Implementation of BIM for Off-Site Manufacturing in Construction Industry

Hassan Nejat

Submitted to the
Institute of Graduate Studies and Research
in partial fulfilment of the requirements for the degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
September 2016
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Mustafa Tümer
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Civil Engineering.

Assoc. Prof. Dr. Serhan Şensoy
Acting Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Civil Engineering.

Assoc. Prof. Dr. İbrahim Yitmen
Supervisor

Examining Committee

1. Prof. Dr. Tahir Çelik
2. Assoc. Prof. Dr. İbrahim Yitmen
3. Dr. Tolga Çelik

ABSTRACT

Building Information Modeling (BIM) is a new developing technology and a modern approach that could achieve a specific position in construction in recent years due to its abilities and capabilities. Since, this technology and new approach is able to create a virtual model of building with details and all components, the authority of stakeholder's initiative and creativity will incredibly increase and they will be able to predict the most important problems and limitations before implementation.

Traditional or conventional construction is proven due to non-flexibility against different types of environment conditions, problems in terms of quality control of materials and consuming more energy will increase risks, time and cost in construction.

Prefabrication or off-site construction is an offsite manufacturing process that takes place at a specialized facility in which various materials and building systems are joined to form a component or part of a larger final installation. The most important benefits of off-site construction in comparison with traditional methods is time and cost reduction and its abilities to increased quality.

According to the young population of Iran and enormous demand for homeownership, the use of modern technologies in construction section is unavoidable in order to increase productivity and optimal use of resources. Due to the benefits of off-site construction from the sustainable development point of view, this method has high potential to response this demand. But the use of off-site construction could not find its proper position in Iranian construction industry due to some barriers and limitation.

Integrating BIM and off-site process due to the capabilities of BIM to share information and increase communication among different parts of project before, in design phase and during construction has a high potential to overcome obstacles and solved them. Moreover, due to abilities of BIM approach to create a virtual model and existing potential of BIM tools to simulate and experiment various component testing in virtual environment, integration of these modern technologies can improve the benefits of construction.

In this research in the first step as an initial objective, critical factors of off-sit construction barriers are measured. Then as the main objective by statistical methods, it is investigated at what extend building information modeling (BIM) can overcome on these critical off-site construction limitation in Iran construction industry. The results shows that BIM adoption and operation has high potential to overcome off-site construction limitation.

In addition, by integrating BIM and modern construction, duration period of construction, cost and risks will be decreased.

Keywords: Building Information Modeling (BIM), Off-Site Manufacturing (OSM), barriers of prefabrication, Iran construction industry

ÖZ

Yapı Bilgi Modellemesi (YBM) yeni gelişen bir teknoloji ve modern bir yaklaşım olarak yetenekleri ve kabiliyetleri sayesinde son yıllarda inşaat sektöründe söz sahibi olmuştur. Bu teknoloji ve yeni bir yaklaşım sayesinde bir binanın ayrıntıları ve tüm bileşenleri ile sanal bir modelini oluşturmak mümkün olacağına göre, paydaşların insiyatif ve yaratıcılık yetkisinde inanılmaz artış olacak, uygulamadan önce en önemli sorunları ve sınırlamaları tahmin etmek mümkün olacaktır.

Geleneksel ya da geleneksel yapımın çevre durumunun farklı türlerine karşı esnekliği olmadığı kanıtlanmış, malzemelerin kalite kontrolü ve daha fazla enerji tüketmesine ililşkin sorunlar yapımda riskleri, süreyi ve maliyeti artıracaktır.

Prefabrik ya da şantiye dışı imalat, çeşitli malzemeleri ve yapı sistemlerinin daha büyük bir son montaj bileşenini ya da bir kısmını oluşturmak üzere birleştirilmiş özel bir tesiste yer alan bir üretim sürecidir. Geleneksel yöntemlerle karşılaştırıldığında şantiye dışı imalatın en önemli faydaları zaman ve maliyet düşürme ve kaliteyi artırmaya yönelik yetenekleridir.

İran'daki genç nüfusunun muazzam ev sahibi olma talebine göre inşaat sektöründe modern teknolojilerin kullanımı, verimlilik ve kaynakların optimum kullanımını artırmak amacıyla kaçınılmazdır. Sürdürülebilir kalkınma bakış açısı ve şantiye dışı yapım yararları nedeniyle, bu yöntem bu talebi karşılamada yüksek potansiyele sahiptir. Fakat şantiye dışı imalat, bazı engeller ve sınırlamalar nedeniyle İran inşaat sektöründe tam olarak kabul görmemiştir. Tasarım öncesi, tasarım aşaması ve inşaat sırasında, bilgi paylaşmak ve projenin farklı tarafları arasında iletişimi artırmak amacıyla YBM yetenekleri doğrultusunda YBM ve şantiye dışı imalat sürecinin bütünleştirilmesi engelleri aşmada ve çözmede yüksek bir potansiyele sahiptir. Ayrıca, YBM yaklaşımının yeteneklerine bağlı olarak sanal bir model oluşturması ve mevcut YBM araçları potansiyelini simüle etmesi ve çeşitli bileşenlerin testini sanal ortamda denemesi, bu modern teknolojilerin bütünleştirilmesi ile yapım yararlarını artırabilir.

Bu araştırmada başlangıç amacı olarak ilk adımda, şantiye dışı imalat engellerinin kritik faktörleri ölçülmektedir. Daha sonra ana hedef olarak istatistiksel yöntemlerle, İran inşaat sektöründe YBM'nin bu kritik şantiye dışı yapım sınırlamalarının üstesinden ne derecede gelebildiği incelenmiştir. Sonuçlar YBM'nin benimsenmesi ve işleyişinin şantiye dışı yapım sınırlamasını aşmada yüksek bir potansiyele sahip olduğunu göstermiştir.

Buna ek olarak, YBM ve modern yapımın bütünleştirilmesi yapım süresi, maliyeti ve riskleri azaltacaktır.

Anahtar kelimeler: Yapı Bilgi Modellemesi, Şantiye dışı yapım, prefabrikasyon engelleri, İran inşaat sektörü

ACKNOWLEDGMENT

First of all, I admit that words and sentences are incapable of gratitude who support me to conduct successfully my dissertation.

For tribute:

Firstly, I would like to deeply thank my supervisor the honorable Assoc. Prof. Ibrahim Yitmen that from the beginning of research, support me with his excellent consultation in order to select and operate new subject and fruitful issue in the construction industry despite he was busy at university. Actually he was that directly guide me with his valuable instruction how to organize and arrange studies in various stages of my thesis.

I would like to appreciate of committee members for their consideration and also allocated times to review my thesis**.**

I would appreciate the Department of Civil Engineering to present Building Information Modeling course. Also, I would like to especially thank Prof. Dr. Tahir Çelik and Prof. Dr. Özgür Eren for sharing their precious experience with me during their courses.

With special thanks of my family especially my wife that without her support I have never started an interesting experience in North Cyprus.

And finally I will never forget Saied Nakhaee for his immeasurable kindness during three years of my study as best friends.

TABLE OF CONTENTS

ABSTRACT iii
ÖZ… v
ACKNOWLEDGMENT vii
LIST OF TABLES xiii
LIST OF FIGURES xiv
LIST OF ABBREVIATIONS xvi
1 INTRODUCTION 1
1.1 Background study 1
1.2 Problem Statement 4
1.3 Research Scope and Objective 7
1.4 Research methodology 7
1.5 Research limitations 8
1.6 Thesis outline 8
2 OFF-SITE MANUFACTURING 10
2.1 Introduction 10
2.2 Off-Site Construction Definition 11
2.3 Permanent Modular Construction 11
2.4 Off-Site Construction to Simulate Sustainable Development 11
2.4.1 Social Considerations 12
2.4.2 Environmental Considerations 14
2.4.3 Economic and Financial Considerations 16
2.5 Offsite Construction Benefits 18
2.5.1 Time Saving 18

2.5.2 Quality Improvement 18

2.5.3 Cost Reduction 18

2.5.4 Productivity Improvement 19

2.6 Comparison of OSM in Developing and Developed Countries 19

2.6.1 Materials 19

2.6.2 Workmanship 19

2.6.3 New Technology 20

2.7 Offsite Construction Barriers 20

2.8 Conclusion 23

3 BUILDING INFORMATION MODELING 24

3.1 Introduction 24

3.2 BIM Definition 27

3.3 BIM and Stakeholders 30

3.3.1 BIM for Investors and Employers 30

3.3.2 BIM for Engineers 32

3.3.3 BIM for Supplier of Materials 33

3.3.4 BIM for construction manager and contractor 34

3.4 Benefits of BIM 37

3.4.1 Modeling vs. 2D Drafting 37

3.4.2 Parametric Elements 37

3.4.3 Improved Coordination 38

3.4.4 Improved Accuracy and Efficiency 38

3.4.5 Client Satisfaction 38

3.4.6 Facility Management 38

3.5 BIM and Intelligent Building 39

3.6 BIM and Teleworking 40

3.7 BIM and Net Zero Energy Buildings 41

3.7.1 Complementary task for architects 42

3.8 Key Steps to Successful BIM Implementation 43

3.8.1 Analysis 43

3.8.2 Personnel Analysis 43

3.8.3 Implementation 44

4 INTEGRATION BIM AND OSM 45

4.1 BIM AND OSM 48

4.2 Costs Comparison Traditional OSM and BIM with OSM 51

4.2.1 Direct Cost 51

4.2.2 Indirect Cost 52

4.3 Manage the Changes in OSM Integrated with BIM 54

4.4 BIM function for OSM barriers 56

4.4.1 High Initial Cost 56

4.4.2 Lack of Experience 57

4.4.3 Monotony of Structure 59

4.4.4 Disinclination to Innovation 60

4.4.5 Transportation of Prefabricated Elements 61

4.4.6 Fragmented Structure 62

5 RESEARCH METHODOLOGY 64

5.1 Introduction 64

5.2 Questionnaire survey 64

5.2.1 Questionnaire A 64

5.2.2 Questionnaire B 66

5.3 Population of research 66
5.4 Data Collection 67
5.5 Ranking Analysis 67
5.6 Factor Analysis 67
5.7 Reliability 68
5.8 Correlation Analysis 68
5.9 Hypothesis 68
6 ANALYSIS AND DISCUSSION 70
6.1 Questionnaire A 70
6.1.1 Part A (General Information) 70
6.1.2 PART B (OSM Benefits) 73
6.1.3 Critical OSM Factors (Questionnaire A) 78
6.2 Questionnaire B 83
6.2.1 Part A (General Information) 83
6.2.2 PART B (BIM Benefits) 88
6.2.3 PART C: Functionality of BIM for OSM Barriers 90
6.2.4 Ranking Analysis Technique 91
6.2.5 Result of Factor Analysis 97
6.2.6 Correlation Analysis 104
6.2.7 Hypothesis 105
6.2.8 Comparing the Literature Review and Questionnaire Results 106
7 CONCLUSION 109
7.1 Recommendation for future research 111
REFERENCE 112
APPENDIX 119

Appendix A: Questionnaire A... 120

Appendix B: Questionnaire B 129

LIST OF TABLES

Table 1: Sustainability indictors and required attributes (Krug & Miles, 2013) 12

Table 2: Hindering the Utilization of OSM 22

Table 3: Benefit of BIM in construction (in common with OSM) 49

Table 4: Benefits of OSM in construction (in common with BIM)........................... 50

Table 5: Diagonal Matrix of the Most Important Intersections of BIM and OSM.... 51

Table 6: Coding the Critical Factors Preventing the Utilization of OSM................. 65

Table 7: Interpret of Cronbach's Alpha coefficient (George and Mallery, 2003) 68

Table 8: Ranking Analysis of Critical Factors for Preventing the Utilization of OSM 80

Table 9: Critical Factors Hindering the Utilization of OSM in Iran 91

Table 10: Ranking Analysis for Functionality of BIM for Critical Factors Hindering the Utilization of OSM in Iran 93

Table 11: Variance of Critical Factors 97

Table 12: Cluster Matrix after Varimax Rotation 98

Table 13: The Result of Correlation Analysis... 105

LIST OF FIGURES

Figure 1: Overview of off-site construction characteristics.. 2

Figure 2: Population Pyramid Charts of Iran 5

Figure 3: Classification of BIM Challenges (Arayici, 2015)...................................... 6

