly Agree أوافق بشدة (5)	العامل
5	The availability of supporting resources such as computer hardware equipment.	4	10	34	132	92	توفر الموارد الداعمة مثل أجهزة الكمبيوتر.
6	Awareness of the technology among industry stakeholders.	2	11	58	143	58	الوعي بأهمية التكنولوجيا بين أصحاب المصلحة.
7	Standardization of data format.		19	84	118	51	توحيد شكل البيانات.
8	Usefulness digital transfer of data.	3	7	88	130	44	فائدة النقل الرقمي للمعلومات.
9	The availability of 3D model visualization.	1	17	45	144	65	توفير التصور الثلاثي للابعاد.
10	The availability of security of confidential information on project data.	7	19	72	136	38	توفير الأمن المعلوماتي للبيانات.
11	The availability of BIM libraries to facilitate the work.	8	56	102	78	28	توفر مكتبات BIM (المجسمات الجاهزة) لتسهيل العمل.
12	Uninterrupted power and a strong Internet.	5	19	76	119	53	توفر الإنترنت بكفاءة.
13	The effortless observability of results in BIM.	3	17	83	124	45	قلة الجهد المطلوب لرؤية النتائج .
Process related factors / العوامل المتعلقة بالعملية							
1	Developing data exchange standards.	2	9	86	141	34	وضع معايير لتبادل البيانات.
2	Companies' collaboration experience with project partners.	1	8	81	143	39	التعاون بين الشركات وشركاء المشروع.
3	The availability of BIM standards & rules.	3	15	77	133	44	توافر المعايير والقواعد الخاصة به .
4	The need of collaboration management tools.	5	9	82	145	31	الحاجة إلى أدوات لإدارة التعاون.
5	Desire to speed up the design process.	1	10	48	132	81	الرغبة في تسريع عملية التصميم.
6	The need of communication among team members.	2	7	63	117	83	الحاجة للتواصل بين أعضاء الفريق.
7	The availability of shared norms and collective expectations diffused through information exchange activities.	2	10	92	137	31	وجود معايير وتوقعات مشتركة لتبادل المعلومات.
8	Contractual sharing norm between team members.	2	15	108	109	38	المشاركة التعاقدية بين أعضاء الفريق.
9	Leadership of senior management.	2	18	92	99	61	قيادة الإدارة العليا.
10	Shared liability between project participants.	1	9	74	141	47	المسؤولية المشتركة بين المشاركين في المشروع .
11	Providing guidance on use of BIM.	3	8	63	137	61	توافر التوجيه المساعد على استخدامه.
12	Information availability and sharing features of BIM.	2	15	52	137	66	توافر المعلومات ومشاركتها.
People related factors / العوامل المتعلقة بالأشخاص							
1	Providing process and workflow training.	3	6	32	139	92	توفير التدريب على العملية وسير العمل .
2	Qualified cadres and experts to train BIM software.	1	9	37	124	101	توافر الكوادر والخبراء للتدريب على برامجه.
3	Need to innovate, and the diffusion of innovation.	1	9	49	150	63	الحاجة إلى الابتكار وانتشاره.
4	Supporting individual characteristics.	4	14	81	131	42	دعم الخصائص الفردية.
5	Providing software and technology training.		11	39	131	91	توافر التدريب على البرامج والتكنولوجيا.
6	Interest in learning BIM.	4	9	56	113	90	الاهتمام بتعلمه .

	Factor	Strongly disagree لا أوافق بشدة (1)	Disagree لا أوافق (2)	Uncertain غير محدد (3)	Agree أوافق (4)	Strongly Agree أوافق بشدة (5)	العامل
7	Level of awareness and knowledge about BIM.	3	10	73	111	75	مستوى الوعي والمعرفة به.
8	Observable large productivity gain after using BIM.	3	13	53	145	58	الزيادة الملحوظة في الإنتاجية بعد استخدامه.
9	Desire of Professional development.	3	5	46	134	75	الرغبة في التطور المهني.
10	Project team expectations about results.	1	8	79	133	51	توقعات فريق المشروع حول النتائج.
Environment related factors / العوامل المتعلقة بالبيئة							
1	Globalization and competitive strategies.	6	7	70	132	57	العولمة والاستراتيجيات التنافسية.
2	Market demands.	1	14	48	142	67	التكيف مع متطلبات السوق.
3	International flexibility/adaptability to market.	2	11	63	143	53	المرونة والقدرة على التكيف للسوق الدولي.
4	Gaining competitive advantages in market.		9	59	142	62	اكتساب المزايا التنافسية في السوق.
5	Pressure from competitors.	2	21	104	111	34	ضغوط المنافسين للمنظمة.
6	Influence from partners who have adopted BIM.	2	19	103	116	32	تأثير الشركاء الذين اعتمدوه.
7	Best practices for constructible implementation.	4	12	87	121	48	يعد أفضل الممارسات لتنفيذ البناء.
8	Gaining Comparative advantage.	1	12	73	133	53	اكتساب المنظمة ميزة نسبية.
9	The benefits of using BIM.	2	8	61	148	53	فوائد استخدامه.
10	Enabling environment.	1	11	117	104	39	البيئة المواتية.
Organization related factors / العوامل المتعلقة بالمنظمة							
1	Top management support.	3	6	42	137	84	توافر دعم الإدارة العليا.
2	Performance measures and benchmarking for continuous improvement.	1	6	42	163	60	قياس الأداء والتحسين المستمر.
3	Financial resources of organization.	2	15	57	129	69	توافر الموارد المالية اللازمة.
4	The availability of organizational structure that supports BIM.	3	13	63	133	60	توافر الهيكل التنظيمي الداعم له.
Policy related factors / العوامل المتعلقة بسياسة العمل							
1	The availability of regulation & policy.	1	14	76	137	44	توافر اللوائح والسياسات التنظيمية.
2	The availability of industry standards.	1	18	70	143	40	توافر معايير الصناعة.
3	Required project delivery modes.		14	92	124	42	التوافق مع الطرق المطلوبة لتسليم المشاريع.
4	The increased demand for design and Build contracts.	1	20	76	125	50	زيادة الطلب على عقود التصميم والبناء.
BIM adoption related factors/ عوامل متعلقة بتبني البيم							
1	BIM self-efficacy.	5	9	81	138	39	الكفاءة الذاتية لـ BIM

In your opinion what are other factors that influence the adoption of BIM in Bahraini construction industry (optional)? **برأيك ما هي العوامل الأخرى التي تؤثر على اعتماد BIM في صناعة البناء البحرينية (اختياري) ؟**

	Suggested Factors	Strongly disagree لا أوافق بشدة 1	Disagree لا أوافق 2	Uncertain غير محدد 3	Agree أوافق 4	Strongly Agree أوافق بشدة 5	العوامل المقترحة
1							
2							

APPENDIX 7

VIF and Tolerance Values

Coefficient			
Model		Collinearity Statistics	
		Tolerance	VIF
t	TE3	.546	t .532
	TE4	.459	2.047
	TES	.453	2.205
	TE6	.547	t .829
	TE7	.556	t .795
	TES	.52t	t .920
	TE9	.575	t .735
	TEt 0	.673	t .456
	TEt t	.63t	t .554
	TEt 2	.555	t .70t
	TE13	.557	t .794
	PRt	.505	t .952
	PR2	.529	t .59t
	PR3	.434	2.303
	PR4	.470	2.t30
	PRS	.543	t .542
	PR6	.425	2.350
	PR7	.464	2.t54
	PRS	.523	t .9tt
	PR9	.530	t .556
	PRt 0	.52t	t .9t5
	PRt t	.409	2.446
	PRt 2	.434	2.302
	PEt	.346	2.59t
	PE2	.325	3.075
	PE3	.427	2.343
	PE4	.459	2.179
	PES	.4t t	2.43t
	PE6	.463	2.t62
	PE7	.459	2.175
	PE8	.463	2.t6t
	PE9	.370	2.703
	PEt 0	.45t	2.050
	ENt	.395	2.532
	EN2	.376	2.66t
	EN3	.423	2.366
	EN4	.445	2.247
	ENS	.60t	t .663
	EN6	.546	t .53t
	EN7	.472	2.t20
	ENS	.457	2.t55
	EN9	.469	2.t33
	ENt 0	.630	t .557
	ORt	.357	2.502
	OR2	.394	2.537
	OR3	.377	2.650
	OR4	.356	2.5t2
	POt	.364	2.744
	P02	.352	2.542
	P03	.492	2.032
	P04	.565	t .765
	TEt	.634	t .575

a. Dependent Variable: TE2

Coefficient			
Model		Collinearity Statistics	
		Tolerance	VIF
t	TE4	.559	t .697
	TES	.447	2.235
	TE6	.545	t .526
	TE7	.555	t .502
	TES	.525	t .904
	TE9	.576	t .737
	TEt 0	.674	t .454
	TEtt	.630	t .557
	TEt 2	.557	t .704
	TEt 3	.570	t .754
	PRt	.505	t .950
	PR2	.530	t .555
	PR3	.436	2.293
	PR4	.459	2.t 79
	PRS	.549	t .52t
	PR6	.426	2.346
	PR 7	.455	2.t 52
	PRS	.526	t .900
	PR9	.5t 3	t .950
	PRt 0	.524	t .9t 0
	PRtt	.407	2.459
	PRt2	.434	2.303
	PEt	.344	2.9t 0
	PE2	.325	3.048
	PE3	.4t5	2.395
	PE4	.462	2.t 66
	PES	.4t 2	2.428
	PE6	.460	2.t 72
	PE7	.459	2.t 5t
	PES	.462	2.t 62
	PE9	.367	2.723
	PEt 0	.475	2.09t
	ENt	.395	2.530
	EN2	.376	2.657
	EN3	.423	2.367
	EN4	.447	2.240
	ENS	.595	t .673
	EN6	.549	t .523
	EN7	.472	2.t 20
	ENS	.455	2.t 53
	EN9	.465	2.t 36
	ENt 0	.63t	t .554
	ORt	.363	2.753
	OR2	.40t	2.494
	OR3	.373	2.678
	OR4	.356	2.508
	POt	.365	2.737
	P02	.353	2.532
	P03	.490	2.040
	P04	.563	t .775
	TEt	.557	t .795
	TE2	.55t	t .5t 4

a. Dependent Variable: TE3

Coefficient			
Model		Collinearity Statistics	
		Tolerance	VIF
t	TES	.454	2.20t
	TE6	.549	t .52t
	TE7	.553	t .5t 0
	TE8	.520	1.921
	TE9	.575	t .740
	TEt 0	.673	t .455
	TEt t	.63t	t .555
	TEt 2	.595	t .652
	TEt 3	.562	t .775
	PRt	.507	t .974
	PR2	.53t	t .555
	PR3	.44t	2.266
	PR4	.460	2.t 75
	PRS	.544	t .535
	PR6	.425	2.337
	PR7	.466	2.t 47
	PRS	.524	t .905
	PR9	.5t 4	t .946
	PRt 0	.52t	t .9t 9
	PRtt	.406	2.466
	PRt2	.434	2.303
	PEt	.344	2.906
	PE2	.325	3.076
	PE3	.417	2.395
	PE4	.465	2.t 5t
	PES	.4t 0	2.436
	PE6	.462	2.t 65
	PE7	.455	2.t 53
	PE8	.46t	2.t 7t
	PE9	.366	2.733
	PEt 0	.474	2.t t 0
	ENt	.395	2.534
	EN2	.376	2.655
	EN3	.423	2.365
	EN4	.447	2.236
	ENS	.595	t .673
	EN6	.545	t .536
	EN7	.473	2.t t5
	ENS	.457	2.t 55
	EN9	.465	2.t 35
	ENt 0	.632	t .552
	ORt	.357	2.500
	OR2	.394	2.540
	OR3	.372	2.692
	OR4	.356	2.5t 3
	POt	.365	2.743
	P02	.352	2.54t
	P03	.489	2.046
	P04	.564	t .773
	TEt	.565	t .770
	TE2	.522	t .9t5
	TE3	.624	t .603

a. Dependent Variable: TE4

Coefficient			
Model		Collinearity Statistics	
		Tolerance	VIF
1	TE6	.594	1.653
	TE7	.553	1.807
	TES	.522	1.914
	TE9	.579	1.727
	TE10	.675	1.475
	TE11	.631	1.585
	TE12	.590	1.694
	TE13	.552	1.810
	PR1	.505	1.979
	PR2	.531	1.883
	PR3	.437	2.281
	PR4	.459	2.179
	PR5	.544	1.840
	PR6	.430	2.325
	PR7	.460	2.174
	PRS	.523	1.910
	PR9	.513	1.950
	PR10	.525	1.904
	PR11	.407	2.454
	PR12	.434	2.302
	PE1	.350	2.855
	PE2	.327	3.060
	PE3	.422	2.370
	PE4	.460	2.172
	PE5	.413	2.420
	PE6	.462	2.164
	PE7	.461	2.167
	PES	.461	2.171
	PE9	.367	2.726
	PE10	.477	2.096
	EN1	.395	2.529
	EN2	.376	2.659
	EN3	.422	2.370
	EN4	.445	2.247
	EN5	.595	1.673
	EN6	.545	1.835
	EN7	.474	2.105
	ENS	.455	2.155
	EN9	.477	2.095
	EN10	.630	1.587
	OR1	.359	2.752
	OR2	.403	2.454
	OR3	.373	2.651
	OR4	.356	2.811
	P01	.365	2.721
	P02	.353	2.833
	P03	.490	2.040
	P04	.565	1.769
	TE1	.559	1.759
	TE2	.529	1.891
	TE3	.517	1.934
	TE4	.496	2.014

a. Dependent Variable: TE5

Coefficient				
Model		Collinearity Statistics		
		Tolerance	VIF	
1	TE7	.565	1.759	
	TES	.520	1.923	
	TE9	.571	1.751	
	TE10	.674	1.453	
	TE11	.644	1.553	
	TE12	.590	1.694	
	TE13	.553	1.807	
	PR1	.514	1.945	
	PR2	.531	1.883	
	PR3	.437	2.291	
	PR4	.459	2.180	
	PR5	.543	1.841	
	PR6	.430	2.325	
	PR7	.459	2.180	
	PRS	.523	1.912	
	PR9	.509	1.965	
	PR10	.528	1.893	
	PR11	.410	2.440	
	PR12	.434	2.303	
	PE1	.347	2.882	
	PE2	.325	3.075	
	PE3	.415	2.395	
	PE4	.463	2.160	
	PE5	.409	2.445	
	PEG	.468	2.137	
	PE7	.480	2.054	
	PES	.461	2.170	
	PE9	.366	2.735	
	PE10	.474	2.109	
	EN1	.397	2.517	
	EN2	.379	2.635	
	EN3	.422	2.370	
	EN4	.446	2.244	
	EN5	.597	1.674	
	EN6	.545	1.836	
	EN7	.456	2.055	
	ENS	.457	2.155	
	EN9	.465	2.136	
	EN10	.631	1.584	
	OR1	.355	2.796	
	OR2	.394	2.536	
	OR3	.373	2.675	
	OR4	.361	2.765	
	P01	.371	2.695	
	P02	.356	2.813	
	P03	.491	2.036	
	P04	.570	1.754	
	TE1	.559	1.759	
	TE2	.522	1.916	
	TE3	.517	1.933	
	TE4	.491	2.039	
	TE5	.456	2.059	

a. Dependent Variable: TE6

Coefficient			
Model		Collinearity Statistics	
		Tolerance	VIF
1	TES	.535	1.869
	TE9	.571	1.752
	TE10	.675	1.475
	TE11	.631	1.585
	TE12	.587	1.703
	TE13	.566	1.766
	PR1	.504	1.952
	PR2	.530	1.855
	PR3	.442	2.262
	PR4	.460	2.174
	PR5	.547	1.829
	PR6	.426	2.345
	PR7	.461	2.170
	PRS	.523	1.913
	PR9	.510	1.960
	PR10	.522	1.916
	PR11	.406	2.461
	PR12	.437	2.290
	PE1	.346	2.894
	PE2	.326	3.070
	PE3	.425	2.355
	PE4	.460	2.173
	PE5	.411	2.435
	PE6	.460	2.172
	PE7	.466	2.144
	PES	.464	2.154
	PE9	.366	2.735
	PE10	.452	2.074
	EN1	.395	2.533
	EN2	.379	2.642
	EN3	.423	2.367
	EN4	.455	2.199
	EN5	.595	1.673
	EN6	.545	1.835
	EN7	.480	2.082
	ENS	.455	2.152
	EN9	.469	2.131
	EN10	.634	1.575
	OR1	.357	2.801
	OR2	.394	2.540
	OR3	.376	2.655
	OR4	.356	2.805
	P01	.365	2.740
	P02	.353	2.834
	P03	.495	2.021
	P04	.564	1.773
	TE1	.557	1.797
	TE2	.525	1.905
	TE3	.519	1.925
	TE4	.455	2.049
	TE5	.447	2.235
	TE6	.562	1.775

a. Dependent Variable: TE7

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	TE9	.571	1.753
	TE10	.695	1.432
	TE11	.634	1.575
	TE12	.557	1.703
	TE13	.565	1.770
	PR1	.507	1.974
	PR2	.537	1.563
	PR3	.434	2.303
	PR4	.463	2.159
	PR5	.544	1.539
	PR6	.430	2.324
	PR7	.459	2.175
	PR5	.527	1.599
	PR9	.509	1.964
	PR10	.523	1.911
	PR11	.406	2.463
	PR12	.435	2.300
	PE1	.344	2.907
	PE2	.325	3.076
	PE3	.417	2.396
	PE4	.462	2.166
	PE5	.410	2.435
	PE6	.463	2.160
	PE7	.459	2.175
	PES	.462	2.166
	PE9	.367	2.723
	PE10	.474	2.109
	EN1	.395	2.535
	EN2	.376	2.659
	EN3	.435	2.300
	EN4	.452	2.211
	EN5	.604	1.656
	EN6	.545	1.526
	EN?	.472	2.120
	ENS	.455	2.154
	EN9	.473	2.114
	EN10	.630	1.557
	OR1	.355	2.791
	OR2	.371	2.696
	OR3	.356	2.513
	P01	.365	2.735
	P02	.359	2.759
	P03	.491	2.035
	P04	.573	1.745
	TE1	.557	1.795
	TE2	.522	1.915
	TE3	.522	1.917
	TE4	.455	2.047
	TE5	.449	2.225
	TE6	.547	1.530
	TE7	.569	1.759

a. Dependent Variable: TES

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	TE10	.679	1.473
	TE11	.630	1.586
	TE12	.591	1.691
	TE13	.572	1.750
	PR1	.505	1.975
	PR2	.525	1.592
	PR3	.434	2.303
	PR4	.460	2.175
	PR5	.554	1.505
	PR6	.426	2.349
	PR7	.463	2.160
	PR5	.523	1.911
	PR9	.509	1.963
	PR10	.541	1.545
	PR11	.405	2.453
	PR12	.434	2.303
	PE1	.346	2.559
	PE2	.327	3.062
	PE3	.415	2.392
	PE4	.477	2.095
	PE5	.410	2.440
	PE6	.462	2.163
	PE7	.460	2.175
	PES	.461	2.167
	PE9	.367	2.727
	PE10	.475	2.105
	EN1	.396	2.525
	EN2	.375	2.644
	EN3	.423	2.364
	EN4	.445	2.245
	EN5	.599	1.669
	EN6	.546	1.532
	EN?	.474	2.109
	ENS	.464	2.155
	EN9	.475	2.103
	EN10	.630	1.557
	OR1	.357	2.502
	OR2	.394	2.539
	OR3	.372	2.690
	OR4	.355	2.790
	P01	.365	2.742
	P02	.354	2.526
	P03	.459	2.047
	P04	.565	1.761
	TE1	.570	1.756
	TE2	.526	1.901
	TE3	.521	1.915
	TE4	.492	2.033
	TE5	.453	2.206
	TE6	.547	1.525
	TE7	.553	1.509
	TES	.520	1.923

a. Dependent Variable: TE9

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	TE2	.594	1.653
	TE3	.517	1.934
	TE4	.496	2.015
	TE5	.449	2.229
	TE6	.549	1.521
	TE7	.553	1.510
	TES	.521	1.921
	TE9	.554	1.712
	TE10	.674	1.453
	TE11	.633	1.550
	TE12	.593	1.657
	TE13	.554	1.506
	PR1	.509	1.964
	PR2	.536	1.566
	PR3	.435	2.295
	PR4	.459	2.177
	PR5	.544	1.535
	PR6	.429	2.331
	PR7	.460	2.175
	PR5	.523	1.913
	PR9	.505	1.969
	PR10	.521	1.920
	PR11	.405	2.450
	PR12	.436	2.293
	PE1	.344	2.905
	PE2	.325	3.079
	PE3	.420	2.379
	PE4	.461	2.165
	PE5	.409	2.446
	PE6	.461	2.169
	PE7	.455	2.153
	PES	.466	2.145
	PE9	.366	2.730
	PE10	.475	2.094
	EN1	.395	2.532
	EN2	.376	2.662
	EN3	.425	2.351
	EN4	.446	2.243
	EN5	.595	1.672
	EN6	.547	1.525
	EN?	.472	2.117
	ENS	.457	2.157
	EN9	.469	2.134
	EN10	.632	1.552
	OR1	.355	2.793
	OR2	.395	2.535
	OR3	.372	2.692
	OR4	.356	2.505
	P01	.365	2.743
	P02	.354	2.526
	P03	.494	2.025
	P04	.569	1.755

a. Dependent Variable: TE1

Coefficients•			
Model		Collinearity Statistics	
		Tolerance	VIF
1	TE11	.631	1.586
	TE12	.596	1.677
	TE13	.554	1.805
	PR1	.504	1.953
	PR2	.530	1.857
	PR3	.434	2.303
	PR4	.459	2.180
	PR5	.547	1.830
	PR6	.430	2.326
	PR7	.459	2.179
	PRS	.524	1.908
	PR9	.509	1.966
	PR10	.521	1.919
	PR11	.406	2.463
	PR12	.434	2.302
	PE1	.344	2.908
	PE2	.326	3.069
	PE3	.421	2.375
	PE4	.460	2.172
	PE5	.412	2.430
	PE6	.461	2.171
	PE7	.464	2.153
	PES	.466	2.147
	PE9	.366	2.735
	PE10	.450	2.055
	EN1	.395	2.533
	EN2	.376	2.659
	EN3	.425	2.355
	EN4	.447	2.239
	EN5	.598	1.672
	EN6	.545	1.835
	EN?	.472	2.120
	ENS	.458	2.185
	EN9	.469	2.131
	EN10	.631	1.585
	OR1	.357	2.802
	OR2	.394	2.539
	OR3	.371	2.696
	OR4	.356	2.810
	P01	.365	2.739
	P02	.352	2.841
	P03	.459	2.045
	P04	.563	1.775
	TE1	.558	1.792
	TE2	.522	1.916
	TE3	.517	1.933
	TE4	.459	2.047
	TE5	.450	2.221
	TE6	.548	1.825
	TE7	.557	1.796
	TES	.540	1.853
	TE9	.576	1.736

a. Dependent Variable:TE10

Coefficients•			
Model		Collinearity Statistics	
		Tolerance	VIF
1	TE12	.587	1.703
	TE13	.574	1.741
	PR1	.512	1.953
	PR2	.529	1.890
	PRJ	.439	2.275
	PR4	.459	2.180
	PR5	.544	1.838
	PR6	.426	2.349
	PR7	.459	2.177
	PRS	.532	1.880
	PR9	.509	1.963
	PR10	.521	1.918
	PR11	.415	2.412
	PR12	.440	2.275
	PE1	.344	2.907
	PE2	.326	3.072
	PE3	.418	2.393
	PE4	.465	2.151
	PE5	.419	2.387
	PE6	.462	2.166
	PE7	.458	2.183
	PES	.462	2.163
	PE9	.366	2.736
	PE10	.479	2.089
	EN1	.395	2.532
	EN2	.376	2.658
	EN3	.424	2.360
	EN4	.448	2.233
	EN5	.599	1.670
	EN6	.548	1.825
	EN?	.472	2.120
	ENS	.472	2.118
	EN9	.468	2.136
	EN10	.637	1.570
	OR1	.357	2.801
	OR2	.394	2.540
	OR3	.382	2.620
	OR4	.356	2.812
	P01	.370	2.704
	P02	.352	2.841
	P03	.459	2.047
	P04	.565	1.771
	TE1	.559	1.788
	TE2	.523	1.912
	TE3	.517	1.935
	TE4	.459	2.044
	TE5	.448	2.234
	TE6	.559	1.789
	TE7	.554	1.807
	TES	.524	1.910
	TE9	.571	1.751
	TE10	.674	1.484