Figure 4: “Thirty-seven percent of materials become waste” (Deutsch, 2011) 15

Figure 5: Comparison Traditional Information exchange and BIM Information exchange... 26

Figure 6: Some common suggested terms for BIM (Succar, 2009)........................... 27

Figure 7: periodic table of BIM (National Building Specification, 2015)................. 29

Figure 8: “Ninety-two percent of project owners said that architects’ drawings are typically not sufficient for construction.”(Deutsch, 2011)... 31

Figure 9: “BIM showing how can view the hallway of a building” (Reddy, 2012) .. 32

Figure 10: A door as a BIM object- SMARTBIM Library (Reddy, 2012)................ 33

Figure 11: BIM benefits for stakeholders 36

Figure 12: Benefit of BIM and OSM integration for stakeholders 48

Figure 13: Mobile 3D mapping for surveying earthwork projects using an 58

Figure 14: Fabricating walls in Revit... 60

Figure 15: Site Safety Visualization (Hardi & McCoo, 2015).................................. 62

Figure 16: Superintendent using BIM Anywhere to scan QR codes for quality control 63

Figure 17: Job Title of Participants.. 71

Figure 18: Education Level of Participants.. 71

Figure 19: Experience in Construction Industry 72

Figure 20: Experience in OSM 73

Figure 21: Effect of OSM in Reducing the Cost of Construction.............................. 73

Figure 22: Effect of OSM in Reducing Time of Construction.................................. 74

Figure 23: Effect of OSM to Enhancing Construction Quality................................. 75

Figure 24: Effect of OSM to Preventing Entrance of Non-Specialist in Construction Industry 76

Figure 25: Effect of OSM to Improve Labor Productivity 77

Figure 26: Effect of OSM to Reduce the Legal Problems in Construction Industry . 78

Figure 27: Radar Chart of Critical Factors of OSM Barriers.................................... 81

Figure 28: Questionnaire A Process.. 82

Figure 29: Job Title of Participants... 83

Figure 30: Education of Participants... 84

Figure 31: Experience in construction 85

Figure 32: experience in BIM 86

Figure 33: The Necessity of BIM Knowledge for All Engineering........................... 87

Figure 34: construction manager should be BIM expert... 88

Figure 35: Enhancing Construction Quality by operating BIM................................. 88

Figure 36: Preventing Of Entrance of Non-Specialist by Operating BIM................. 89

Figure 37: Reduce the Legal Problems by Operating BIM....................................... 90

Figure 38: Radar chart of functionality of BIM for OSM barriers 95

Figure 39: Questionnaire B Process.. 96

Figure 40: Factor Analysis Diagram.. 103

Figure 41: The Results of Questionnaire Survey in Comparison with Literature Review 108

LIST OF ABBREVIATIONS

BIM	Building Information Modeling.
OSM	Off-Site Manufacturing
OSC	Off-Site Construction
PMC	Permanent Modular Construction.
IMF	International Monetary Fund
SPSS	Statistical Package for the Social Sciences

Chapter 1

INTRODUCTION

1.1 Background study

Manufactured construction, off-site construction, off-site manufacturing, industrialized building systems and modern methods of construction are some generic terms that have been used interchangeably in extant literature to describe pre-fabricated construction; where the intent of which is to move some of the construction effort into controlled environments within manufacturing facilities. Offsite construction can provide such specific benefits, as higher speed of construction, enhanced quality outputs, higher tolerances, lower costs, and reduced labor re-works on-site.

Alazzaz & Whyte (2014), cited that the main advantage of off-site construction in this regard is that it enables a tighter control over quality than an on-site environment. Also Molavi & Barral, (2016), mentioned that the advantages of using multiple modular construction methods is contingent upon early and complete communication between all contractors and suppliers involved.

The use of this approach will have substantially effected for sustainable development that has been the primary priority of governments worldwide during last few years and is certainly attended to obtain this purpose in recent years. Obviously, prefabrication could not receive its position in construction industry even in developed countries and it is clearly could not be used in scale can be expected in Iran construction industry.

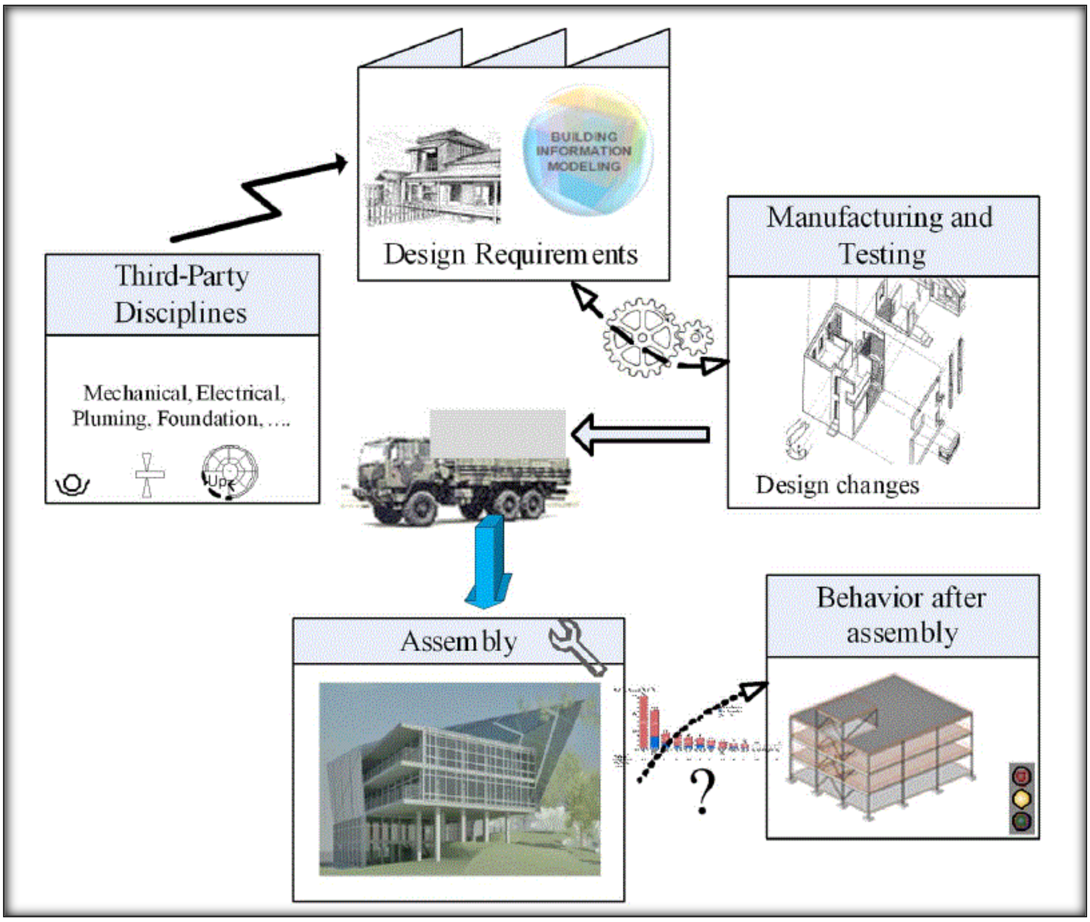

Figure 1: Overview of off-site construction characteristics

The construction process is more complicated (see Figure 1). A variety of products and prefabricated components such as pipes, walls, windows are produced with different suppliers. Hence, there is a fundamental essential for specialties in order to combine and operate these different components in construction industry. Modeling them could be useful to reach the final composition and reducing waste. Possible changes in the manufacturing process is also inevitable. It is very important to communicate among different groups involved in the manufacturing process such as architectures, civil engineers, electrical and mechanical engineers, managers, owners, fabricators to achieve the desired product (Nawari, 2012).

On the other side, it is obviously that modelling has been implemented in the largest and the most advanced industries and utilize for many year. A good example to mention is the Boeings Company by using this technology is able to manufacture and take control the most advanced man-made machines. For instance, by simulating 777 model of Boeing for their airplane interiors, removed approximately 6,000 needed changes and reduced a 90% in rework (Wiley et al., 2011).

BIM is a very effective approach for construction industry with capability to create widespread corporation amongst different parts of lifecycle of projects. An approach that has able to measure properties, details and structures of construction in order to analyze them for variety situation during carrying out the process.

Predicting the next condition of the process that it could be incredibly considered for stakeholders. It helps the stakeholders to better orientate the progress and to cooperate effectively due to an imagined data format (Chen & Luo, 2014).

BIM thanks to development of technology has able to transcend over conventional method because this approach has able to create a virtual model with entire components. Obviously, stakeholders will have unequivocal perspective of their projects, consequently will be able to predict the most important factors of the construction project such as time, cost and risk from time to time.

As mentioned above, BIM approach creates a virtual model of building that has high potential in order to corporation and collaboration with construction team with both substantially abilities to integrate as well as share information for solving projects problems. Obviously, based on BIM capability such as improve quality and quantity of components, reducing project cost and shortening construction duration and high potential for prediction is expected by adopting and operating BIM can overcome obstacles of offsite construction. In terms of the prefabrication industry, there is a strong correlation between the computational ability of BIM and the off-site constructional technology. Proper use of these technologies will make possible the goal that all components that go into making standardized or modular building elements are available digitally as BIM models that accurately represented their geometry and as well as their behavior and properties (Nawari, 2012).

1.2 Problem Statement

According to the young Iranian population (see Figure 2), Population growth and massive migration to urban areas, indiscriminate expansion of existing cities especially the metropolises, the ravages of the settlement system, intensifying the need for construction of urban housing and land constraints within the cities, the need to create new cities as one of the most important strategies of the urban development has proposed in Iran. In order to Preventing the accumulation of demand and probable problems, speed in construction and cost reduction by considering lean manufacturing index can appropriate response to this growing demand. But due to using conventional construction many resources are wasted. Hence, deliberate choice of modern construction method instead of conventional construction is necessary.

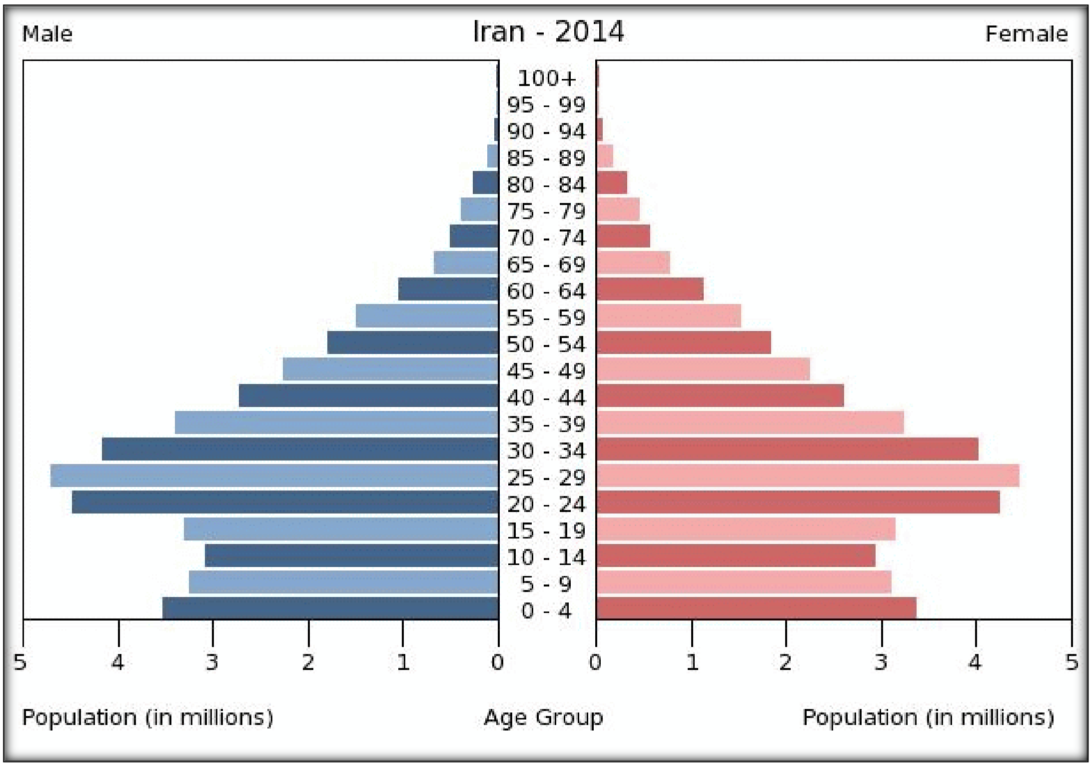

Figure 2: Population Pyramid Charts of Iran

In order to encourage investors that can be included governments, organizations and even though individuals to invest establishment off-site manufacturing is to solve the challenges. Recognition the major barriers and constraints of off-site construction is the first step to adopt an approach to solve them. Some serious challenges of implementation OSM in construction have been mentioned by researchers. Jaillion and Poon (2008), cited that initial cost and cost of transportation are limitation factors from the economic point-of-view for OSM. Fragmented structure as another prefabricated challenge has been mentioned by Mao, Chao, et al. (2013). Kamar et al. (2009), cited the Shortage of Experience from Local Jobs as a OSM challenge. Interesting to traditional methods is other obstacles for developing OSM that has been referred by Pan (2008)). Shortage of Qualified R&D Institution and services has been mentioned by Blismas et al. (2005). The lack of working experience among different member teams involved in projects is another barriers for OSM (Lovell & Smith, 2010). Other barrier that has important role for adoption OSM is inattention governments (Blismas & Wakefield, 2009).