a. Dependent Variable:TE11

Coefficients•			
Model		Collinearity Statistics	
		Tolerance	VIF
1	TE13	.556	1.799
	PR1	.506	1.976
	PR2	.528	1.892
	PR3	.434	2.302
	PR4	.463	2.160
	PR5	.543	1.842
	PR6	.426	2.347
	PR7	.462	2.165
	PRS	.523	1.913
	PR9	.510	1.959
	PR10	.522	1.915
	PR11	.407	2.460
	PR12	.436	2.292
	PE1	.356	2.809
	PE2	.333	3.007
	PE3	.418	2.395
	PE4	.463	2.160
	PE5	.410	2.442
	PE6	.462	2.163
	PE7	.458	2.181
	PES	.461	2.171
	PE9	.366	2.729
	PE10	.475	2.103
	EN1	.395	2.535
	EN2	.380	2.634
	EN3	.422	2.370
	EN4	.448	2.234
	EN5	.597	1.674
	EN6	.545	1.834
	EN?	.472	2.120
	ENS	.458	2.184
	EN9	.468	2.136
	EN10	.633	1.580
	OR1	.371	2.693
	OR2	.394	2.535
	OR3	.371	2.696
	OR4	.356	2.812
	P01	.365	2.741
	P02	.353	2.831
	P03	.490	2.040
	P04	.564	1.772
	TE1	.562	1.779
	TE2	.523	1.913
	TE3	.517	1.936
	TE4	.494	2.022
	TE5	.449	2.226
	TE6	.550	1.819
	TE7	.553	1.808
	TES	.520	1.922
	TE9	.575	1.740
	TE10	.683	1.463
	TE11	.630	1.587

a. Dependent Variable:TE12

Coefficients^a

Model		Collinearity Statistics	
		Tolerance	VIF
1	PR1	.505	1.982
	PR2	.529	1.892
	PR3	.435	2.300
	PR4	.459	2.180
	PR5	.564	1.772
	PR6	.425	2.351
	PR7	.459	2.177
	PR8	.524	1.908
	PR9	.512	1.954
	PR10	.524	1.909
	PR11	.411	2.433
	PR12	.435	2.299
	PE1	.344	2.908
	PE2	.328	3.047
	PE3	.422	2.371
	PE4	.470	2.126
	PE5	.411	2.434
	PE6	.464	2.155
	PE7	.459	2.178
	PE8	.462	2.163
	PE9	.366	2.736
	PE10	.476	2.100
	EN1	.395	2.535
	EN2	.378	2.647
	EN3	.422	2.370
	EN4	.446	2.242
	EN5	.598	1.673
	EN6	.546	1.832
	EN7	.472	2.120
	EN8	.457	2.186
	EN9	.469	2.132
	EN10	.630	1.586
	OR1	.357	2.799
	OR2	.394	2.539
	OR3	.371	2.696
	OR4	.356	2.810
	PO1	.366	2.736
	PO2	.354	2.827
	PO3	.489	2.044
	PO4	.564	1.774
	TE1	.558	1.792
	TE2	.527	1.899
	TE3	.533	1.875
	TE4	.497	2.011
	TE5	.447	2.237
	TE6	.548	1.826
	TE7	.566	1.765
	TE8	.532	1.879
	TE9	.591	1.693
	TE10	.675	1.482
	TE11	.655	1.527
	TE12	.591	1.693

a. Dependent Variable: TE13

Coefficients^a

Model		Collinearity Statistics	
		Tolerance	VIF
1	PR2	.598	1.672
	PR3	.439	2.277
	PR4	.459	2.180
	PR5	.544	1.840
	PR6	.427	2.344
	PR7	.460	2.174
	PR8	.523	1.914
	PR9	.507	1.973
	PR10	.533	1.876
	PR11	.407	2.455
	PR12	.435	2.298
	PE1	.344	2.903
	PE2	.327	3.062
	PE3	.422	2.370
	PE4	.467	2.141
	PE5	.409	2.442
	PE6	.476	2.102
	PE7	.463	2.159
	PE8	.461	2.169
	PE9	.370	2.703
	PE10	.475	2.104
	EN1	.396	2.523
	EN2	.380	2.635
	EN3	.436	2.294
	EN4	.445	2.247
	EN5	.600	1.666
	EN6	.547	1.829
	EN7	.473	2.113
	EN8	.457	2.187
	EN9	.469	2.132
	EN10	.638	1.567
	OR1	.357	2.802
	OR2	.394	2.540
	OR3	.373	2.680
	OR4	.361	2.772
	PO1	.368	2.719
	PO2	.352	2.841
	PO3	.492	2.034
	PO4	.564	1.772
	TE1	.562	1.780
	TE2	.522	1.916
	TE3	.517	1.934
	TE4	.490	2.039
	TE5	.448	2.234
	TE6	.557	1.795
	TE7	.553	1.810
	TE8	.522	1.914
	TE9	.572	1.749
	TE10	.673	1.487
	TE11	.639	1.565
	TE12	.589	1.698
	TE13	.552	1.810

a. Dependent Variable: PR1

Coefficients^a

Model		Collinearity Statistics	
		Tolerance	VIF
1	PR3	.446	2.243
	PR4	.459	2.180
	PR5	.548	1.824
	PR6	.429	2.332
	PR7	.459	2.180
	PR8	.525	1.905
	PR9	.517	1.933
	PR10	.521	1.919
	PR11	.411	2.433
	PR12	.442	2.262
	PE1	.344	2.910
	PE2	.325	3.072
	PE3	.417	2.396
	PE4	.459	2.177
	PE5	.410	2.437
	PE6	.463	2.158
	PE7	.458	2.183
	PE8	.463	2.161
	PE9	.366	2.736
	PE10	.474	2.111
	EN1	.395	2.535
	EN2	.376	2.662
	EN3	.431	2.323
	EN4	.445	2.248
	EN5	.602	1.661
	EN6	.545	1.836
	EN7	.475	2.107
	EN8	.459	2.178
	EN9	.470	2.128
	EN10	.632	1.583
	OR1	.362	2.765
	OR2	.394	2.540
	OR3	.372	2.690
	OR4	.356	2.807
	PO1	.365	2.741
	PO2	.352	2.844
	PO3	.497	2.014
	PO4	.565	1.769
	TE1	.564	1.772
	TE2	.522	1.916
	TE3	.518	1.929
	TE4	.490	2.040
	TE5	.449	2.226
	TE6	.549	1.820
	TE7	.554	1.806
	TE8	.528	1.893
	TE9	.571	1.753
	TE10	.675	1.482
	TE11	.631	1.586
	TE12	.587	1.704
	TE13	.552	1.810
	PR1	.571	1.752

a. Dependent Variable: PR2

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PR4	.51S	1.929
	PR5	.544	1.S39
	PR6	.442	2.263
	PR7	.460	2.175
	PRS	.530	1.SS6
	PR9	.515	1.941
	rn1o	.521	1.919
	PR11	.406	2.466
	PR12	.440	2.271
	PE1	.344	2.90S
	PE2	.325	3.0SO
	PE3	.41S	2.391
	PE4	.462	2.164
	PE5	.409	2.445
	PE6	.461	2.171
	PE7	.45S	2.1S3
	PES	.463	2.15S
	PE9	.366	2.730
	PE10	.476	2.100
	EN1	.396	2.52S
	EN2	.376	2.660
	EN3	.422	2.369
	EN4	.44S	2.231
	EN5	.599	1.670
	EN6	.546	1.S30
	EN?	.473	2.114
	ENS	.45S	2.1S4
	EN9	.479	2.0S7
	EN10	.630	1.5S7
	OR1	.361	2.770
	OR2	.394	2.541
	OR3	.373	2.6S3
	OR4	.363	2.751
	P01	.366	2.731
	P02	.352	2.S41
	P03	.4S9	2.047
	P04	.564	1.774
	TE1	.55S	1.793
	TE2	.522	1.916
	TE3	.519	1.92S
	TE4	.496	2.015
	TE5	.450	2.223
	TE6	.550	1.S20
	TE7	.563	1.777
	TES	.520	1.922
	TE9	.571	1.752
	TE10	.673	1.4S6
	TE11	.637	1.569
	TE12	.5S7	1.703
	TE13	.553	1.S0S
	PR1	.510	1.960
	PR2	.543	1.S43

a. Dependent Variable: PR3

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PR5	.555	1.S03
	PR6	.427	2.340
	PR7	.459	2.17S
	PRS	.523	1.911
	PR9	.50S	1.969
	PR10	.521	1.920
	PR11	.406	2.465
	PR12	.434	2.302
	PE1	.347	2.SS3
	PE2	.326	3.06S
	PE3	.423	2.363
	PE4	.460	2.174
	PE5	.409	2.446
	PE6	.461	2.167
	PE7	.45S	2.1S2
	PES	.466	2.145
	PE9	.366	2.735
	PE10	.4S1	2.0SO
	EN1	.39S	2.512
	EN2	.37S	2.644
	EN3	.423	2.362
	EN4	.446	2.240
	EN5	.600	1.667
	EN6	.546	1.S32
	EN?	.476	2.100
	ENS	.459	2.1S1
	EN9	.475	2.107
	EN10	.635	1.576
	OR1	.357	2.S02
	OR2	.395	2.532
	OR3	.371	2.693
	OR4	.357	2.802
	P01	.367	2.722
	P02	.35S	2.792
	P03	.4S9	2.046
	P04	.563	1.775
	TE1	.557	1.794
	TE2	.534	1.S72
	TE3	.517	1.935
	TE4	.4S9	2.044
	TE5	.447	2.237
	TE6	.547	1.S29
	TE7	.554	1.S05
	TES	.525	1.904
	TE9	.572	1.749
	TE10	.673	1.4S7
	TE11	.630	1.5SS
	TE12	.592	1.6SS
	TE13	.552	1.S11
	PR1	.504	1.9S3
	PR2	.52S	1.S92
	PR3	.491	2.03S

a. Dependent Variable: PR4

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PR6	.436	2.296
	PR7	.460	2.175
	PRS	.522	1.914
	PR9	.511	1.956
	PR10	.522	1.915
	PR11	.406	2.466
	PR12	.434	2.303
	PE1	.344	2.90S
	PE2	.325	3.07S
	PE3	.424	2.360
	PE4	.459	2.179
	PE5	.411	2.433
	PE6	.460	2.172
	PE7	.459	2.177
	PES	.461	2.171
	PE9	.371	2.697
	PE10	.474	2.110
	EN1	.399	2.50S
	EN2	.376	2.662
	EN3	.423	2.367
	EN4	.447	2.239
	EN5	.599	1.670
	EN6	.545	1.S34
	EN?	.472	2.120
	ENS	.45S	2.1S6
	EN9	.47S	2.094
	EN10	.632	1.5S2
	OR1	.362	2.759
	OR2	.395	2.534
	OR3	.373	2.6S2
	OR4	.357	2.799
	P01	.365	2.743
	P02	.353	2.S32
	P03	.491	2.037
	P04	.563	1.775
	TE1	.55S	1.793
	TE2	.522	1.916
	TE3	.522	1.914
	TE4	.4S9	2.044
	TE5	.447	2.236
	TE6	.547	1.S2S
	TE7	.556	1.797
	TES	.521	1.920
	TE9	.5S2	1.71S
	TE10	.677	1.477
	TE11	.631	1.5S5
	TE12	.5S7	1.704
	TE13	.574	1.742
	PR1	.505	1.9S1
	PR2	.533	1.S74
	PR3	.435	2.299
	PR4	.46S	2.135