BIM as a new approach has a high potential to increase communication among different teams in construction in order to share necessary information in proper circumstances. But due to be as a new technology needs to introduce correctly for stakeholders in Iran construction industry. Some considerable challenges to implementation BIM in construction are high cost for training the personnel, the lack of human resources, high initial cost to buy required hardware and software, the lack of demand for BIM due to the lack of knowledge of BIM benefits for construction industry (see Figure 3).

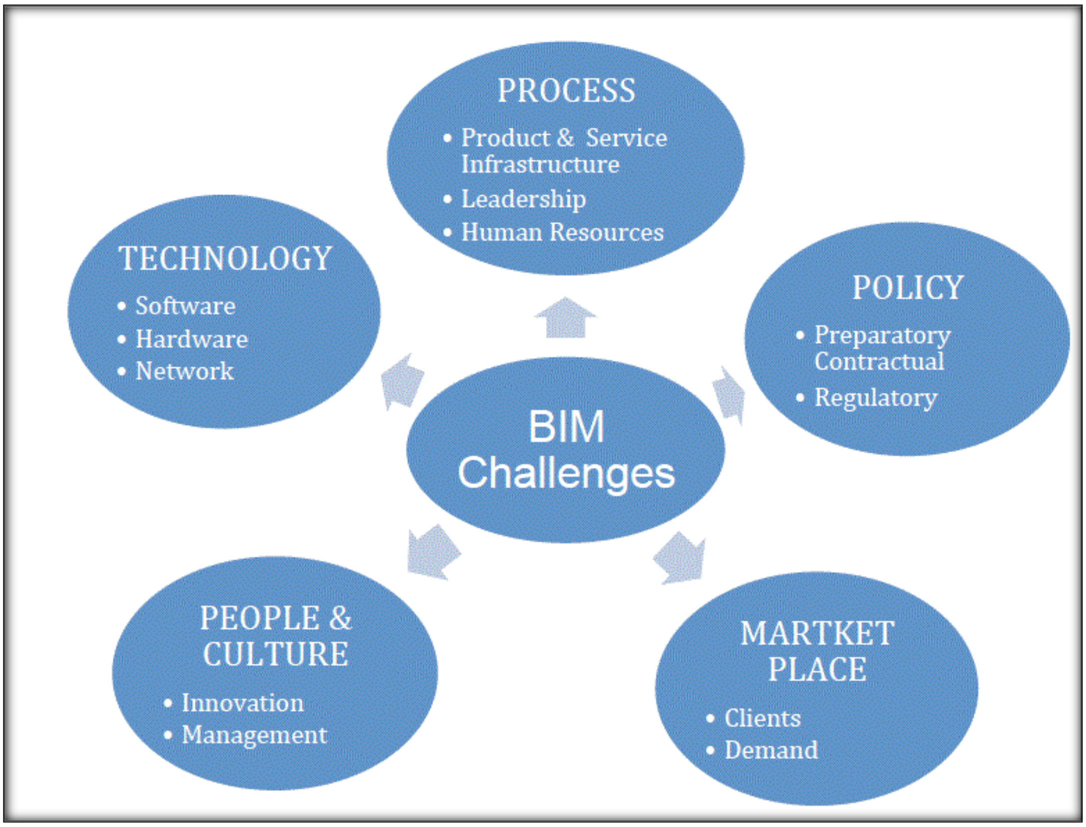

Figure 3: Classification of BIM Challenges (Arayici, 2015)

1.3 Research Scope and Objective

The research questions of this dissertation is classified as follows:

- What are the most important barriers for executing OSM?
- Which ones are recognized as critical factors for implementation of OSM in Iran?
- Which ones of OSM critical factors will be solved by operating BIM approach?

The objective of this research is to:

- Identify the major challenges of execution OSM method in construction industry and classify these limitations in Iran construction industry.
- Identify similarities between BIM and OSM advantages to better understand their benefits in Simultaneous performance in Iran
- Analyze and classify the functionality of BIM on OSM challenges and obstacles in Iran construction industry.

1.4 Research methodology

In the first step, by investigating in-depth review various literature such as books, thesis and papers based on OSM subject, the most important barriers was extracted. Two kind of questionnaire was designed:

- Questionnaire A was designed in order to extract the critical OSM barriers in Iran.
- Questionnaire B was designed in order to find out which ones of these critical factors will be solved by using BIM method.

Google Doc is used to prepare on line questionnaire survey in order to send participants in construction such as architectures, engineers, manufactures, contractors and members of Tehran Construction Engineering Organization and khorasan Construction Engineering Organization in Iran in order to collect data.

Factor analysis technique is used to find clusters related variables to compress them in order to be smaller for better investigation (Norusis 2008). Descriptions and results of factor analysis of the survey will be stated in chapter 5 and chapter 6.

Two hypothesis is exposed to dissection:

- There is a correlation between BIM knowledge and BIM functionality in order to overcome OSM obstacles
- There is a correlation between the knowledge of BIM and OSM Beneficial

The results of hypothesis testing is expressed in chapter 6.

Statistical method is conducted to analyze the data collection by using SPSS (Statistical Package of Social Sciences) software version 22.

1.5 Research limitations

The participants of this survey is limited by only two main regions of Iran, Khorasan and Tehran. Since, Khorasan province is the biggest province and also Tehran is the capital of Iran, therefore, the research results can be distributed to Iran.

1.6 Thesis outline

The study has classified into seven (7) chapters as follows:

Chapter 1 provides an introduction about research topic, problem statement, introduction to BIM and OSM and the objective of this study.

Chapter 2 investigates OSM as a sustainable development technique and its benefits in construction industry. Also, the limitation of this method will be discusses.

Chapter 3 provides an introduction BIM as a new approach in construction, states relationship between BIM and stakeholders such as investors, engineers, construction managers and contractors. In this chapter is mentioned the benefits of BIM and the capability of BIM for Intelligent Building, Net Zero Energy Building and Teleworking. Finally, in this chapter will be stated the key steps in order to successful BIM implementation.

Chapter 4 allocates to the benefits of integration BIM and OSM with review of relevant content in construction industry. In this chapter will be discussed how BIM can overcome to some factors that are prevented the implementation of OSM in construction.

Chapter 4 states the methodology of the research such as questionnaire survey, data collection method and also hypothesis of the research.

Chapter 5 provides the analysis and discussion of the research results. In the first stage, the critical factors of OSM is investigated. Then functionality of BIM is assessed in order to find that what extent BIM operating can solve or reduce the critical OSM barriers in Iran construction industry.

Chapter 7 contains the conclusion of the survey and states recommendation for future research in related issues with BIM and OSM.

Chapter 2

OFF-SITE MANUFACTURING

2.1 Introduction

This chapter provide an introduction about OSM and also will be investigated the benefits of off-site construction from the sustainable development point of view.

Prefabricated structures thanks to its unique characteristics and its advantages from the sustainable development point of view, will be a good choice for the century ahead. As outlined, three major factors that are important for sustainable development is included society, economy and environment. Some features are more important because, realization of them, achieve multi-purpose at the same time. For example, traffic reduction that has multiple effects. Naturally, reduction of the traffic volume is important socially aspect. In addition, thanks to reduced traffic fuel consumption and Co2 production will indeed decrease that are important the environmental and economic point of view.

Ganiron and Almarwae (2014), cited that by operating Modular construction the time of construction reduce in about half in contrast to traditional construction. It means added revenue will achieve in contrast to stick-built construction.

Ganiron and Almarwae (2014), cited that due to repeated operations on prefabricated methods, worker productivity increases. In addition, they mentioned that the quality will improve due to assemble components in the factory and the possibility of cutting parts with laser cutter machine.

2.2 Off-Site Construction Definition

In 2010, Modular Building Institute defined: “Prefabrication, preassembly, modularization, and off–site fabrication involve the fabrication or assembly of systems and components at off-site locations and manufacturing plants. Once completed, the systems or components are shipped to a construction job site for installation at the appropriate time. These techniques offer the promise (if used appropriately) of lower project costs, shorter schedules, improved quality, and more efficient use of labor and materials.”

OSM has classified into four section as follows(Alazzaz & Whyte, 2014):

1) Component manufacture, 2) Non-volumetric preassembly, 3) Volumetric preassembly, 4) Modular building

2.3 Permanent Modular Construction

PMC is an innovative, sustainable construction delivery method utilizing offsite, lean manufacturing techniques to prefabricate single or multi-story whole building solutions in deliverable module sections. PMC buildings are manufactured in a safe, controlled setting and can be constructed of wood, steel, or concrete. PMC modules can be integrated into site built projects or stand alone as a turn-key solution and can be delivered with MEP, fixtures and interior finishes in less time, with less waste, and higher quality control compared to projects utilizing only traditional site construction.

2.4 Off-Site Construction to Simulate Sustainable Development

The following table mention the advantages of off-site construction the point-of-view of sustainable development. It will be discussed in detail in the following sections.

Table 1: Sustainability indictors and required attributes (Krug & Miles, 2013)

Sustainability Category	Attribute
Social	Health & Safety
	Better Working Conditions
Environmental	Road Traffic Reduction
	Energy Use Reduction on Site
	Reduced Waste
	Energy Use Reduction in Operation
Economic	Faster Construction
	Alternative Purchasing Models
	Snagging & Defects Reduction

2.4.1 Social Considerations

2.4.1.1 Health & Safety

Conventional construction due to its nature, is a high-risk activities. Zhang et al (2015), cited 36% of all us fatal accidents happen in the construction industry. However, in recent years special attention to reducing the risks and increasing the safety of employees has been discussed, but as mentioned, its nature is dangerous. The movement of heavy vehicles is inevitable. Installation and utilization of large construction cranes are essential in conventional construction. Work at height level for workers is obvious and under controlled atmospheric conditions is impossible. As a result, Workers who work in off- site manufacturing will be faced with minimize risks in comparison with the conventional construction. Hence, the increase of production housing in manufactories, have a significant decrease in construction-related abnormalities. Research shows that prefabricated housing production, is caused the mortality rate reduce to %52 and %29 reduced rate of major injuries in construction industry (Krug & Miles, 2013).

Blismas and Wakefield (2009), cited that risks is reduced in order to spend less time onsite and fewer workers onsite. The environments of factory are controlled better and the use of heavy equipment such as tower crane is reduced.

Emmitt and Christopher (2014), mentioned that Control of contaminants during component production is safer and easier and the use of scaffolding is reduced.

Obviously, reduction of fatalities and accidents related to construction have positive effects in society.

2.4.1.2 Better Working Conditions

In addition to health issues, there are additional benefits for employee:

Blismas and Wakefield (2009), cited OSM due to capability to control better the work environment for workers and protect them against accidents provide better conditions and also mentioned in bad weather condition the quality is reduced on the construction site while produced elements and components with OSM method can be protected in safer environment.

Job Security: unquestionably, for employees have a permanent employment is a priority and due to the nature of work in the off-site manufactures, the priority will be met. But, clearly, job security is less in conventional construction. The likelihood of unemployment for employees and Project closure will be followed job insecurity and stress for staff (Krug & Wood, 2013).

Blismas and Wakefield (2009) referred:” The provision of better job security for workers is also offered by OSM since variable subcontract work is no longer relied upon solely.”

2.4.2 Environmental Considerations

Blismas and Wakefield (2009) referred:” The environmental advantages that OSM can offer through waste minimization and better engineering are also recognized.”

Kamali and Hewage (2016), cited that by contrasting the results of case studies, on average, the negative environmental impacts of OSM is lower than on-site construction.

2.4.2.1 Road Traffic Reduction

Workers usually ply by private vehicle to the project site in conventional construction. And moreover, materials must also be carried to the site. This will increase the amount of traffic that will be followed air pollution, noise pollution and increased emissions. Research has shown that reduction of private vehicle and use more of public transportation will be a great impact on social. Due to the nature of off-site construction, workers are usually fly by manufacture’s car that can be expected to reduce the amount of CO_2 and road traffic. Moreover, due to technological advances in the field of traffic control, public transport can better monitor and control. There is no doubt that all of the above mentioned, will be effective on budgets (Krug & Miles, 2013).

2.4.2.2 Energy Use Reduction on Site

Staff Accommodation and Services: Energy consumption depends on the number and volume of activities. Efficient use of human resources that are considerable amount of construction costs, will consequently be much reduced the cost of labor and energy as well. The energy used in this application includes heating and lighting, plus onsite services such as catering and staff welfare (Krug & Miles, 2013).

Lighting and Equipment/Plant: As specified time on a project that is being built with prefabricated method, is less in comparison with conventional construction. Reducing construction time will be caused to reduce the cost of lighting, heating and cooling.

2.4.2.3 Material Waste

Conventional construction methods are very wasteful in terms of efficiency. Research shows that on average 20% of the total weight of materials used in conventional construction methods is wasted (Krug & Miles, 2013). Precise control and using modern machines in the cutting and assembling parts, waste materials will be reduced to a minimum.

McGraw-Hill Construction (2011), cited that three quarters (76%) of respondents of research believed by applying OSM the construction waste is reduced.

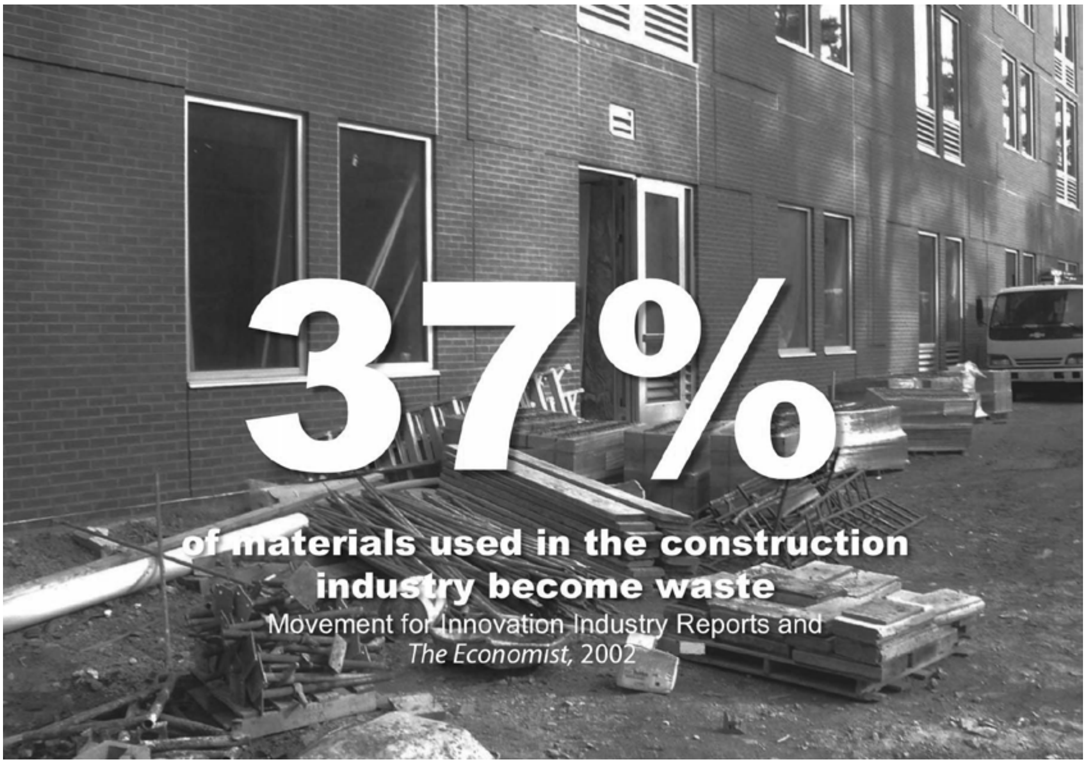

Figure 4: “Thirty-seven percent of materials become waste” (Deutsch, 2011)

In addition, collection, separation and reuse of materials in off-site manufacturing are better managed. The volume of waste materials and disposal costs are significantly reduced which leads to higher profits. One very important point in prefabricated buildings, reuse of the building. It is likely that the building will be needed for a particular activity in a limited time. These kinds of buildings have the potential for re-use after expiry of operation used in another location. Therefore, this approach has a major impact in reducing the time, cost and the amount of waste material and finally on environment.

2.4.2.4 Energy Use Reduction in Operation

Because more accurate control takes place in off-site manufacturing process in design phase, since survey the environmental impact on them is more accurate. In addition, because components are assembled at the factory, hence monitoring and optimization of consumer materials will be more accurate. Also thanks to new tools in analyzing the instruments, such as BIM tools, which enable to provide energy analysis for buildings, it can be hoped that by choosing the best materials, the use of energy and costs will be reduced at all stages of the construction (Krug & Miles, 2013).

2.4.3 Economic and Financial Considerations

2.4.3.1 Faster Construction

There are many advantages of prefabricated structures, but perhaps the most important and most significant advantage of prefabricated buildings, is their construction speed. Many reasons can be stated that led to speed up buildings. One reason which can mention is trust to environmental sustainability factors. In the conventional buildings due to the impossibility of predicting factors that effect on construction time, such as weather conditions and terms of location, delivery time will be long. But in modern construction it is possible to control weather. therefore, delivery time is shorter (Krug & Wood, 2013).

2.4.3.2 Improved Cash Flow

It is obvious that by reducing delivery time in manufacturing, contractor will achieve the anticipated financial benefit in project. Moreover, with the completion of the building, the owner will be allowed to sell or rent it faster to gain financial benefit and start new option (Krug & Miles, 2013).

2.4.3.3 Snagging and Defects Reduction

As previously mentioned, due to increased efficiency and experience of workers in off-site manufacture, shortcomings and standard deficiencies of the final product will be diminished in comparison with the conventional buildings. Another reason to reduce defects in prefabricated is more control over the manufacturing process by the relevant experts. Moreover, because of the large volume of work is done at the manufacture so observers and experts are deployed in off- site manufactures will have more time to monitor the works. Whereas, due to time off in switching between different projects and spent a lot of time in the traffic, surveillance and control over the manufacturing process will be reduced in the conventional construction. On the other hand, in case of any technical problem during work, access to relevant expertise is better and faster and also communication between workers and professionals is more (Krug & Miles, 2013).

As mentioned in the previous section, OSM has many advantages, especially from the point-of-view of sustainable development. Unfortunately, with all its benefits, prefabricated structures has failed to achieve its rightful place in the construction industry. It should be noted that the positive points of OSM execution from the sustainable development point of view t, could not benefits direction for developers and moreover, barriers and constraints OSM also have a great impact to the lack of use of this modern method (Krug & Miles, 2013).

Thus, in the next section will be reviewed some of the limitations of prefabricated structures that has been collected by reviewing literatures.

2.5 Offsite Construction Benefits

Off-site construction can bring about several benefits to the construction process as follows:

2.5.1 Time Saving

“The most significant benefit of off-site construction is the time savings that it brings about” (Alazzaz & Whyte, 2014).

Emmitt and Christopher (2014), cited that “Off-site testing and commissioning can help to reduce potential problems, and hence delays, on site.”

Blismas and Wakefield (2009), mentioned that the decrease of construction time was determined as a main advantages of OSM in US and UK studies.

2.5.2 Quality Improvement

Alazzaz and Whyte (2014), cited that all stakeholders believed that significant benefit is quality improvement thanks to a tighter control on production processes. They also has mentioned that quality of elements and components in OSM method is most important benefits by contrasting on-site construction

2.5.3 Cost Reduction

“Off-site construction is more predictable and less likely to suffer from cost blowouts caused by unknown factors such as the weather” (Alazzaz & Whyte, 2014).

2.5.4 Productivity Improvement

Alazzaz and Whyte (2014), cited that the fourth most significant advantage of OSM methods is Productivity in construction. With time reduction, cost reduction and improve quality actually is meaning that the method is more productive by contrasting on-site construction (Alazzaz & Whyte, 2014).

2.6 Comparison of OSM in Developing and Developed Countries

Iran is developing countries According to the International Monetary Fund (IMF). In the following, OSM in Iran as a developing country would be compared with developed countries in terms of some indexes:

2.6.1Materials

It is clearly that the lack of manufacturers is as a main challenge in Iran construction industry. The lack of manufacturers cause disinclination in order to utilize OSM in Iran construction. Because the lack of OSM components is obstacle for stakeholders in adoption OSM.

But on the other side, the price of raw material such as steel or concrete is cheaper in Iran because of the use of cheaper energy such as oil or gas in production process in comparison with developed countries such as UK or China. Undoubtedly, this can an appropriate opportunity in order to operating OSM in Iran.

2.6.2Workmanship

The labor cost in Iran base on per capita income of Iranian is less than labor cost of developed countries such as United States. In addition, the number of university graduates in Iran has been increased during last two decades. These two significant factors create an appropriate potential in order to adoption OSM in construction industry in comparison with developed countries.

But on the other side, the lack of qualified designers, the shortage of skilled installers and prefabricators, the lack of prefabricated contractors are barriers and limitation that would be prevented for OSM utilization in Iran construction.

2.6.3 New Technology

The transfer of digital goods and products are relatively simple; however, the transfer of invention and innovation of the process of production is difficult.

The shortage of technologies for prefabricated components, the shortage of qualified R&D institution, the shortage of guideline and standard for precast components are constraints that hindering of the use of OSM in comparison with developed countries.

2.7 Offsite Construction Barriers

Several researchers and practitioners have studied the restrictions of OSM. Three factors such as time, cost and lack of awareness of prefabricated have been examined as key factors in the investigation. In a survey have been conducted by Goodier and Gibb (2004) in the UK, over 90% of participants in the questionnaire survey have approved that they have adopted OSM at least in one of their projects. Most of them have mentioned that cost is a key factor in the reluctance to the adoption of OSM. Jaillion and Poon (2008), have analyzed economic constraints by questionnaire methodology and found that more initial cost and cost of transportation are limitation factors from the economic point-of-view. Fragmented structure as another prefabricated has mentioned by Mao, Chao, et al. (2013).Another limitation is Shortage of Experience from Local Jobs (Mao, Chao, et al. 2013).Interesting to traditional methods is other obstacles for developing OSM that has been referred by Mao, Chao, et al. (2013).Shortage of Qualified R&D Institution and services has been mentioned by Mao, Chao, et al. (2013).The lack of working experience among different member teams involved in projects is another barriers for OSM (Mao, Chao, et al. 2013).Other barrier that has important role for adoption OSM is inattention governments. In the other word, investors needs to encourage and support to establish prefabrication manufactures by government and achieve motivation (Blismas and Wakefield 2009).

The collection of the some important barriers for OSM is listed in Table 2 that in fact have been inducted as major barriers by several researchers.