a. Dependent Variable: PR5

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
t	PR7	.469	2.133
	PRS	.53t	t.SS5
	PR9	.508	1.968
	PRt 0	.543	t.S4t
	PRtt	.407	2.459
	PRt 2	.435	2.300
	PEt	.345	2.90t
	PE2	.335	2.9S3
	PE3	.4t 9	2.3S7
	PE4	.46t	2.t 69
	PE5	.4t 2	2.425
	PE6	.469	2.t 34
	PE7	.459	2.t 77
	PES	.463	2.t 62
	PE9	.36S	2.7t 7
	PEt 0	.474	2.t 0S
	ENt	.400	2.500
	EN2	.376	2.659
	EN3	.422	2.370
	EN4	.446	2.245
	EN5	.59S	t .672
	EN6	.545	t .S34
	EN?	.4S4	2.065
	ENS	.459	2.tSO
	EN9	.473	2.tt4
	ENt 0	.634	t .57S
	ORt	.35S	2.796
	OR2	.394	2.537
	OR3	.37S	2.645
	OR4	.363	2.754
	POt	.366	2.732
	P02	.352	2.S43
	P03	.490	2.040
	P04	.563	t.775
	TEt	.56t	t.7S2
	TE2	.522	t.9t 6
	TE3	.5tS	t .932
	TE4	.49t	2.037
	TE5	.45t	2.2t 6
	TE6	.553	t .S09
	TE7	.554	t .S05
	TES	.526	t .90t
	TE9	.57t	t.75t
	TEt 0	.6S0	t.47t
	TEtt	.630	t.5S7
	TEt2	.5SS	t .70t
	TEt3	.552	t .Stt
	PRt	.506	t .977
	PR2	.533	t .S77
	PR3	.45t	2.2tS
	PR4	.46t	2.t 70
	PR5	.556	t .799

a. Dependent Variable:PR 6

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
t	PRS	.57S	t .730
	PR9	.5t 2	t.953
	PR10	.522	1.916
	PRtt	.406	2.465
	PRt 2	.436	2.292
	PEt	.34S	2.S72
	PE2	.326	3.070
	PE3	.4tS	2.395
	PE4	.46t	2.t 7t
	PE5	.409	2.445
	PE6	.46t	2.t 7t
	PE7	.459	2.t 77
	PES	.46t	2.t 69
	PE9	.367	2.725
	PEt 0	.4S0	2.0S3
	ENt	.395	2.533
	EN2	.376	2.660
	EN3	.422	2.370
	EN4	.447	2.235
	EN5	.597	t .674
	EN6	.545	t .S36
	EN?	.472	2.t 20
	ENS	.457	2.tSS
	EN9	.473	2.tt 6
	ENt 0	.630	t .5S6
	ORt	.36t	2.773
	OR2	.400	2.50t
	OR3	.373	2.6S4
	OR4	.356	2.S09
	POt	.365	2.737
	P02	.352	2.S43
	P03	.49t	2.036
	P04	.563	t.775
	TEt	.55S	t .79t
	TE2	.529	t .S9t
	TE3	.5t 7	t .936
	TE4	.496	2.0t 5
	TE5	.449	2.229
	TE6	.547	t .S27
	TE7	.556	t.S00
	TES	.52t	t .9t 9
	TE9	.577	t.735
	TEt 0	.674	t.4S5
	TEtt	.63t	t .5S4
	TEt2	.592	t .690
	TEt3	.554	t .S06
	PRt	.506	t.975
	PR2	.529	t .S90
	PR3	.436	2.295
	PR4	.460	2.t 76
	PR5	.545	t .S35
	PR6	.435	2.297

a. Dependent Variable:PR 7

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
t	PR9	.527	t .S99
	PRt 0	.522	t .9t4
	PRtt	.406	2.46t
	PRt 2	.436	2.295
	PEt	.344	2.909
	PE2	.339	2.94S
	PE3	.424	2.35S
	PE4	.459	2.t 79
	PE5	.409	2.446
	PE6	.463	2.t 60
	PE7	.460	2.t 72
	PES	.46t	2.t 70
	PE9	.367	2.725
	PEt 0	.474	2.t 09
	ENt	.395	2.534
	EN2	.37S	2.647
	EN3	.422	2.370
	EN4	.445	2.24S
	EN5	.599	t .67t
	EN6	.546	t .S33
	EN?	.472	2.t 20
	ENS	.457	2.tS7
	EN9	.469	2.t 33
	EN10	.631	1.585
	ORt	.357	2.799
	OR2	.394	2.537
	OR3	.372	2.6S9
	OR4	.356	2.S07
	POt	.365	2.73S
	P02	.352	2.S43
	P03	.49t	2.03S
	P04	.564	t.773
	TEt	.557	t .796
	TE2	.523	t .9t 3
	TE3	.520	t .922
	TE4	.490	2.042
	TE5	.44S	2.234
	TE6	.547	t .S27
	TE7	.553	t .S09
	TES	.524	t .90S
	TE9	.572	t .749
	TEt 0	.675	t.4S2
	TEtt	.64t	t .560
	TEt2	.5S7	t .703
	TEt3	.554	t .S05
	PRt	.504	t .9S2
	PR2	.53t	t.SS4
	PR3	.44t	2.269
	PR4	.459	2.t 76
	PR5	.543	t .S42
	PR6	.432	2.3t 5
	PR7	.507	t .972

a. Dependent Variable:PRS

Coefficients•

Mode 1		Collinearity Statistics	
		Tolerance	VIF
t	PRt 0	.566	t.766
	PRtt	.406	2.466
	PRt 2	.435	2.300
	PEt	.344	2.905
	PE2	.325	3.050
	PE3	.4t5	2.394
	PE4	.466	2.t47
	PE5	.4t 0	2.440
	PE6	.46t	2.t72
	PE7	.462	2.t66
	PES	.469	2.t3t
	PE9	.376	2.662
	PEt 0	.476	2.t00
	ENt	.395	2.5t 5
	EN2	.376	2.66t
	EN3	.429	2.330
	EN4	.445	2.247
	EN5	.597	t.674
	EN6	.545	t.S35
	EN?	.476	2.t00
	ENS	.459	2.t79
	EN9	.465	2.t35
	ENt 0	.635	t.567
	ORt	.365	2.720
	OR2	.397	2.5t 7
	OR3	.372	2.690
	OR4	.356	2.Stt
	POt	.364	2.744
	P02	.352	2.S44
	P03	.459	2.043
	P04	.574	t.742
	TEt	.555	t.793
	TE2	.546	t.S32
	TE3	.523	t.9t 3
	TE4	.495	2.02t
	TE5	.452	2.2t 2
	TE6	.549	t.S22
	TE7	.556	t.797
	TES	.523	t.9t4
	TE9	.574	t.743
	TEt 0	.675	t.45t
	TEtt	.633	t.550
	TEt 2	.59t	t.692
	TEt 3	.555	t.794
	PRt	.504	t.952
	PR2	.540	t.S53
	PR3	.442	2.265
	PR4	.460	2.t75
	PR5	.545	t.S25
	PR6	.427	2.344
	PR7	.463	2.t60
	PRS	.543	t.S42

a. Dependent Variable: PR9

Coefficients•

Mode 1		Collinearity Statistics	
		Tolerance	VIF
t	PRtt	.4t 2	2.429
	PRt 2	.434	2.303
	PEt	.345	2.902
	PE2	.326	3.070
	PE3	.420	2.379
	PE4	.465	2.t36
	PE5	.409	2.443
	PE6	.477	2.097
	PE7	.455	2.t53
	PES	.466	2.t47
	PE9	.370	2.706
	PEt 0	.45t	2.050
	ENt	.402	2.456
	EN2	.379	2.637
	EN3	.424	2.36t
	EN4	.446	2.244
	EN5	.606	t.65t
	EN6	.554	t.S04
	EN?	.472	2.t20
	ENS	.460	2.t75
	EN9	.469	2.t33
	ENt 0	.630	t.557
	ORt	.357	2.795
	OR2	.395	2.534
	OR3	.372	2.656
	OR4	.355	2.792
	POt	.369	2.7t 3
	P02	.353	2.S36
	P03	.492	2.033
	P04	.55t	t.72t
	TEt	.557	t.797
	TE2	.522	t.9t4
	TE3	.5t 9	t.926
	TE4	.455	2.047
	TE5	.45t	2.2t 9
	TE6	.554	t.S04
	TE7	.554	t.S06
	TES	.522	t.9t4
	TE9	.593	t.657
	TEt 0	.673	t.456
	TEtt	.630	t.556
	TEt 2	.555	t.700
	TEt 3	.555	t.S00
	PRt	.5t 6	t.937
	PR2	.529	t.S9t
	PR3	.434	2.302
	PR4	.459	2.t50
	PR5	.544	t.S37
	PR6	.444	2.254
	PR7	.459	2.t75
	PRS	.524	t.905
	PR9	.55t	t.St 5

a. Dependent Variable: PRt 0

Coefficients•

Mode 1		Collinearity Statistics	
		Tolerance	VIF
t	PRt 2	.553	t.S09
	PEt	.345	2.S72
	PE2	.334	2.995
	PE3	.420	2.354
	PE4	.462	2.t66
	PE5	.423	2.363
	PE6	.462	2.t64
	PE7	.455	2.t53
	PES	.465	2.t35
	PE9	.367	2.725
	PEt 0	.474	2.ttt
	ENt	.396	2.525
	EN2	.377	2.654
	EN3	.430	2.327
	EN4	.445	2.245
	EN5	.597	t.674
	EN6	.555	t.S00
	EN?	.473	2.tt 3
	ENS	.467	2.t4t
	EN9	.474	2.tt 0
	ENt 0	.630	t.557
	ORt	.36t	2.767
	OR2	.396	2.524
	OR3	.379	2.64t
	OR4	.36t	2.770
	POt	.365	2.739
	P02	.352	2.S42
	P03	.49t	2.035
	P04	.566	t.765
	TEt	.560	t.755
	TE2	.526	t.902
	TE3	.5t5	t.93t
	TE4	.455	2.049
	TE5	.449	2.225
	TE6	.552	t.St 0
	TE7	.554	t.S06
	TES	.52t	t.92t
	TE9	.574	t.743
	TEt 0	.673	t.455
	TEtt	.644	t.553
	TEt 2	.555	t.700
	TEt 3	.560	t.757
	PRt	.507	t.974
	PR2	.536	t.S67
	PR3	.434	2.303
	PR4	.459	2.t79
	PR5	.543	t.S42
	PR6	.427	2.344
	PR7	.455	2.t52
	PRS	.523	t.9t 0
	PR9	.507	t.973
	PRt 0	.529	t.S9t

a. Dependent Variable: PRtt

Coefficients^a

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE1	.344	2.910
	PE2	.331	3.025
	PE3	.422	2.372
	PE4	.464	2.155
	PE5	.412	2.426
	PE6	.462	2.164
	PE7	.472	2.119
	PE8	.466	2.146
	PE9	.375	2.665
	PE10	.475	2.107
	EN1	.395	2.534
	EN2	.376	2.660
	EN3	.429	2.332
	EN4	.454	2.201
	EN5	.597	1.674
	EN6	.548	1.826
	EN7	.473	2.116
	EN8	.457	2.188
	EN9	.469	2.130
	EN10	.635	1.575
	OR1	.357	2.802
	OR2	.394	2.541
	OR3	.372	2.692
	OR4	.356	2.807
	PO1	.368	2.718
	PO2	.354	2.828
	PO3	.492	2.034
	PO4	.566	1.766
	TE1	.559	1.789
	TE2	.522	1.916
	TE3	.517	1.936
	TE4	.488	2.048
	TE5	.447	2.238
	TE6	.547	1.829
	TE7	.556	1.800
	TE8	.521	1.920
	TE9	.571	1.752
	TE10	.673	1.486
	TE11	.637	1.569
	TE12	.590	1.696
	TE13	.553	1.808
	PR1	.505	1.979
	PR2	.538	1.859
	PR3	.440	2.271
	PR4	.459	2.180
	PR5	.543	1.842
	PR6	.426	2.348
	PR7	.460	2.172
	PR8	.524	1.908
	PR9	.508	1.970
	PR10	.521	1.920
	PR11	.516	1.937

a. Dependent Variable: PR12

Coefficients^a

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE2	.389	2.571
	PE3	.427	2.343
	PE4	.461	2.171
	PE5	.414	2.416
	PE6	.461	2.169
	PE7	.459	2.180
	PE8	.464	2.155
	PE9	.373	2.683
	PE10	.477	2.098
	EN1	.395	2.534
	EN2	.376	2.657
	EN3	.422	2.369
	EN4	.446	2.242
	EN5	.600	1.667
	EN6	.549	1.822
	EN7	.472	2.120
	EN8	.458	2.185
	EN9	.469	2.130
	EN10	.633	1.581
	OR1	.368	2.719
	OR2	.395	2.535
	OR3	.392	2.551
	OR4	.361	2.770
	PO1	.367	2.728
	PO2	.363	2.754
	PO3	.492	2.031
	PO4	.563	1.775
	TE1	.557	1.796
	TE2	.525	1.904
	TE3	.517	1.936
	TE4	.489	2.046
	TE5	.455	2.195
	TE6	.552	1.812
	TE7	.556	1.800
	TE8	.521	1.921
	TE9	.575	1.740
	TE10	.673	1.485
	TE11	.630	1.586
	TE12	.608	1.645
	TE13	.553	1.809
	PR1	.506	1.978
	PR2	.528	1.892
	PR3	.434	2.302
	PR4	.463	2.160
	PR5	.543	1.841
	PR6	.427	2.344
	PR7	.464	2.153
	PR8	.523	1.914
	PR9	.507	1.972
	PR10	.522	1.915
	PR11	.411	2.433
	PR12	.434	2.303

a. Dependent Variable: PE1

Coefficients^a

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE3	.439	2.280
	PE4	.461	2.171
	PE5	.437	2.287
	PE6	.468	2.135
	PE7	.460	2.173
	PE8	.461	2.171
	PE9	.370	2.702
	PE10	.477	2.098
	EN1	.395	2.529
	EN2	.378	2.645
	EN3	.422	2.369
	EN4	.445	2.245
	EN5	.602	1.661
	EN6	.551	1.815
	EN7	.472	2.117
	EN8	.458	2.182
	EN9	.473	2.116
	EN10	.630	1.587
	OR1	.357	2.802
	OR2	.394	2.537
	OR3	.376	2.661
	OR4	.367	2.726
	PO1	.365	2.738
	PO2	.353	2.829
	PO3	.489	2.047
	PO4	.565	1.771
	TE1	.557	1.796
	TE2	.523	1.914
	TE3	.522	1.916
	TE4	.489	2.046
	TE5	.450	2.224
	TE6	.547	1.828
	TE7	.554	1.804
	TE8	.521	1.920
	TE9	.574	1.742
	TE10	.675	1.481
	TE11	.631	1.584
	TE12	.601	1.663
	TE13	.558	1.791
	PR1	.507	1.971
	PR2	.530	1.887
	PR3	.434	2.303
	PR4	.460	2.172
	PR5	.543	1.840
	PR6	.439	2.276
	PR7	.460	2.175
	PR8	.546	1.832
	PR9	.507	1.973
	PR10	.523	1.914
	PR11	.417	2.397
	PR12	.442	2.262
	PE1	.412	2.429

a. Dependent Variable: PE2

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE4	.526	1.900
	PE5	.410	2.441
	PE6	.462	2.162
	PE7	.455	2.153
	PES	.461	2.165
	PE9	.366	2.736
	PE10	.450	2.055
	EN1	.395	2.531
	EN2	.354	2.601
	EN3	.422	2.367
	EN4	.447	2.239
	EN5	.597	1.674
	EN6	.547	1.529
	EN?	.472	2.119
	ENS	.455	2.154
	EN9	.469	2.131
	EN10	.632	1.552
	OR1	.359	2.752
	OR2	.396	2.524
	OR3	.372	2.657
	OR4	.357	2.505
	P01	.364	2.744
	P02	.352	2.542
	P03	.492	2.035
	P04	.572	1.749
	TE1	.560	1.754
	TE2	.533	1.575
	TE3	.517	1.936
	TE4	.455	2.045
	TE5	.452	2.215
	TE6	.547	1.529
	TE7	.562	1.779
	TES	.520	1.923
	TE9	.571	1.750
	TE10	.675	1.474
	TE11	.630	1.556
	TE12	.557	1.703
	TE13	.555	1.793
	PR1	.510	1.961
	PR2	.525	1.592
	PR3	.435	2.299
	PR4	.465	2.151
	PR5	.551	1.515
	PR6	.427	2.343
	PR7	.455	2.152
	PRS	.531	1.555
	PR9	.507	1.972
	PR10	.524	1.907
	PR11	.405	2.454
	PR12	.435	2.251
	PE1	.351	2.547
	PE2	.341	2.931

a. Dependent Variable: PE3

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE5	.429	2.332
	PE6	.463	2.160
	PE7	.455	2.151
	PES	.461	2.171
	PE9	.366	2.735
	PE10	.475	2.091
	EN1	.395	2.534
	EN2	.375	2.643
	EN3	.422	2.365
	EN4	.446	2.242
	EN5	.595	1.673
	EN6	.547	1.529
	EN?	.474	2.110
	ENS	.459	2.150
	EN9	.473	2.116
	EN10	.631	1.554
	OR1	.357	2.502
	OR2	.394	2.535
	OR3	.371	2.694
	OR4	.361	2.770
	P01	.366	2.730
	P02	.352	2.544
	P03	.490	2.039
	P04	.563	1.775
	TE1	.559	1.757
	TE2	.522	1.917
	TE3	.520	1.924
	TE4	.495	2.022
	TE5	.445	2.231
	TE6	.552	1.513
	TE7	.554	1.504
	TES	.523	1.911
	TE9	.594	1.655
	TE10	.675	1.452
	TE11	.635	1.567
	TE12	.592	1.655
	TE13	.566	1.766
	PR1	.513	1.945
	PR2	.529	1.590
	PR3	.437	2.257
	PR4	.460	2.175
	PR5	.543	1.542
	PR6	.425	2.339
	PR7	.460	2.174
	PRS	.523	1.914
	PR9	.514	1.944
	PR10	.531	1.552
	PR11	.405	2.450
	PR12	.439	2.277
	PE1	.345	2.595
	PE2	.326	3.065
	PE3	.479	2.055

a. Dependent Variable: PE4

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE6	.467	2.141
	PE7	.461	2.171
	PES	.462	2.167
	PE9	.366	2.733
	PE10	.476	2.100
	EN1	.402	2.459
	EN2	.377	2.655
	EN3	.423	2.363
	EN4	.445	2.245
	EN5	.602	1.661
	EN6	.546	1.533
	EN?	.475	2.107
	ENS	.460	2.175
	EN9	.470	2.126
	EN10	.630	1.557
	OR1	.355	2.792
	OR2	.394	2.536
	OR3	.373	2.650
	OR4	.359	2.755
	P01	.365	2.742
	P02	.352	2.539
	P03	.490	2.041
	P04	.571	1.752
	TE1	.557	1.797
	TE2	.525	1.905
	TE3	.520	1.922
	TE4	.490	2.040
	TE5	.451	2.215
	TE6	.547	1.529
	TE7	.555	1.502
	TES	.522	1.917
	TE9	.572	1.745
	TE10	.677	1.477
	TE11	.645	1.550
	TE12	.555	1.701
	TE13	.555	1.502
	PR1	.505	1.950
	PR2	.530	1.556
	PR3	.434	2.302
	PR4	.459	2.150
	PR5	.546	1.532
	PR6	.429	2.331
	PR7	.455	2.152
	PRS	.522	1.914
	PR9	.505	1.969
	PR10	.521	1.915
	PR11	.420	2.353
	PR12	.435	2.255
	PE1	.345	2.575
	PE2	.347	2.550
	PE3	.415	2.391
	PE4	.451	2.075

a. Dependent Variable: PE5

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE7	.529	1.890
	PES	.462	2.165
	PE9	.367	2.721
	PE10	.474	2.105
	EN1	.395	2.531
	EN2	.376	2.661
	EN3	.425	2.335
	EN4	.446	2.243
	EN5	.602	1.660
	EN6	.545	1.834
	EN?	.472	2.120
	ENS	.455	2.182
	EN9	.465	2.135
	EN10	.631	1.586
	OR1	.355	2.793
	OR2	.395	2.529
	OR3	.380	2.631
	OR4	.361	2.769
	P01	.364	2.744
	P02	.352	2.842
	P03	.489	2.047
	P04	.564	1.775
	TE1	.557	1.794
	TE2	.524	1.905
	TE3	.517	1.936
	TE4	.490	2.042
	TE5	.445	2.230
	TE6	.555	1.800
	TE7	.553	1.810
	TES	.523	1.912
	TE9	.573	1.745
	TE10	.673	1.486
	TE11	.631	1.584
	TE12	.559	1.697
	TE13	.557	1.797
	PR1	.521	1.919
	PR2	.532	1.880
	PR3	.434	2.303
	PR4	.460	2.176
	PR5	.543	1.842
	PR6	.433	2.310
	PR7	.455	2.182
	PRS	.525	1.904
	PR9	.507	1.973
	PR10	.539	1.854
	PR11	.407	2.457
	PR12	.436	2.295
	PE1	.344	2.906
	PE2	.330	3.025
	PE3	.419	2.385
	PE4	.461	2.167
	PE5	.415	2.411

a. Dependent Variable:PE6

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PES	.461	2.170
	PE9	.369	2.712
	PE10	.474	2.110
	EN1	.403	2.483
	EN2	.375	2.645
	EN3	.424	2.360
	EN4	.445	2.246
	EN5	.597	1.674
	EN6	.545	1.826
	EN?	.472	2.120
	ENS	.461	2.167
	EN9	.469	2.133
	EN10	.632	1.583
	OR1	.357	2.801
	OR2	.394	2.541
	OR3	.375	2.665
	OR4	.355	2.793
	P01	.366	2.732
	P02	.354	2.827
	P03	.489	2.047
	P04	.564	1.774
	TE1	.557	1.797
	TE2	.523	1.912
	TE3	.517	1.934
	TE4	.485	2.045
	TE5	.450	2.222
	TE6	.573	1.746
	TE7	.563	1.777
	TES	.521	1.915
	TE9	.573	1.746
	TE10	.652	1.466
	TE11	.630	1.585
	TE12	.557	1.703
	TE13	.554	1.807
	PR1	.510	1.961
	PR2	.525	1.892
	PR3	.434	2.303
	PR4	.459	2.179
	PR5	.544	1.837
	PR6	.427	2.344
	PR7	.460	2.176
	PRS	.525	1.904
	PR9	.511	1.955
	PR10	.521	1.920
	PR11	.406	2.466
	PR12	.447	2.235
	PE1	.344	2.906
	PE2	.326	3.066
	PE3	.417	2.395
	PE4	.459	2.175
	PE5	.411	2.432
	PE6	.532	1.880

a. Dependent Variable:PE7

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE9	.400	2.495
	PE10	.479	2.086
	EN1	.397	2.521
	EN2	.376	2.656
	EN3	.423	2.367
	EN4	.445	2.245
	EN5	.595	1.673
	EN6	.545	1.836
	EN?	.474	2.112
	ENS	.457	2.157
	EN9	.485	2.049
	EN10	.630	1.587
	OR1	.359	2.784
	OR2	.394	2.536
	OR3	.373	2.675
	OR4	.356	2.807
	P01	.364	2.744
	P02	.357	2.804
	P03	.489	2.047
	P04	.565	1.761
	TE1	.563	1.776
	TE2	.524	1.905
	TE3	.519	1.925
	TE4	.485	2.049
	TE5	.447	2.235
	TE6	.547	1.829
	TE7	.557	1.796
	TES	.521	1.919
	TE9	.572	1.750
	TE10	.680	1.471
	TE11	.632	1.582
	TE12	.587	1.704
	TE13	.554	1.805
	PR1	.505	1.981
	PR2	.531	1.884
	PR3	.437	2.289
	PR4	.464	2.155
	PR5	.543	1.842
	PR6	.427	2.342
	PR7	.459	2.180
	PRS	.523	1.913
	PR9	.516	1.937
	PR10	.527	1.899
	PR11	.412	2.429
	PR12	.439	2.277
	PE1	.346	2.889
	PE2	.325	3.080
	PE3	.415	2.393
	PE4	.459	2.180
	PE5	.410	2.441
	PE6	.462	2.166
	PE7	.455	2.183