Table 2: Hindering the Utilization of OSM

No.	Elementary list of OSM Barriers and Limitation	Citation
1	High Initial Cost	Jaillon (2009), Lovell and Smith (2010)
2	Incertitude of Market Request	Lovell and Smith (2010)
3	Shortage of Technologies for Prefabricated Components	Kamar et al. (2009)
4	Doubt about Stability of Prefabricated	Lovell and Smith (2010)
5	Shortage of Governmental Rules and Motivations	Lovell and Smith (2010)
6	Transportation of Precast Elements	Blismas and Wakefield (2009)
7	The Interest to Traditional Construction Method	Pan (2008)
8	Shortage of manufacturers of Precast Components	Blismas et al. (2005), Kamar et al. (2009)
9	Shortage of Qualified Designers	Blismas et al. (2005), Kamar et al. (2009)
10	Unable To Modify Design Scheme	Blismas et al. (2005), Pan et al. (2007)
11	Difficulty to the maintenance of Precast Elements	Blismas et al. (2005), Jaillon (2009)
12	Shortage of Qualified Contractors for Prefabrication	Kamar et al. (2009)
13	Monotony of Structure	Jaillon (2009)
14	Shortage of Skilled and Qualified Collaboration Groups	Jaillon (2009), Pan et al. (2007)
15	Disinclination to Innovation	Pan et al. (2007)
16	Shortage of Experience from Local Jobs	Goodier and Gibb (2004)
17	Shortage of Skilled Fabricators/Installers	Kamar et al. (2009), Pan et al. (2007)
18	Shortage of Qualified R&D Institution	Blismas et al. (2005), Kamar et al. (2009)
19	High Cost Pressure without Economics Scale Effect	Blismas et al. (2005)
20	Fragmented Structure	Kamar et al. (2009)
21	Longer Lead-In Time during Design Stage	Goodier and Gibb (2004)
22	Shortage of Guidelines for Precast Components	Kamar et al. (2009)

2.8 Conclusion

In this chapter, OSM was investigated as a reliable method for gain the aims of sustainable development in construction industry. As already mentioned, OSM has a high potential to increase quality and quantity of construction, reducing time and cost as a social and economic benefit for all sides involved in construction. Moreover, OSM enables to reduce significantly waste of materials in construction and the ability to reuse waste materials that are great ability to protect the environment. But, OSM could not achieve real position among stakeholders and investors due to its barriers that mentioned to them. In the next chapter will be discussed the potential of BIM in order to overcome some limitation and how integration of BIM and OSM can create a high potential in order to achieve more benefits in construction.

Chapter 3

BUILDING INFORMATION MODELING

3.1 Introduction

Construction projects are becoming much more complex and difficult to manage (Bryde, 2013).Complex construction projects require inter-organizational associations (Maurer, 2010). To ensure success in interorganizational project ventures, trust between the different project partners is acknowledged as a key success factor (Bryde, 2013).

In all activities related to construction industry, controlling cost, time and also waste have the most important role for all participated groups such as architectures, engineers and construction (AEC) in projects.

Each part of construction projects needs information related to its nature as well as information will be changed for various parts of project. For example, information related to structure parts are completely different by electrical information during different phase of project. In addition, the importance of access to information during execution of project is really different.

Construction companies due to respond market demand and increase efficiency, productivity and quality have been persuaded to adoption and utilization of computer programs during last two decades. Computer programs had been provided for measuring and calculating data in different parts of business. For example, calculating program for estimating cost could not be integrated with programs that its nature were dynamic analysis of structures. Obviously, scattering between dissimilar teams such as financial and technical groups in a one project has been caused to increase the budgets, waste of time and also increase risks. As a result, creating a powerful structure based on information that be able to collect information of different field of project and share or offer them at the right time amongst related work groups in order to reduce cost and delivery time and in contrast, improve quality and productivity has mattered.

For instance, according to the National Building Specification Report (NBS, 2013) highlights that at least 64% of participants of the research believed that functionality of BIM cause fundamental productivity in construction (Elhag & Al-sharifi, 2014).

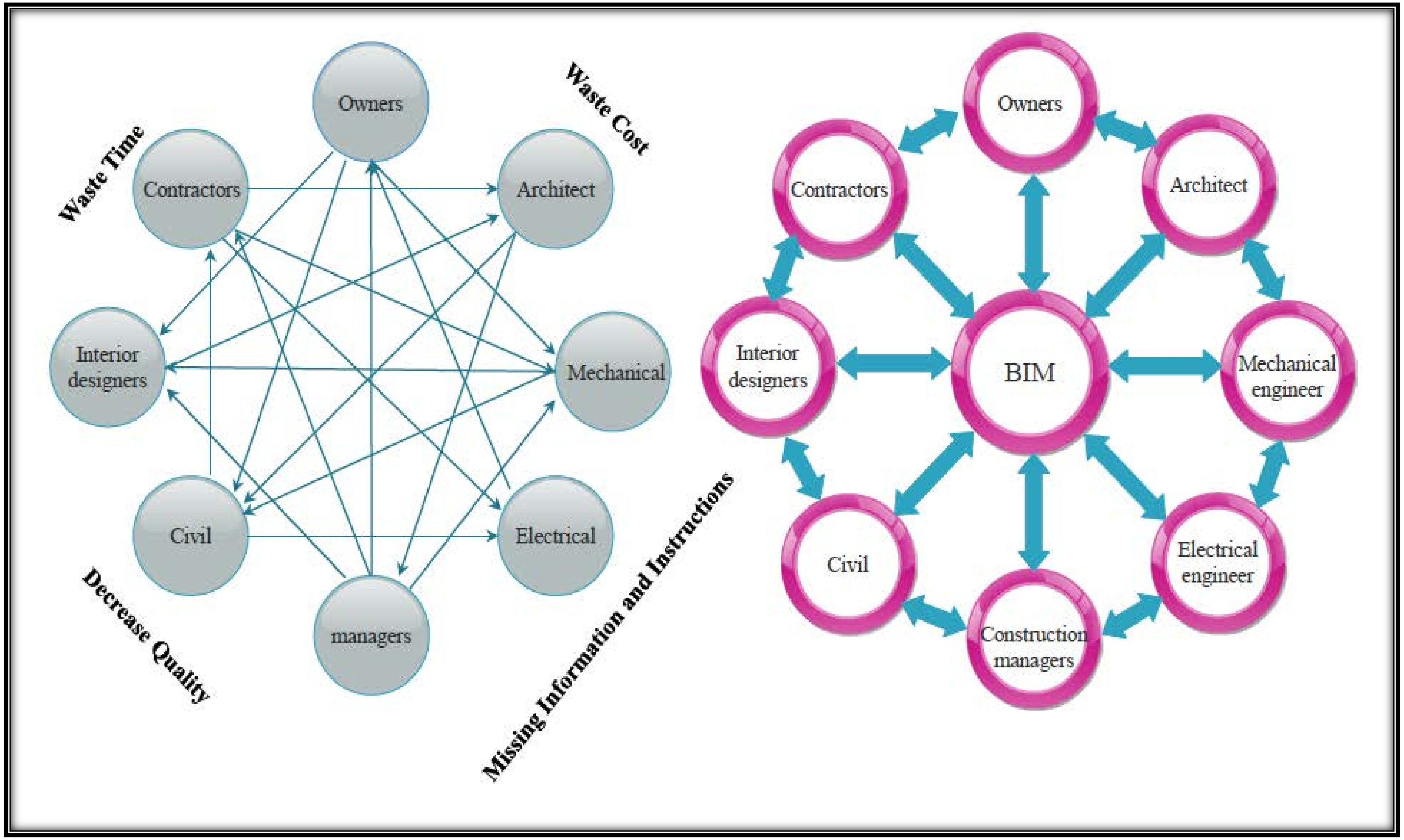

Figure 5: Comparison Traditional Information exchange and BIM Information exchange

3.2 BIM Definition

BIM means the ability to manage all aspects of project lifecycle by using the latest technologies to create and apply until now and actually relative by all requirements of construction industry. The word manage that is mentioned above, include all administrative and executive function in construction industry with purpose to improving quality, quantity and productivity. Actually, BIM create a simulated model in a virtual environment.

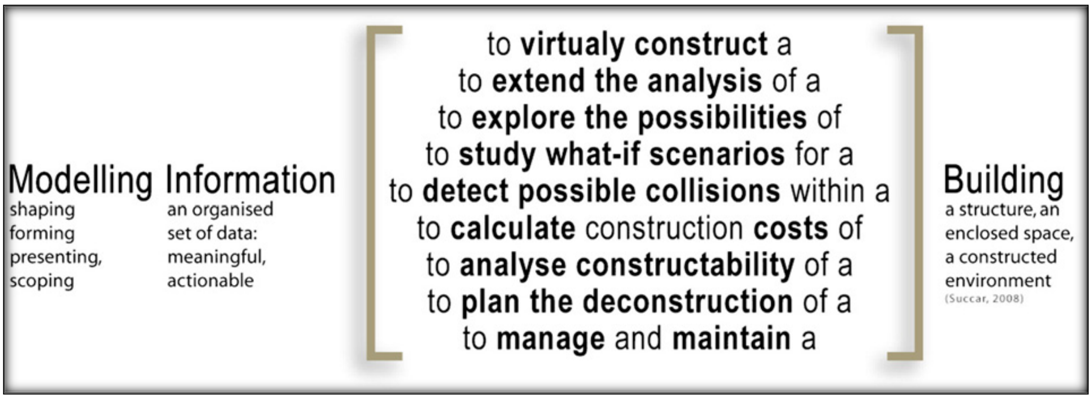

Figure 6: Some common suggested terms for BIM (Succar, 2009)

The National Building Information Modeling Standards (NBIMS) committee of USA defines BIM as follows: “BIM is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition.

It should be noted that purpose of information in BIM is divided to main two parts that is included:

➢ Physical information: weight, color, texture, transparency, absorption and reflection or something like these.

- Administrative and technical information: positioning applications, connect to other building elements, computational roll, producer and distributer cost, the time of purchase, installation and other information that are necessary in construction industry.

BIM is a movement from analog style design structure to digital side that the modeling was based on the original data. Design building was based on 2D in traditional method but BIM caused more widespread to 3dimention such as width, height and depth and also cost and time for 4d and 5D and so on. As a result, BIM covers more than geometry. In fact, BIM consider spatial relationships, lightening analysis, geographic information, quantities and properties of different component of building.

Generally, use of BIM serve as dynamic modeling software that include 4D and 5D in management field, can improve productivity, capacity and reduce cost in design and build phase and reduce cost performance and maintenance.

However, BIM is not a software and BIM is doctrine indeed. Based on architectures and engineers demand to change from traditional phase to a new method in construction industry and their tendency to collect and cooperation with other parties in construction cause evaluation that BIM can accept these responsibilities.

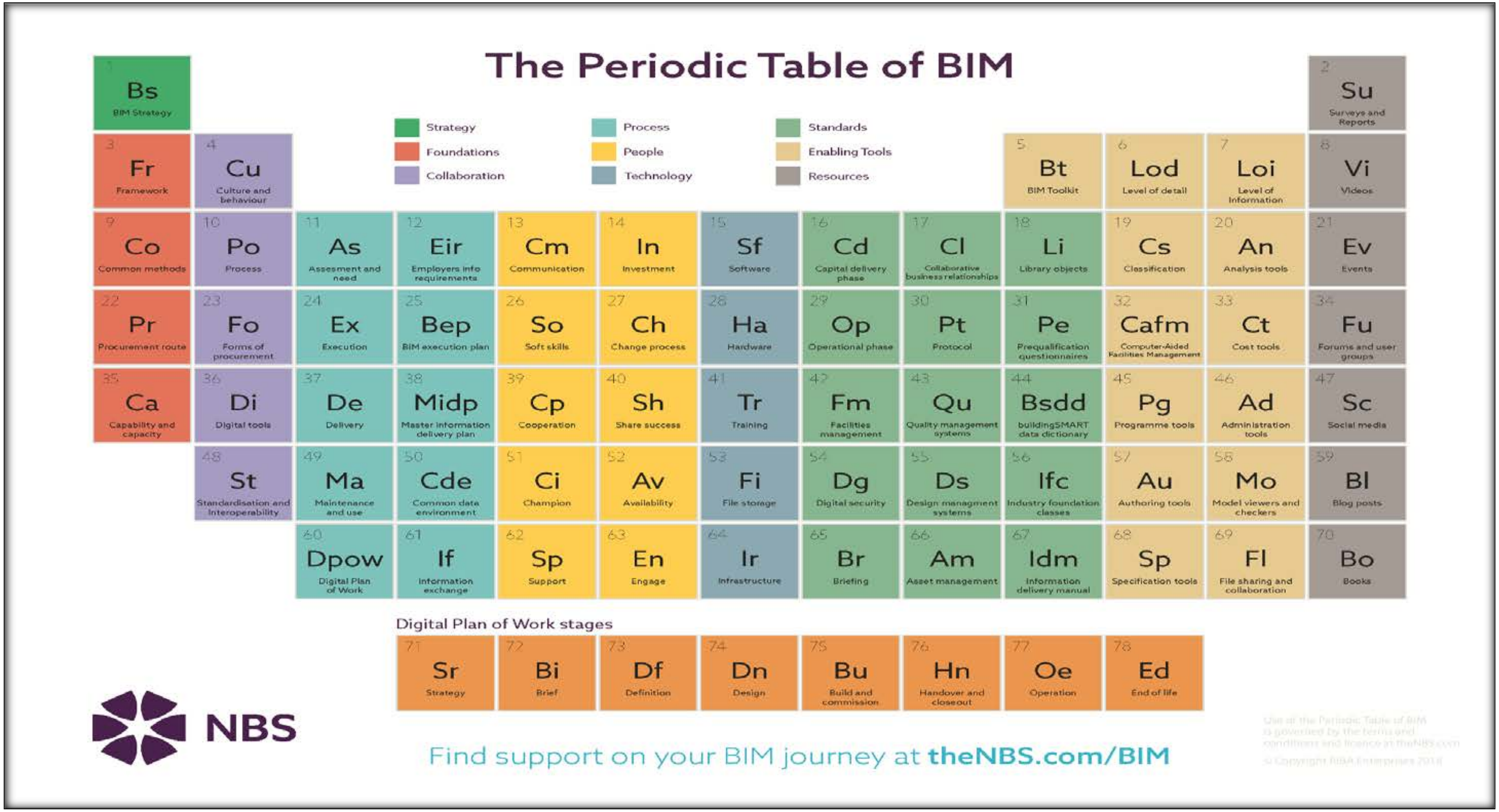

Figure 7: periodic table of BIM (National Building Specification, 2015)