a. Dependent Variable:PES

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	PE10	.507	1.972
	EN1	.395	2.532
	EN2	.380	2.634
	EN3	.426	2.345
	EN4	.456	2.194
	EN5	.600	1.666
	EN6	.549	1.522
	EN?	.496	2.017
	ENS	.455	2.152
	EN9	.465	2.135
	EN10	.636	1.573
	OR1	.357	2.502
	OR2	.394	2.536
	OR3	.371	2.695
	OR4	.357	2.504
	P01	.365	2.739
	P02	.354	2.522
	P03	.507	1.974
	P04	.567	1.765
	TE1	.555	1.793
	TE2	.525	1.594
	TE3	.519	1.927
	TE4	.459	2.047
	TE5	.448	2.230
	TE6	.547	1.529
	TE7	.553	1.509
	TES	.522	1.914
	TE9	.572	1.747
	TE10	.673	1.456
	TE11	.630	1.555
	TE12	.555	1.700
	TE13	.552	1.511
	PR1	.510	1.959
	PR2	.525	1.592
	PR3	.435	2.295
	PR4	.459	2.150
	PR5	.551	1.516
	PR6	.425	2.335
	PR7	.460	2.174
	PRS	.524	1.907
	PR9	.521	1.920
	PR10	.526	1.900
	PR11	.407	2.456
	PR12	.446	2.244
	PE1	.350	2.555
	PE2	.329	3.042
	PE3	.417	2.396
	PE4	.459	2.179
	PE5	.409	2.443
	PE6	.463	2.161
	PE7	.462	2.164
	PES	.505	1.952

a. Dependent Variable: PE9

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	EN1	.396	2.523
	EN2	.376	2.662
	EN3	.433	2.312
	EN4	.445	2.234
	EN5	.597	1.674
	EN6	.546	1.531
	EN?	.472	2.120
	ENS	.470	2.127
	EN9	.465	2.136
	EN10	.635	1.575
	OR1	.367	2.727
	OR2	.397	2.515
	OR3	.372	2.655
	OR4	.362	2.764
	P01	.365	2.741
	P02	.353	2.532
	P03	.491	2.035
	P04	.573	1.744
	TE1	.561	1.752
	TE2	.529	1.559
	TE3	.521	1.915
	TE4	.455	2.045
	TE5	.450	2.222
	TE6	.547	1.527
	TE7	.562	1.775
	TES	.521	1.920
	TE9	.572	1.745
	TE10	.651	1.465
	TE11	.636	1.572
	TE12	.559	1.697
	TE13	.555	1.501
	tK1	bUt1	1. fti
	PR2	.525	1.592
	PR3	.437	2.291
	PR4	.465	2.145
	PR5	.543	1.541
	PR6	.426	2.347
	PR7	.464	2.153
	PRS	.523	1.912
	PR9	.509	1.963
	PR10	.529	1.591
	PR11	.406	2.466
	PR12	.435	2.295
	PE1	.346	2.593
	PE2	.327	3.061
	PE3	.423	2.366
	PE4	.463	2.159
	PE5	.411	2.432
	PE6	.461	2.165
	PE7	.455	2.152
	PES	.466	2.145
	PE9	.391	2.556

a. Dependent Variable: PE10

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	EN2	.457	2.190
	EN3	.435	2.254
	EN4	.446	2.244
	EN5	.601	1.663
	EN6	.547	1.529
	EN?	.472	2.119
	ENS	.459	2.150
	EN9	.450	2.054
	EN10	.632	1.553
	OR1	.362	2.759
	OR2	.395	2.515
	OR3	.371	2.696
	OR4	.360	2.777
	P01	.365	2.743
	P02	.356	2.511
	P03	.459	2.045
	P04	.573	1.745
	TE1	.557	1.795
	TE2	.522	1.915
	TE3	.515	1.932
	TE4	.455	2.045
	TE5	.445	2.233
	TE6	.550	1.517
	TE7	.553	1.809
	TES	.520	1.923
	TE9	.573	1.746
	TE10	.673	1.455
	TE11	.630	1.556
	TE12	.557	1.704
	TE13	.552	1.511
	PR1	.507	1.974
	PR2	.525	1.592
	PR3	.435	2.295
	PR4	.463	2.161
	PR5	.549	1.522
	PR6	.431	2.319
	PR7	.455	2.151
	PRS	.522	1.914
	PR9	.511	1.955
	PR10	.531	1.553
	PR11	.407	2.460
	PR12	.434	2.302
	PE1	.344	2.910
	PE2	.325	3.074
	PE3	.415	2.392
	PE4	.459	2.179
	PE5	.416	2.402
	PE6	.461	2.169
	PE7	.465	2.139
	PES	.463	2.159
	PES	.366	2.733
	PE10	.476	2.102

a. Dependent Variable: EN1

Coefficients•

Mode 1		Collinearity Statistics	
		Tolerance	VIF
t	EN3	.459	2.1SO
	EN4	.446	2.24t
	EN5	.597	t.674
	EN6	.555	t.S03
	EN?	.472	2.tt9
	ENS	.45S	2.tS4
	EN9	.46S	2.t35
	ENt O	.632	t.5S2
	ORt	.35S	2.790
	OR2	.403	2.4S4
	OR3	.37t	2.695
	OR4	.356	2.St2
	POt	.366	2.730
	P02	.352	2.S40
	P03	.49t	2.037
	P04	.565	t.769
	TEt	.557	t.797
	TE2	.522	t.9t6
	TE3	.5t7	t.933
	TE4	.4S9	2.046
	TE5	.447	2.236
	TE6	.552	t.St3
	TE7	.557	t.796
	TES	.52t	t.92t
	TE9	.574	t.74t
	TEt O	.673	t.4S5
	TEtt	.63t	t.5S6
	TEt2	.593	t.6S6
	TEt3	.555	t.S0t
	PRt	.5t0	t.963
	PR2	.52S	t.S92
	PR3	.434	2.302
	PR4	.462	2.t65
	PR5	.543	t.S42
	PR6	.426	2.349
	PR7	.45S	2.tSt
	PRS	.525	t.903
	PR9	.507	t.973
	PRt O	.526	t.902
	PRtt	.407	2.459
	PRt2	.435	2.30t
	PEt	.344	2.906
	PE2	.327	3.06t
	PE3	.427	2.34t
	PE4	.462	2.t64
	PE5	.4t0	2.440
	PE6	.46t	2.t7t
	PE7	.460	2.t72
	PES	.462	2.t66
	PE9	.369	2.70S
	PEt O	.474	2.ttt
	ENt	.479	2.0S6

a. Dependent Variable: EN2

Coefficients•

Mode 1		Collinearity Statistics	
		Tolerance	VIF
t	EN4	.470	2.t29
	EN5	.59S	t.672
	EN6	.546	t.S32
	EN?	.4S2	2.073
	ENS	.45S	2.tS4
	EN9	.476	2.t00
	CN10	.633	1.500
	ORt	.35S	2.793
	OR2	.394	2.540
	OR3	.374	2.676
	OR4	.362	2.76t
	POt	.367	2.722
	P02	.352	2.S44
	P03	.494	2.024
	P04	.563	t.775
	TEt	.56t	t.7S2
	TE2	.523	t.9t4
	TE3	.5t7	t.933
	TE4	.4S9	2.044
	TE5	.447	2.23S
	TE6	.547	t.S29
	TE7	.553	t.S07
	TES	.536	t.S66
	TE9	.572	t.74S
	TEt O	.677	t.477
	TEtt	.632	t.5St
	TEt2	.5S7	t.704
	TEt3	.552	t.Stt
	PRt	.52t	t.9t9
	PR2	.539	t.S55
	PR3	.434	2.302
	PR4	.460	2.t73
	PR5	.544	t.S39
	PR6	.425	2.35t
	PR7	.45S	2.tS2
	PRS	.522	t.9t4
	PR9	.5t5	t.940
	PRt O	.523	t.9t3
	PRtt	.4t3	2.42t
	PRt2	.44t	2.266
	PEt	.344	2.909
	PE2	.325	3.079
	PE3	.4tS	2.392
	PE4	.459	2.t7S
	PE5	.4t0	2.43S
	PE6	.467	2.t39
	PE7	.460	2.t74
	PES	.46t	2.t6S
	PE9	.369	2.707
	PEt O	.456	2.060
	ENt	.4t0	2.442
	EN2	.40S	2.44S

a. Dependent Variable: EN3

Coefficients•

Mode 1		Collinearity Statistics	
		Tolerance	VIF
t	EN5	.63S	t.567
	EN6	.545	t.S36
	EN?	.476	2.t02
	ENS	.475	2.t06
	EN9	.46S	2.t36
	ENt O	.630	t.5S6
	ORt	.35S	2.796
	OR2	.394	2.537
	OR3	.37t	2.696
	OR4	.356	2.S0S
	POt	.369	2.709
	P02	.35S	2.795
	ro3	.409	2.046
	P04	.564	t.774
	TEt	.55S	t.793
	TE2	.522	t.9t6
	TE3	.5t9	t.929
	TE4	.49t	2.037
	TE5	.447	2.23S
	TE6	.54S	t.S26
	TE7	.565	t.770
	TES	.529	t.S90
	TE9	.57t	t.753
	TEt O	.675	t.4St
	TEtt	.634	t.577
	TEt2	.59t	t.693
	TEt3	.554	t.S06
	PRt	.505	t.9S2
	PR2	.529	t.S92
	PR3	.43S	2.2S5
	PR4	.460	2.t72
	PR5	.545	t.S34
	PR6	.426	2.347
	PR7	.46t	2.t69
	PRS	.522	t.9t4
	PR9	.507	t.972
	PRt O	.522	t.9t6
	PRtt	.406	2.462
	PRt2	.444	2.254
	PEt	.345	2.902
	PE2	.325	3.076
	PE3	.4t9	2.3S6
	PE4	.460	2.t74
	PE5	.409	2.446
	PE6	.462	2.t67
	PE7	.45S	2.tSt
	PES	.46t	2.t70
	PE9	.375	2.670
	PEt O	.477	2.09S
	ENt	.395	2.529
	EN2	.377	2.653
	EN3	.446	2.244

a. Dependent Variable: EN4

Coefficients•

Mode l		Collinearity Statistics	
		Tolerance	VIF
t	EN6	.606	t.650
	EN?	.472	2.t20
	ENS	.45S	2.tS4
	EN9	.47t	2.t22
	ENt 0	.642	t.55S
	ORt	.357	2.S02
	OR2	.394	2.539
	OR3	.372	2.6S7
	OR4	.356	2.S09
	POt	.372	2.690
	P02	.352	2.S3S
	P03	.50t	t.997
	P04	.565	t.77t
	TEt	.557	t.795
	TE2	.525	t.904
	TE3	.5t 7	t.935
	TE4	.4SS	2.04S
	TE5	.447	2.237
	TE6	.547	t.S29
	TE7	.553	t.S0S
	TES	.526	t.902
	TE9	.572	t.74S
	TEt 0	.673	t.4S5
	TEtt	.63t	t.5S4
	TEt 2	.5S7	t.704
	TEt 3	.552	t.St 0
	PRt	.507	t.973
	PR2	.533	t.S77
	PR3	.435	2.29S
	PR4	.46t	2.t 7t
	PR5	.544	t.S3S
	PR6	.426	2.347
	PR7	.45S	2.tS3
	PRS	.524	t.9t 0
	PR9	.507	t.973
	PRt 0	.52S	t.S94
	PRtt	.406	2.465
	PRt 2	.434	2.303
	PEt	.345	2.S97
	PE2	.327	3.057
	PE3	.4t 7	2.395
	PE4	.459	2.t 79
	PE5	.4t 2	2.426
	PE6	.464	2.t 54
	PE7	.45S	2.tS3
	PES	.46t	2.t 70
	PE9	.367	2.723
	PEt 0	.474	2.ttt
	ENt	.397	2.5tS
	EN2	.376	2.662
	EN3	.422	2.367
	EN4	.475	2.t05