3.3 BIM and Stakeholders

BIM is a comprehensive information procedure and this production and extraction process of information and documentation is effective and essential for all operators and agents in a project. Usage of BIM can be important for entire related groups from different aspect. Related groups can achieve required productivity of documentation results. They can more effective for better and safer future. Some of distinctive features of this system are observation, feedback control, reduction time for design, careful planning, reform and change desirable information before the start of construction. For example, Eastman et al (2013), cited “hazardous work spaces can be identified and potential hazards can be prevented already at the design stage, before any field work is started.

3.3.1 BIM for Investors and Employers

Investors and employers are here the organizations that provide budget for construction. Maybe one of the most characteristics that BIM has attracted investors and employers is leadership opportunities in the shortest time with the least and the most professional teams for aims and strategies of projects. Employers can obtain prototype of the projects by using design and computing group. Then, they can focus on the purpose of project, gain required documentation from modeling reference and finally, codify a more detailed plan to get their goals.

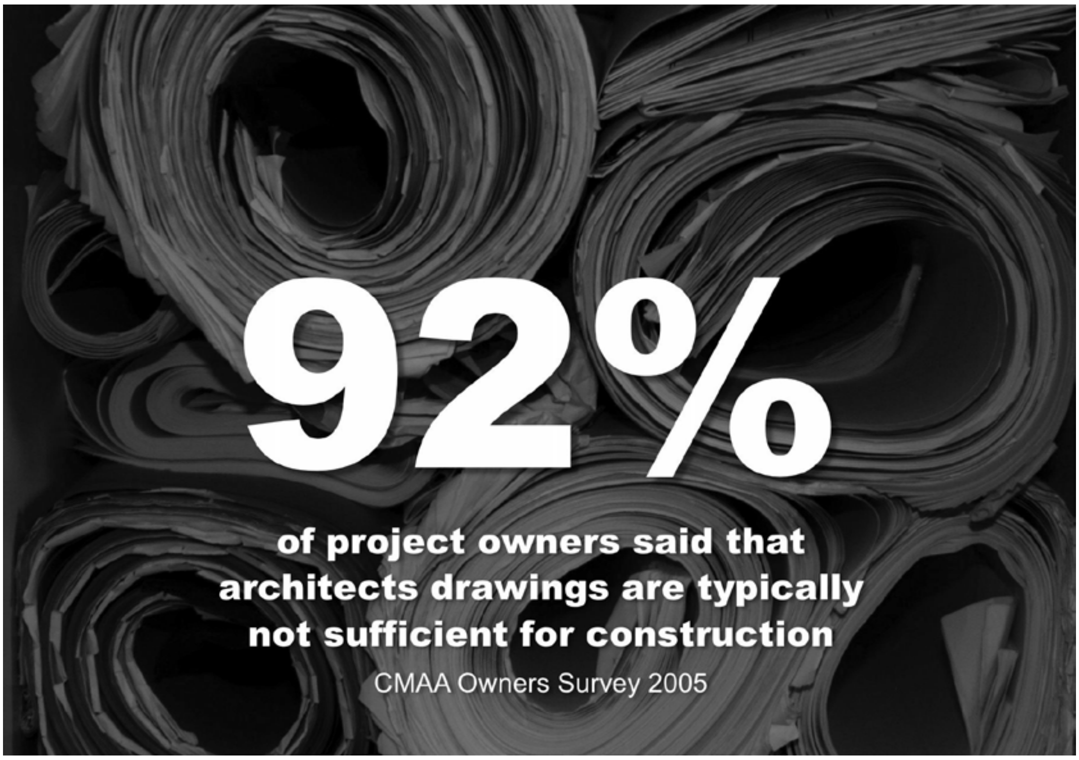

Figure 8: “Ninety-two percent of project owners said that architects’ drawings are typically not sufficient for construction.”(Deutsch, 2011)

When employers dominate over project information modeling, it cause to overcome all aspect such as technical issues, planning, and implementation and financial topics. Therefore, they can control better the project with more confidence and also lead to achieve the best results. Obviously, this is the most important issues for employers and investors that will be solved by BIM. The other important condition for them is to create a context for coordination with engineers and contractors in projects.

Todays, employers and investors prefer to handle BIM for their project. Because, By BIM, implementation of works will be safer with more confidence amongst working groups on site.

Figure 9: “BIM showing how can view the hallway of a building” (Reddy, 2012)

3.3.2 BIM for Engineers

In traditional methods, architectures usually design their 3D modeling with software such as 3D max or Arch cad, then they apply CAD to create 2D maps. During these processes, a lots of errors will be occur.

Parametric and intelligent models that create by BIM tools will be included with 2D and 3D views. By BIM tools, architecture will be select ready-Door with all of details, just to be established in suitable position in wall. It will not happen to put door in column, BIM tools will alert that it is necessary to delete or move it.

Generally, there are many options that will be change during construction time in site. These changes maybe occur in different sections such as plans or documentation. Sin-+ce BIM is a smart system, by changing each section in model, it will change automatically in all other parts of documentation for example plans, views and also sections. These processes cause more cooperation between AEC that reduction cost and time will be results of these corporations. There are the minimum bonus of BIM application for engineers.

3.3.3 BIM for Supplier of Materials

Construction industry and product of construction materials is one of the most complicated markets and it was difficult to classification and coding for goods. But today, BIM can respond to this vital need by standardization and international method. Therefore, builders can recourse to central database and/or manufactures of equipment and materials and extract which 3D catalog of variety of materials. They can also have accurate information without intermediaries for technical and administrative calculation. Todays, many producers and distributors of construction materials can be more available immediately for owners, engineers and contractors by introducing 3D digital models of their goods.

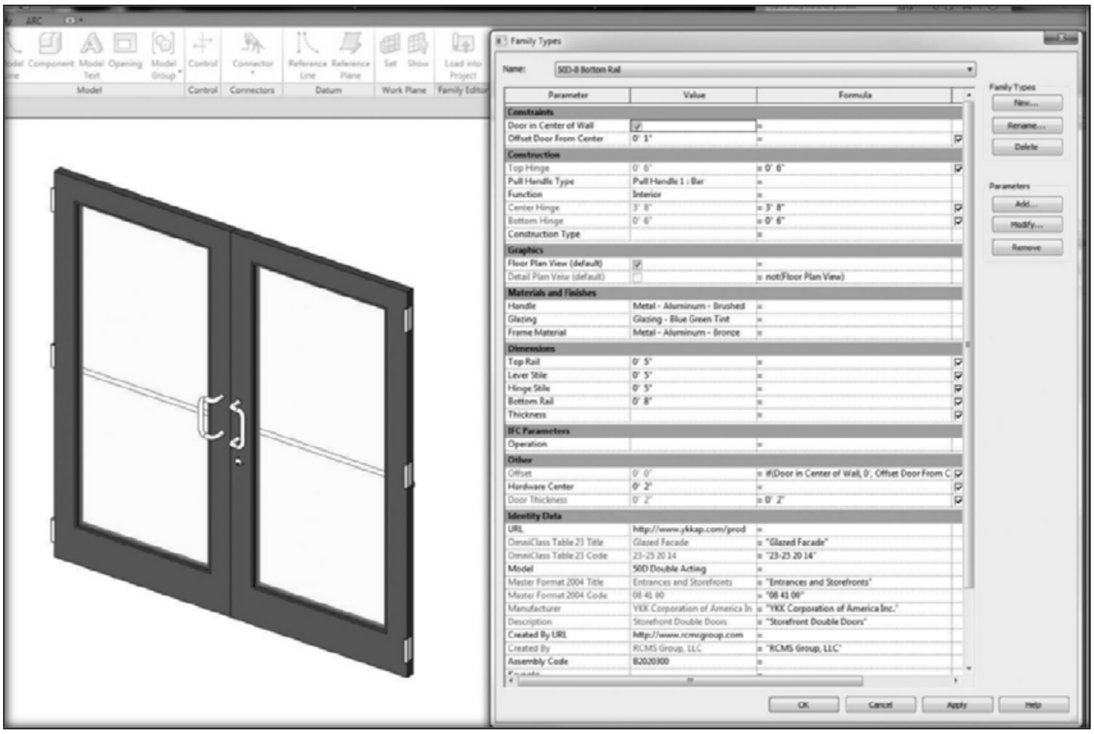

Figure 10: A door as a BIM object- SMARTBIM Library (Reddy, 2012)

As a result, this process will implement more effective by understanding of their applications. Acknowledge of supplier chain and updated production by supplier and distributors are other properties by using BIM in construction industry.

3.3.4 BIM for construction manager and contractor

The biggest challenge for construction manager and contractors is understanding of all aspects of projects before participation in construction. But todays, use of complete project modeling will be executed very simple and they are able to perceive drawings, calculations, structural patterns and feedback between structure and architecture before entrance to the projects. In addition, it will be available accurate cost estimate and complete assessment of construction budgets by using BIM.

Eastman and Liston (2011), cited that BIM has high potential to detect probable problems in the early stages of construction, enabling different involved group in construction to resolve limitation.

Fazli et al (2014), cited functionality of BIM cause Construction managers can handle BIM to manage and control the work in order to estimate construction budgets.

BIM can be used as a connector to provide effective relationship with subcontractors. (Fazli et al, 2014).

The quality benefits that BIM provides are most valuable for project managers concerning maintaining control of a project.

Planning for purchase and project suppliers and also modeling storage of materials and positioning for machinery are the most important of using BIM in off-site and on-site construction industry. By BIM tools, contractors enable reconstruction of projects duration. It has able to assess all parts of project the point of view of financial, time and manpower of different aspects. Construction managers and contractors will be able to provide as-build model and locate for operation management for use of monitoring system and control intelligent buildings. Therefore, facilities maintenance will be more efficiently by adoption suitable solution to eliminate probable problems.

3.3.4.1 Marketing and Tendering

Another positive point of this model for contractors is that the completion of the project designs and prepare drawings, they will be able to have an accurate estimate of costs and with conversance and awareness of project details to proceed participation in tenders. In addition, according to data that provides by BIM tools contractors will be able to utilize the results for other software to optimize prices, with higher margins benefit.

3.3.4.2 Increased Use of Automated Manufacturing Technologies

Growth of industrial machines and facility precise cutting of parts in various industries, is caused increasing accuracy and improving efficiency and reducing waste in the production process. Forasmuch as, BIM tools will be able to simulate all parts and components and details in different section of projects therefore, can be expected by integration BIM tools and Computer Numerical control (CNC), will perceive Dramatic change to improve quality and increase accuracy in OSM (Eastman, 2011)

Obviously, off-site buildings are made up of different parts. By searching in markets we will face a wide range of building materials. For example, there are many manufacturers of doors and windows that based on their work, offer different kinds of materials .Other parts have the same conditions therefore purchase risks will increase.