a. Dependent Variable: EN5

Coefficients•

Mode l		Collinearity Statistics	
		Tolerance	VIF
t	EN?	.490	2.043
	ENS	.46S	2.t 3S
	EN9	.472	2.tt 7
	ENt 0	.646	t.549
	ORt	.35S	2.796
	OR2	.397	2.522
	OR3	.37t	2.696
	OR4	.356	2.S07
	POt	.365	2.73S
	P02	.352	2.S43
	P03	.4S9	2.046
	P04	.570	t.755
	TC1	.559	1.709
	TE2	.523	t.9tt
	TE3	.520	t.922
	TE4	.4SS	2.04S
	TE5	.447	2.237
	TE6	.547	t.S29
	TE7	.553	t.S09
	TES	.523	t.9tt
	TE9	.572	t.749
	TEt 0	.673	t.4S5
	TEtt	.634	t.57S
	TEt 2	.5SS	t.702
	TEt 3	.553	t.S07
	PRt	.507	t.974
	PR2	.52S	t.S92
	PR3	.436	2.296
	PR4	.460	2.t 75
	PR5	.543	t.S40
	PR6	.426	2.347
	PR7	.45S	2.tS2
	PRS	.523	t.9tt
	PR9	.507	t.972
	PRt 0	.530	t.SS6
	PRtt	.4t4	2.4t 7
	PRt 2	.437	2.290
	PEt	.346	2.SSS
	PE2	.32S	3.045
	PE3	.4t 9	2.3S6
	PE4	.46t	2.t 7t
	PE5	.4t 0	2.44t
	PE6	.46t	2.t 69
	PE7	.46t	2.t 7t
	PES	.46t	2.t 7t
	PE9	.369	2.7t4
	PEt 0	.475	2.t 05
	ENt	.396	2.525
	EN2	.3S3	2.6t 3
	EN3	.423	2.365
	EN4	.445	2.24S
	EN5	.665	t.504

a. Dependent Variable: EN6

Coefficients•

Mode l		Collinearity Statistics	
		Tolerance	VIF
t	ENS	.490	2.040
	EN9	.472	2.tttS
	ENt 0	.637	t.569
	ORt	.359	2.7SS
	OR2	.394	2.54t
	OR3	.37t	2.693
	OR4	.356	2.St 2
	POt	.370	2.703
	P02	.357	2.S05
	P03	.495	2.022
	P04	.567	t.764
	TEt	.557	t.794
	TE2	.522	t.9t 7
	TE3	.5t 7	t.936
	TE4	.4S9	2.044
	TE5	.449	2.226
	TE6	.563	t.776
	TE7	.563	t.777
	TES	.520	t.922
	TE9	.574	t.743
	TEt 0	.673	t.4S6
	TEtt	.630	t.5SS
	TEt 2	.5S7	t.703
	TEt 3	.552	t.Stt
	PRt	.506	t.976
	PR2	.532	t.SSO
	PR3	.435	2.296
	PR4	.463	2.t 59
	PR5	.543	t.S4t
	PR6	.437	2.2S9
	PR7	.45S	2.tS2
	PRB	.522	1.014
	PR9	.5t 2	t.954
	PRt 0	.52t	t.920
	PRtt	.407	2.457
	PRt 2	.435	2.29S
	PEt	.344	2.9t 0
	PE2	.325	3.076
	PE3	.4tS	2.394
	PE4	.46t	2.t 69
	PE5	.4tt	2.430
	PE6	.460	2.t 72
	PE7	.45S	2.tS3
	PES	.463	2.t 62
	PE9	.3S4	2.602
	PEt 0	.474	2.ttt
	ENt	.395	2.533
	EN2	.376	2.660
	EN3	.43t	2.3tS
	EN4	.449	2.229
	EN5	.59S	t.674
	EN6	.565	t.769

a. Dependent Variable: EN?

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	EN9	.485	2.064
	EN10	.647	1.545
	OR1	.357	2.800
	OR2	.395	2.535
	OR3	.371	2.693
	OR4	.359	2.786
	P01	.364	2.744
	P02	.353	2.834
	P03	.494	2.025
	P04	.573	1.746
	TE1	.557	1.796
	TE2	.522	1.917
	TE3	.518	1.932
	TE4	.488	2.049
	TE5	.447	2.236
	TE6	.547	1.829
	TE7	.554	1.805
	TES	.521	1.919
	TE9	.579	1.726
	TE10	.674	1.485
	TE11	.651	1.537
	TE12	.588	1.700
	TE13	.553	1.809
	PR1	.505	1.982
	PR2	.531	1.883
	PR3	.435	2.299
	PR4	.460	2.173
	PR5	.544	1.840
	PR6	.427	2.342
	PR7	.458	2.182
	PRS	.523	1.914
	PR9	.509	1.966
	PR10	.524	1.909
	PR11	.414	2.413
	PR12	.434	2.303
	PE1	.344	2.906
	PE2	.326	3.072
	PE3	.418	2.392
	PE4	.460	2.172
	PE5	.411	2.431
	PE6	.462	2.166
	PE7	.462	2.162
	PES	.461	2.170
	PE9	.366	2.729
	PE10	.487	2.053
	EN1	.396	2.525
	EN2	.376	2.657
	EN3	.423	2.365
	EN4	.462	2.164
	EN5	.599	1.671
	EN6	.557	1.794
	EN?	.506	1.977

a. Dependent Variable:ENS

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	EN10	.662	1.510
	OR1	.357	2.802
	OR2	.397	2.520
	OR3	.371	2.693
	OR4	.357	2.801
	P01	.364	2.744
	P02	.353	2.835
	P03	.490	2.042
	P04	.574	1.743
	TE1	.557	1.795
	TE2	.522	1.914
	TE3	.517	1.936
	TE4	.488	2.048
	TE5	.455	2.199
	TE6	.547	1.829
	TE7	.554	1.805
	TES	.526	1.903
	TE9	.579	1.726
	TE10	.674	1.483
	TE11	.630	1.588
	TE12	.587	1.704
	TE13	.553	1.807
	PR1	.505	1.979
	PR2	.530	1.885
	PR3	.444	2.250
	PR4	.465	2.150
	PR5	.554	1.806
	PR6	.430	2.327
	PR7	.463	2.162
	PRS	.523	1.912
	PR9	.507	1.972
	PR10	.522	1.917
	PR11	.411	2.436
	PR12	.435	2.297
	PE1	.345	2.902
	PE2	.328	3.052
	PE3	.418	2.390
	PE4	.463	2.159
	PE5	.411	2.434
	PE6	.461	2.171
	PE7	.459	2.180
	PES	.480	2.082
	PE9	.366	2.734
	PE10	.474	2.111
	EN1	.404	2.472
	EN2	.376	2.660
	EN3	.429	2.331
	EN4	.445	2.248
	EN5	.601	1.663
	EN6	.549	1.820
	EN?	.476	2.103
	ENS	.473	2.114

a. Dependent Variable:EN9

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	OR1	.358	2.792
	OR2	.395	2.533
	OR3	.376	2.657
	OR4	.356	2.812
	P01	.365	2.743
	P02	.352	2.838
	P03	.489	2.047
	P04	.564	1.773
	TE1	.558	1.791
	TE2	.522	1.917
	TE3	.518	1.932
	TE4	.490	2.043
	TE5	.447	2.238
	TE6	.548	1.826
	TE7	.556	1.800
	TES	.520	1.923
	TE9	.571	1.752
	TE10	.674	1.485
	TE11	.636	1.571
	TE12	.589	1.696
	TE13	.553	1.810
	PR1	.511	1.958
	PR2	.530	1.888
	PR3	.434	2.303
	PR4	.462	2.164
	PR5	.545	1.836
	PR6	.428	2.338
	PR7	.458	2.182
	PRS	.523	1.911
	PR9	.513	1.949
	PR10	.521	1.920
	PR11	.406	2.466
	PR12	.437	2.286
	PE1	.345	2.898
	PE2	.325	3.080
	PE3	.419	2.388
	PE4	.460	2.175
	PE5	.409	2.446
	PE6	.461	2.170
	PE7	.459	2.178
	PES	.461	2.171
	PE9	.369	2.711
	PE10	.477	2.095
	EN1	.396	2.528
	EN2	.377	2.653
	EN3	.424	2.360
	EN4	.445	2.247
	EN5	.608	1.644
	EN6	.558	1.792
	EN?	.477	2.097
	ENS	.469	2.130
	EN9	.492	2.033

a. Dependent Variable:EN10

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	OR2	.455	2.062
	OR3	.372	2.656
	OR4	.357	2.797
	P01	.365	2.740
	P02	.352	2.837
	P03	.459	2.047
	P04	.565	1.762
	TE1	.555	1.791
	TE2	.522	1.917
	TE3	.526	1.902
	TE4	.455	2.047
	TE5	.450	2.222
	TE6	.545	1.525
	TE7	.522	1.915
	TE8	.522	1.915
	TE9	.571	1.752
	TE10	.673	1.457
	TE11	.630	1.555
	TE12	.611	1.635
	TE13	.553	1.809
	PR1	.504	1.952
	PR2	.535	1.567
	PR3	.439	2.277
	PR4	.459	2.150
	PR5	.551	1.513
	PR6	.426	2.345
	PR7	.463	2.159
	PR8	.523	1.912
	PR9	.522	1.916
	PR10	.522	1.917
	PR11	.411	2.435
	PR12	.434	2.303
	PE1	.354	2.524
	PE2	.325	3.050
	PE3	.420	2.379
	PE4	.459	2.150
	PE5	.410	2.437
	PE6	.462	2.165
	PE7	.455	2.153
	PE8	.464	2.156
	PE9	.366	2.736
	PE10	.457	2.055
	EN1	.401	2.495
	EN2	.377	2.650
	EN3	.423	2.362
	EN4	.446	2.243
	EN5	.597	1.674
	EN6	.546	1.532
	EN7	.474	2.110
	EN8	.457	2.156
	EN9	.465	2.136
	EN10	.632	1.551

a. Dependent Variable:OR1

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	OR3	.353	2.605
	OR4	.355	2.795
	P01	.365	2.741
	P02	.357	2.800
	P03	.494	2.023
	P04	.563	1.775
	TE1	.555	1.792
	TE2	.522	1.914
	TE3	.526	1.901
	TE4	.455	2.045
	TE5	.457	2.159
	TE6	.545	1.526
	TE7	.553	1.809
	TE8	.522	1.917
	TE9	.571	1.751
	TE10	.673	1.456
	TE11	.630	1.555
	TE12	.555	1.700
	TE13	.553	1.510
	PR1	.504	1.952
	PR2	.529	1.592
	PR3	.434	2.303
	PR4	.460	2.173
	PR5	.544	1.537
	PR6	.426	2.347
	PR7	.465	2.149
	PR8	.523	1.911
	PR9	.512	1.955
	PR10	.522	1.915
	PR11	.405	2.450
	PR12	.434	2.303
	PE1	.344	2.903
	PE2	.325	3.076
	PE3	.420	2.350
	PE4	.459	2.177
	PE5	.410	2.441
	PE6	.463	2.162
	PE7	.455	2.153
	PE8	.462	2.167
	PE9	.366	2.730
	PE10	.475	2.092
	EN1	.399	2.505
	EN2	.354	2.603
	EN3	.422	2.370
	EN4	.445	2.245
	EN5	.595	1.673
	EN6	.549	1.523
	EN7	.472	2.120
	EN8	.455	2.153
	EN9	.472	2.119
	EN10	.632	1.552
	OR1	.440	2.275

a. Dependent Variable:OR 2

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	OR4	.425	2.355
	P01	.369	2.712
	P02	.355	2.516
	P03	.506	1.975
	P04	.564	1.775
	TE1	.557	1.794
	TE2	.531	1.554
	TE3	.520	1.923
	TE4	.459	2.045
	TE5	.449	2.225
	TE6	.550	1.517
	TE7	.560	1.754
	TE8	.520	1.923
	TE9	.572	1.745
	TE10	.673	1.457
	TE11	.645	1.543
	TE12	.557	1.704
	TE13	.552	1.511
	PR1	.507	1.971
	PR2	.530	1.555
	PR3	.436	2.292
	PR4	.459	2.175
	PR5	.546	1.532
	PR6	.434	2.307
	PR7	.460	2.173
	PR8	.524	1.909
	PR9	.505	1.969
	PR10	.523	1.913
	PR11	.414	2.415
	PR12	.435	2.299
	PE1	.363	2.753
	PE2	.329	3.040
	PE3	.419	2.355
	PE4	.459	2.175
	PE5	.411	2.431
	PE6	.472	2.119
	PE7	.463	2.160
	PE8	.464	2.156
	PE9	.366	2.735
	PE10	.475	2.105
	EN1	.395	2.534
	EN2	.376	2.660
	EN3	.425	2.352
	EN4	.445	2.245
	EN5	.599	1.669
	EN6	.545	1.536
	EN7	.472	2.115
	EN8	.455	2.156
	EN9	.469	2.134
	EN10	.639	1.564
	OR1	.355	2.791
	OR2	.407	2.457

a. Dependent Variable:OR 3

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	P01	.364	2.744
	P02	.354	2.825
	P03	.499	2.002
	P04	.573	1.746
	TE1	.558	1.792
	TE2	.522	1.917
	TE3	.517	1.933
	TE4	.488	2.049
	TE5	.447	2.237
	TE6	.555	1.801
	TE7	.554	1.805
	TES	.520	1.923
	TE9	.575	1.739
	TE10	.673	1.485
	TE11	.630	1.588
	TE12	.587	1.704
	TE13	.553	1.809
	PR1	.512	1.954
	PR2	.530	1.888
	PR3	.444	2.253
	PR4	.460	2.172
	PR5	.546	1.833
	PR6	.434	2.302
	PR7	.459	2.180
	PRS	.524	1.910
	PR9	.507	1.972
	PR10	.525	1.906
	PR11	.412	2.429
	PR12	.435	2.298
	PE1	.349	2.866
	PE2	.335	2.986
	PE3	.419	2.389
	PE4	.466	2.146
	PE5	.412	2.425
	PE6	.468	2.138
	PE7	.461	2.168
	PES	.462	2.166
	PES	.307	2.727
	PE10	.482	2.075
	EN1	.400	2.502
	EN2	.376	2.661
	EN3	.430	2.326
	EN4	.445	2.245
	EN5	.598	1.672
	EN6	.546	1.833
	EN?	.472	2.120
	ENS	.461	2.168
	EN9	.470	2.127
	EN10	.630	1.587
	OR1	.359	2.787
	OR2	.396	2.525
	OR3	.443	2.257

a. Dependent Variable:OR4

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	P02	.548	1.824
	P03	.490	2.040
	P04	.577	1.734
	TE1	.557	1.796
	TE2	.522	1.916
	TE3	.518	1.931
	TE4	.488	2.048
	TE5	.451	2.219
	TE6	.557	1.796
	TE7	.553	1.807
	TES	.521	1.918
	TE9	.571	1.751
	TE10	.674	1.484
	TE11	.639	1.565
	TE12	.588	1.702
	TE13	.554	1.805
	PR1	.509	1.965
	PR2	.529	1.890
	PR3	.436	2.292
	PR4	.462	2.163
	PR5	.543	1.841
	PR6	.427	2.340
	PR7	.459	2.177
	PRS	.524	1.910
	PR9	.507	1.973
	PR10	.527	1.898
	PR11	.406	2.461
	PR12	.438	2.281
	PE1	.346	2.893
	PE2	.325	3.073
	PE3	.418	2.395
	PE4	.461	2.168
	PE5	.409	2.444
	PE6	.461	2.171
	PE7	.460	2.174
	PES	.461	2.170
	PE9	.366	2.731
	PE10	.474	2.109
	EN1	.395	2.533
	EN2	.378	2.648
	EN3	.425	2.351
	EN4	.451	2.219
	EN5	.609	1.641
	EN6	.546	1.832
	EN?	.479	2.089
	ENS	.457	2.188
	EN9	.468	2.136
	EN10	.630	1.586
	OR1	.357	2.798
	OR2	.394	2.537
	OR3	.375	2.664
	OR4	.356	2.812

a. Dependent Variable:P01

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	P03	.505	1.981
	P04	.567	1.763
	TE1	.560	1.786
	TE2	.522	1.916
	TE3	.519	1.928
	TE4	.489	2.047
	TE5	.448	2.230
	TE6	.553	1.810
	TE7	.554	1.804
	TES	.530	1.886
	TE9	.574	1.742
	TE10	.673	1.485
	TE11	.630	1.587
	TE12	.590	1.696
	TE13	.555	1.801
	PR1	.505	1.981
	PR2	.528	1.892
	PR3	.435	2.301
	PR4	.467	2.141
	PR5	.545	1.835
	PR6	.425	2.351
	PR7	.458	2.182
	PRS	.523	1.914
	PR9	.507	1.973
	PR10	.522	1.915
	PR11	.406	2.464
	PR12	.437	2.291
	PE1	.355	2.818
	PE2	.326	3.065
	PE3	.418	2.394
	PE4	.459	2.179
	PE5	.410	2.442
	PE6	.461	2.171
	PE7	.461	2.170
	PES	.467	2.141
	PE9	.368	2.715
	PE10	.476	2.103
	EN1	.399	2.606
	EN2	.376	2.658
	EN3	.422	2.370
	EN4	.453	2.209
	EN5	.599	1.671
	EN6	.545	1.836
	EN?	.478	2.091
	ENS	.459	2.180
	EN9	.470	2.130
	EN10	.631	1.584
	OR1	.358	2.796
	OR2	.400	2.501
	OR3	.375	2.670
	OR4	.357	2.798
	P01	.568	1.760

a. Dependent Variable:P02

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	P04	.557	1.702
	TE1	.563	1.775
	TE2	.526	1.903
	TE3	.515	1.930
	TE4	.455	2.045
	TE5	.448	2.231
	TE6	.550	1.520
	TE7	.560	1.757
	TE8	.523	1.911
	TE9	.571	1.753
	TE10	.673	1.455
	TE11	.630	1.555
	TE12	.559	1.695
	TE13	.553	1.509
	PR1	.505	1.970
	PR2	.537	1.562
	PR3	.434	2.303
	PR4	.459	2.179
	PR5	.545	1.533
	PR6	.427	2.343
	PR7	.461	2.170
	PRS	.525	1.906
	PR9	.505	1.970
	PR10	.524	1.907
	PR11	.407	2.455
	PR12	.437	2.259
	PE1	.346	2.557
	PE2	.325	3.050
	PE3	.420	2.351
	PE4	.461	2.171
	PE5	.410	2.435
	PE6	.460	2.172
	PE7	.455	2.153
	PES	.461	2.170
	PE9	.379	2.637
	PE10	.476	2.102
	EN1	.395	2.532
	EN2	.375	2.649
	EN3	.427	2.343
	EN4	.445	2.247
	EN5	.612	1.633
	EN6	.545	1.535
	EN?	.477	2.095
	ENS	.462	2.164
	EN9	.469	2.131
	EN10	.630	1.557
	OR1	.357	2.502
	OR2	.395	2.511
	OR3	.354	2.602
	OR4	.364	2.751
	P01	.366	2.735
	P02	.363	2.752

a. Dependent Variable: P03

Coefficients•

Model		Collinearity Statistics	
		Tolerance	VIF
1	TE1	.562	1.779
	TE2	.524	1.909
	TE3	.517	1.936
	TE4	.459	2.046
	TE5	.445	2.230
	TE6	.553	1.808
	TE7	.553	1.505
	TE8	.529	1.590
	TE9	.575	1.735
	TE10	.673	1.456
	TE11	.631	1.554
	TE12	.555	1.701
	TE13	.553	1.509
	PR1	.505	1.979
	PR2	.530	1.556
	PR3	.434	2.302
	PR4	.459	2.150
	PR5	.543	1.542
	PR6	.425	2.351
	PR7	.455	2.152
	PRS	.523	1.911
	PR9	.516	1.937
	PR10	.537	1.562
	PR11	.407	2.456
	PR12	.436	2.292
	PE1	.344	2.910
	PE2	.325	3.072
	PE3	.424	2.360
	PE4	.459	2.179
	PE5	.414	2.413
	PE6	.461	2.171
	PE7	.455	2.152
	PES	.464	2.153
	PE9	.365	2.719
	PE10	.452	2.074
	EN1	.401	2.492
	EN2	.377	2.653
	EN3	.422	2.370
	EN4	.445	2.247
	EN5	.599	1.670
	EN6	.551	1.516
	EN?	.475	2.107
	ENS	.465	2.152
	EN9	.477	2.095
	EN10	.631	1.555
	OR1	.360	2.751
	OR2	.394	2.540
	OR3	.371	2.695
	OR4	.361	2.767
	P01	.373	2.651
	P02	.354	2.524
	P03	.509	1.963

a. Dependent Variable: P04

APPENDIX 8

Factor Loadings for Measurement Model

Factor loadings for measurement model (iteration 1)

Indicators	Factor loadings
PE10	.558
EN10	.456
EN9	.558
EN8	.648
EN7	.551
EN6	.478
EN4	.657
EN3	.658
EN2	.694
EN1	.646
PR10	.567
PR9	.519
PR8	.654
PR7	.730
PR6	.664
TE5	.646
TE3	.473
TE2	.614
PE7	.578
PE6	.611
PE5	.748
PE2	.788
PE1	.732
PO3	.570
PO2	.555
PO1	.601
OR4	.709
OR3	.716
OR2	.702
OR1	.695
PR5	.500
PE4	.690
PE3	.807

Factor loadings for measurement model (iteration 2)

Indicators	Factor loadings
PE10	.549
EN9	.534
EN8	.632
EN7	.535
EN6	.480
EN4	.664
EN3	.678
EN2	.708
EN1	.653
PR10	.567
PR9	.519
PR8	.654
PR7	.730
PR6	.663
TE5	.646
TE3	.473
TE2	.614
PE7	.578
PE6	.611
PE5	.748
PE2	.788
PE1	.732
PO3	.569
PO2	.553
PO1	.600
OR4	.710
OR3	.717
OR2	.702
OR1	.697
PR5	.500
PE4	.690
PE3	.807

Factor loadings for measurement model (iteration 3)

Indicators	Factor loadings
PE10	.548
EN9	.534
EN8	.631
EN7	.535
EN6	.482
EN4	.665
EN3	.678
EN2	.708
EN1	.653
PR10	.569
PR9	.517
PR8	.651
PR7	.728
PR6	.669
TE5	.675
TE2	.560
PE7	.575
PE6	.610
PE5	.751
PE2	.784
PE1	.736
PO3	.570
PO2	.554
PO1	.600
OR4	.710
OR3	.716
OR2	.701
OR1	.697
PR5	.498
PE4	.691
PE3	.808

Factor loadings for measurement model (iteration 4)

Indicators	Factor loadings
PE10	.540
EN9	.516
EN8	.613
EN7	.509
EN4	.662
EN3	.693
EN2	.725
EN1	.675
PR10	.568
PR9	.517
PR8	.650
PR7	.728
PR6	.669
TE5	.677
TE2	.559
PE7	.574
PE6	.609
PE5	.751
PE2	.785
PE1	.736
PO3	.569
PO2	.553
PO1	.601
OR4	.708
OR3	.717
OR2	.702
OR1	.698
PR5	.499
PE4	.690
PE3	.808