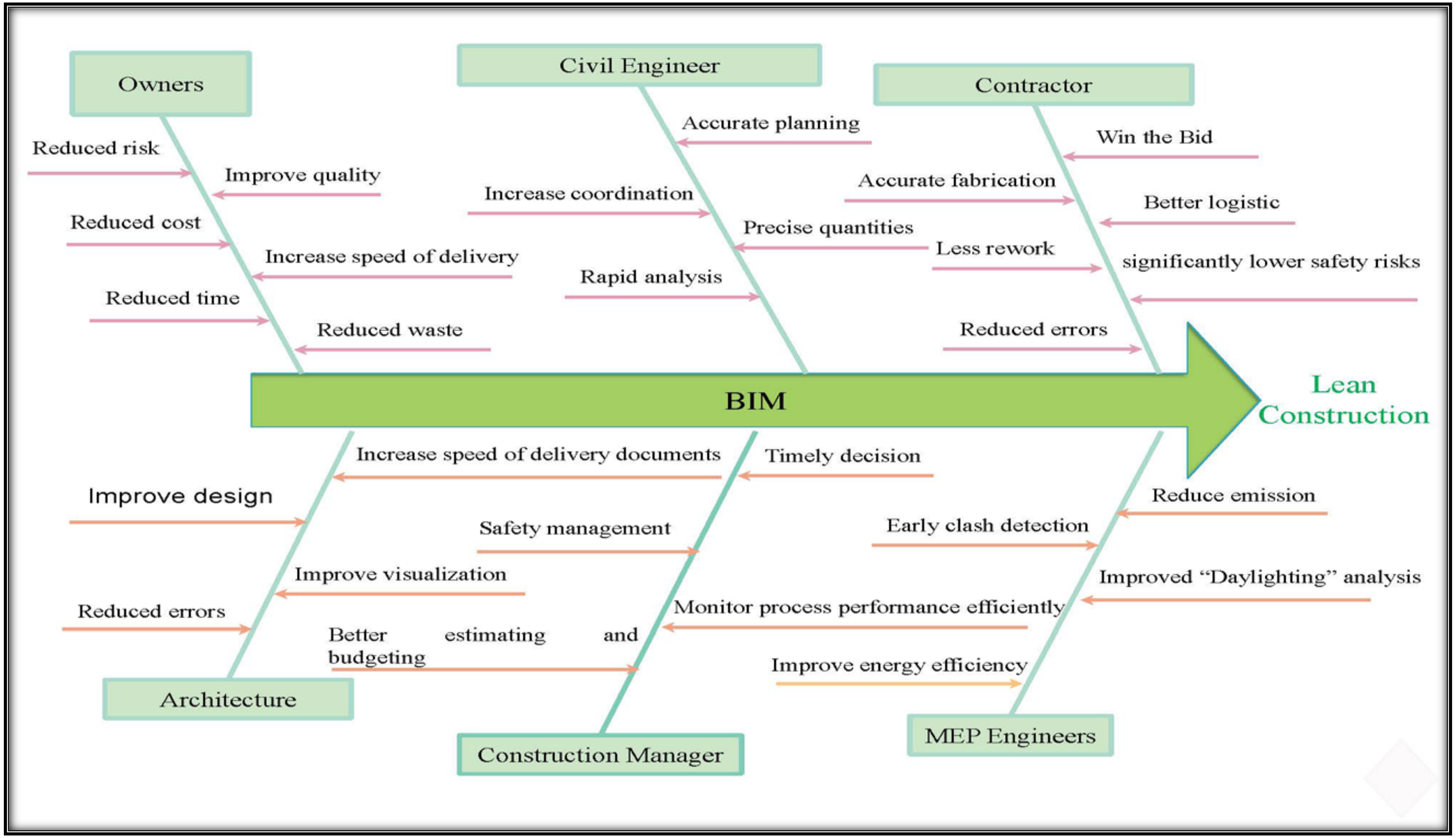

Figure 11: BIM benefits for stakeholders

3.4 Benefits of BIM

3.4.1 Modeling vs. 2D Drafting

Fazli et al (2014), cited “by using BIM the communication process which exists between stakeholders in a project can be enhanced strikingly. This is because the 3D models of buildings are far easier to understand in comparison with 2D drawings.”

Modeling helps designers better controlling their design compared to the two-dimensional designs. Take a closer look at all the angles to engineers and architects and, if necessary, changes will be applied in the first stage, which reduces the cost of changes in comparison with the next steps.Use of BIM modeling reduces design time compared with 2D drafting design because, by using of the capabilities of BIM tools, when the plan is designed, Sections, elevations and three dimensional views will be created simultaneously. Therefore, the time of design will be reduced significantly in comparison with the two-dimensional.

3.4.2 Parametric Elements

By creating parametric elements, designers will be able to use them for various situation. Moreover, they enable to integrate themselves with designs in different layers. For example, by creating a window in a wall, if the length of wall needs to change then the position of windows will be changed simultaneously. Another example for this issue is the changes of furniture in deferent level. Obviously, this property cause to reduce the time and save cost.

3.4.3 Improved Coordination

With BIM, detailed information about each building component is contained within its modeled element. By BIM, all members in construction team can access to information.

Hereupon, changes in the parts will be available and evident for all members involved in the project and coordination between members undoubtedly improve.

3.4.4 Improved Accuracy and Efficiency

By coordination and collaboration among different members errors and omissions will be decreased in projects because, all groups supervise and control all aspects of project in different condition and moreover, BIM tools are capable to determine and detect errors and clash elements and components in design phase.

3.4.5 Client Satisfaction

Visual verification of design intent and knowledge sharing through Virtual Design and Construction (VDC) and BIM make for happier clients. The rapid preparation and exchange of visual information mitigates the time needed for communicating complex ideas and allows more time to be creative for your clients, which should result in repeat business and excellent references.

3.4.6 Facility Management

BIM can link data from manufacturers, construction data and communications into one fully integrated and robust facility dashboard. Facility managers can use BIM to gather helpful data, prepare maintenance schedules by using predictive data, manage daily operations and plan for future purchases and construction additions. Full equipment data including operating parameters, usage data, predictive data, service history, replacement price and links to other manufacturer data, combined with a fully rendered 3D depiction of the equipment creates a powerful tool for facility managers.

3.5 BIM and Intelligent Building

In general, an intelligent building is a building that has equipped to strong communication and able to respond continuously for different environmental situation and adopt itself with them. In the other hand, these kind of building able to allow to residents for better utilization of existing resources more effectively.

Intelligent buildings are able to react to variety weather condition such as wind, heat and cold, and sunlight indeed. In addition, they can respond to excessive concentration of population. This means that by identifying population density, facilities provides intelligently.

By considering a tall tower that able to stop the pressure of wing and ward off and has optimized its Statue, clearly impossible to build these kind of construction without BIM tools. BIM is able to manage and operate different position for Varity of building in virtual world. It has able to measure and evaluate different materials to respond different circumstances. For adopting an intelligent building needs to model and design for HVAC, Lighting Control etc. It is clear that sophisticated tools need to achieve the above mentioned goals and BIM tools have much power to analyze these approaches. Another important issue to build an intelligent building is budget. BIM tools will able to Owners and investors to predict the cost and capital requirements.

Forasmuch as performance and constructing an intelligent building needs to significant investment, BIM will able to reduction of risk and expense for all various stages in construction an intelligent buildings. Importance of BIM approach will be more significant whenever an intelligent building is as Off-Site construction.

3.6 BIM and Teleworking

Teleworking has existed for long time ago and has significantly developed by coming information technology along human lifecycle. Somebody believes that the new teleworking history based on computerized technology has been started in 1970. Governments and big industry firms that have been followed more productivity and improved the quality of their employees, have welcomed and achieved more profits for their staffs and themselves. However, the rate of teleworking is less than 5 percent in the world, and just in the US due to existing computer companies is more than this.

It is predicted in the next few years, teleworking as part of growing global economy and the rapid growth of organization through the world, will spread. Therefore, lots of big Construction Company and infrastructure is predicted to operate of this approach. Investigation shows that either now or future, organizations will be seriously considered this approach.

As already mentioned, BIM thanks to its nature for corporation and collaboration among different team involved in construction industry based on internet communication, have great potential to match with teleworking.

By integrating BIM and teleworking, borders will be faded, because BIM approach has high potential for sharing information and the documents of projects between different team, thanks to its nature.it will not been essential to gather different construction team such as civil engineers, mechanical engineers and electrical engineers in a room for sharing knowledge or information work to overcome to faults and deficiencies. The importance of these issue will be substantially considered when involved individuals of projects live in different countries.

There are mentioned some significant advantages of integration BIM and teleworking:

- significant reduction of transportation
- Reduction of some administrative cost such as electric, equipment and spaces
- Improve productivity and job satisfaction due to employee efficiency
- Reduction of stress and distraction staff
- Reduction of population growth in large cities
- Reduction of risks
- Use of the best BIM expertise all around the world

3.7 BIM and Net Zero Energy Buildings

Constructions have a notable influence on annual energy use in all around the world. Commercial and residential buildings use almost 40% of the primary energy and approximately 70% of the electricity in the United States (EIA, 2005). The energy used by the building sector continues to increase, primarily because new buildings are constructed faster than old ones are retired. Electricity consumption in the commercial building sector doubled between 1980 and 2000, and is expected to increase another 50% by 2025 (EIA, 2005).

Net zero energy buildings (NZE), buildings are to produce required annual energy from renewable sources. Buildings such as these, with intelligent design begin to energy facility without requiring any source of energy.

Given that, the built environment allocated a third of the world's total greenhouse gas emissions. Clearly shows that the effectiveness of climate change, focusing particularly on the reduction of environmental damage related to residential buildings. What those that already exist and those that are being built.

By recognizing this fact, the desire of many applicants to build zero net energy buildings that produce their own renewable energy annually needed to be justified. Although the number of projects with this approach is still very low but, various groups around the world believe that the goal of zero net new methods based on new activities with the use of advanced three-dimensional modeling technology, is possible. The future promises more capabilities for modeling, measuring and managing environmental impact of building using the next-generation tools.

Over the current decade, BIM as an intelligent process based on three-dimensional model allows the opportunity to multiple stakeholders before building to explore all aspects of projects and moreover, as a reliable method to save time and money in construction projects is considered. Unfortunately, there is no single formula to provide a net-zero buildings. Each project requires a unique approach to positioning, navigation, climate and ongoing maintenance and continuous. The correct way to achieve this method, is practice of relevant stakeholders from non-traditional ways. Becauseو estimates were not answerable and approaches based on function is unknown for many industry experts.

3.7.1 Complementary task for architects

According to the new model (Net zero energy buildings), the architects who were considered as master expertise in the past, should be cooperated and solidified culmination their own And the synthesis of a vast network of experts to gather information and provide a product based on function objectives, planned, implemented and evaluated in the design process is necessary. Many believe that BIM is as a vital element to facilitate this process.

3.8 Key Steps to Successful BIM Implementation

Performance BIM in an organization completely requires patience and commitment. Implementing BIM according to the minimum requirements, will be costly and mistake. In order to execute BIM in organizations or firm must be measured all aspects and needs to a comprehensive program to maintenance of main goals. In the other word, without consideration a comprehensive program main objectives will be lost.

3.8.1 Analysis

First of all, needs to gather information from existing methods and strategies for identifying workflow. Thus, survey the workflow for identification of deficiencies and lacks is priority and that what expectations would be of modeling? Current projects must be reviewed and analyzed.

3.8.1.1 Technology Analysis

It is necessary to verify a precise estimate of the technology and hardware and software needed to be done. What is the review of the existing facilities and hardware and software will be required?

3.8.2 Personnel Analysis

The ability of current personnel and a lack of required expertise should be considered to and identified.

- Who are now working with existing condition?
- What type and level of training is required to change approach?

It is necessary to be determined the method for collaboration between old and new personnel.

3.8.2.1 Cost Analysis

Naturally, shift from an AutoCAD-based organization to an organization based on BIM tools will be costly.

Hardware: BIM-based programs will be required to a higher level of hardware compared to AutoCAD-based applications. Therefore, it may be require significant hardware that must be considered.

Software: BIM tools needs to be purchased. It should be consulted with sellers to achieve adequate information about the capabilities of the various software.

3.8.3 Implementation

There should be cooperation and coordination between members in order to successful implementation BIM approach in organizations and owners obviously have a prominent role. Information should be shared among agencies. Managers should promote confidence among organizations. Owners should be noted that successful implementation requires Continuing education and managers must also obtain the necessary training at different levels when software will develop. Therefore, considering the costs and a forecasting profits and losses of the organization and funding have a strong role in order to be successes organizations.

In the next chapter will be discussed about OSM by providing detailed information of benefits of adoption and particularly when applied by BIM.

Chapter 4

INTEGRATION BIM AND OSM

A key point that needs to be noted is that, in fact, prefabricated components are produced by using two factors “B” and “M” of BIM. This is a method that has been used over the years by manufacturers. But when information is entered into the model parts, options facing many designers will be faced with a lot of options, and normally designers will choose the best option. Smaller pieces can certainly be documented in 2D, which in this case create physical models will be necessary to achieve the design goal. But by using virtual models of these parts, will create numerous virtual prototype that can be evaluated in the model and it is clear that this method will save time and labor costs on a large scale.

BIM in OSC will simplify more valid data exchange among project associates, enhance data quality, and enhance basic leadership all the more successfully.

Nawari (2012), mentioned that BIM execution for Prefabrication could have a powerful concept that Resulting in remarkable improvements in the construction industry such as realization of Lean construction, quality, sustainability and cost reduction.

Operating BIM within modular construction will be a promising chance to enhance the efficiency of OSM (Zhang, Long, Lv, & Xiang, 2016).

Zhang et al (2016), cited that some advanced modeling tools such as 3D laser scanners is used to provide as-built information and create a point cloud sample for MEP system proportion, and utilizing robotic total station in order to install faster.

Brad Hardin and McCool (2015), cited that “Due to the fast-track schedule and the limited space on-site, the coordination between the engineer, supplier, fabricators, deliverers, and erectors had to be seamless.”

By considering this issue that the manufacturers can achieve rich information by using the BIM models of prefabricated elements, as a result they can support processes and main activities such as design, preconstruction and construction, execution, production, maintenance and operation (Zhang et al., 2016).

Zhang et al (2016), pointed out that BIM tools provide more accurate information compared to physical models for MEP contractors especially for precast concrete components such as ducts and pipes. Hence, recently by using 3D laser scanning, MEP contractors can create virtual or as-built models for structure MEP systems (Zhang et al., 2016).

Eastman, et al (2011) claims that because of high level of coordination of cross disciplinary parties during the early phase of the project, the exact details of the construction elements are finalized within this early design stage. Therefore, that allows for an increased use of off-site prefabricated construction elements.

Breen (2012), supports this view and suggests even more complex off-site fabricated units can be ordered since the information needed for their order is available in the early stages of the project. Moreover, with the use of the 3D BIM model, the project team are able to see how the building is assembled together, allowing any contractor ordering prefabricated units to be sure that they will fit into the building.

A study by Breen (2012), shows that BIM has transformed the construction processes for a major UK contractor in terms of 'design for manufacture and assembly' methods. That contracting organization have steered towards 70% OSM of building elements, which has reduced their on-site workforce by 60% and the construction programmer by 30%. In addition, when OSM is used, the level of construction waste is greatly reduced which in turn means more cost saving for the construction project (Elhag & Al-sharifi, 2014).

Incorporation of BIM for design, manufacturing, logistic management, and construction of multi-story modular building projects will significantly increase the information integrity level of the projects and would offer a powerful platform for lifecycle management of buildings (Ramaji, 2016).

In addition to facilitating execution of BIM in multi-story modular buildings, the proposed information framework outlines the basis for standardization of digital representation of building information models to address interoperability; provides a design guide for the companies intending to use modular building technology in their projects; and can be used as a resource for software developers to add required features to their software to support modularization (Ramaji, 2016).

The introduction of BIM into this process allows for design teams to actively participate in the review and design of the modules to be prefabricated. By showing where these slices should best occur, design teams are able to optimize modular unit with the fabricator for the layout and sequence of how the buildings' parts are built and installed.

4.1 BIM AND OSM

By considering this issue that OSM are improving the quality and reduce the time of construction delivery, when BIM integrated with this modern method in construction, the amount/scale of facilities will be increased in order that has high potential to model construction component in virtual world in the shortest possible time (Ezcan, Isikdag, & Goulding, 2013).

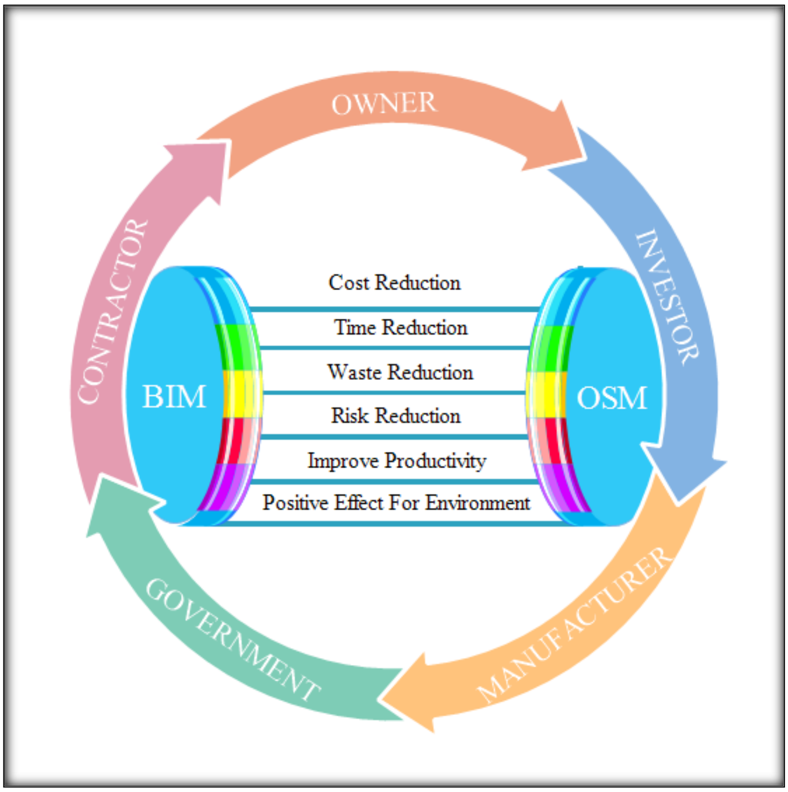

Figure 12: Benefit of BIM and OSM integration for stakeholders

Table 3: Benefit of BIM in construction (in common with OSM)

Benefits of BIM	**Source**
Cost Reduction	(Bryde, Broquetas, & Volm, 2013)
	(Fazli, Fathi, Hadi, Fazli, & Fathi, 2014)
	(Krug & Miles, 2013)
	(Mordue, Swaddle, & Philp, 2015)
	(Eastman & Liston, 2011)
Time Reduction	(Blismas, Wakefield, 2009)
	(Bryde, Broquetas, & Volm, 2013)
	(Fazli et al., 2014)
	(Azhar, Khalfan, & Maqsood, 2012)
Waste Reduction	(Nawari, 2012)
	(Jalaei & Jrade, 2015)
	(Fazli et al., 2014)
	(Hardi & McCoo, 2015)
	(Deutsch, 2011)
Risk Reduction	(Elhag & Al-sharifi, 2014)
	(Fazli, Fathi, Hadi, Fazli, & Fathi, 2014)
	(Bryde, Broquetas, & Volm, 2013)
Improve Productivity	(Nawari, 2012)
	(Bryde et al., 2013)
	(Chen & Luo, 2014)
Positive Effect For Environment	(Nawari, 2012)
	(Zhang, Teizer, Lee, Eastman, & Venugopal, 2013)
	(Hardi & McCoo, 2015)
	(Deutsch, 2011)

Table 4: Benefits of OSM in construction (in common with BIM)

Benefits of OSM	Source
Cost Reduction	(Alazzaz & Whyte, 2014)
	(Schoenborn, Jones, Schubert, & Hardiman, 2012)
	(Ezcan, Isikdag, & Goulding, 2013)
	(Nadim, Goulding, & Goulding, 2011)
Time Reduction	(Nadim, Goulding, & Goulding, 2011)
Waste Reduction	(Mao, Shen, Asce, Pan, & Ye, 2013)
	(Mullens & Arif, 2006)
	(Nawari, 2012)
	(Blismas, Wakefield, 2009)
Risk Reduction	(Lawson, 2014)
	(Blismas, Wakefield, 2009)
	(Nadim et al., 2011)
Improve Productivity	(Khalfan & Maqsood, 2014)
	(Hajdasz, 2014)
	(Connor et al., 2014)
	(Nawari, 2012)
Positive Effect For Environment	(Nawari, 2012)
	(Connor et al., 2014)
	(Blismas, Wakefield, 2009)
	(Lawson, 2014)

The most important Intersections of BIM and OSM are represented by a diagonal matrix in Table 5. Figure 12 shows who are mostly profited by integrating BIM and OSM.

Table 5: Diagonal Matrix of the Most Important Intersections of BIM and OSM

Benefits		**BIM**					
		Cost Reduction	Time Reduction	Improve Productivity	Waste Reduction	Risk Reduction	Efficient Environment
OSM	Cost Reduction	*					
	Time Reduction		*				
	Improve Productivity			*			
	Waste Reduction				*		
	Risk Reduction					*	
	Efficient Environment						*

In the following, it is discussed how BIM can overcome the weakness of OSM.

4.2 Costs Comparison Traditional OSM and BIM with OSM

4.2.1Direct Cost

The costs and expenses that are incurred for a specific activity are termed direct costs. These costs are estimates based on detailed analysis of contract activities, the site conditions, resources productivity data, and the method of construction being used for each activity. A breakdown of direct costs includes labor costs, material costs, and equipment costs.

4.2.1.1 Labor cost

Many labor hours are necessary to learn installation method of different elements and components of the project that by operating BIM for OSM learning process will be happen in short time. Moreover the probably reworks activities will be reduced in manufactures area.

The MEP subcontractors have an obligation to coordinate their systems and produce shop drawings for the engineering team to review. These subcontractors are finding value in BIM models. By coordinating their systems in 3D, the subcontractors can solve issues early, create constructible models, and prefabricate their systems to save on material and labor costs.

4.2.1.2 Material costs

BIM has this potential to link model data to other software such as Excel in order to select the most appropriate material base on the design and schedule by optimization process. This technique enables owner to have variety opportunity to purchase best options that exported from optimization process that undoubtedly reduce the material costs and also cause better management for material expenses in comparison with traditional off-site construction. Moreover, Equipment Management such as cuter machine will be improved in manufacturing that significantly reduce waste material in prefabricated process.

4.2.1.3 Equipment costs

One of the most important question associated with equipment cost is "how to determine what kind and size of equipment seem to be the most suitable for a project?"

Utilizing BIM tools and software enable to provide the right equipment at the right time and place so the work can be accomplished at the lowest cost in OSM. This approach will be decrease the project cost in comparison with traditional OSM method.

4.2.2Indirect Cost

Some items that under indirect cost are training and software, supervision and project management, temporary buildings, and materials handling that will be investigated in the following.

4.2.2.1Training and software

Implementing new technologies such as BIM technologies is costly in terms of training and changing work processes and workflows. By implementation BIM for off-site construction need to consider appropriate budget for train personnel in order to utilize and operate BIM tools during manufacture process.Other indirect cost that will be increased in this stage is related to provide necessity software and hardware in terms of operating BIM.

4.2.2.2Supervision and project management

In the traditional OSM, there is not any link between CAD and project management software, but by integrating BIM into OSM can benefit from linking the geometry to a timeline or schedule that cause to reduce cost.

4.2.2.3Maintenance Cost

The digital information collated during the design and construction is vital in understanding the asset's future operational and maintenance requirements. It allows the client to make better informed decisions and conduct better scenario planning on operation and maintenance costs because it's based on actual statistics and facts on the asset's performance and status. There is also an increased amount of verification of information because information is based upon quality information. The client can also make better organizational and strategic planning decisions because asset information is more accurate and complete, and the client can more easily generate legislative documents such as health and safety files or operational and maintenance manuals.(Mordue, Swaddle, & Philp, 2015)

4.2.2.4Temporary buildings

Using BIM some activities such as control the job site or security issue are being under control and the necessity of temporary buildings will be reduced. For example, quad copters can export images as BIM tools format to office for better management.

4.2.2.5Materials handling

In comparison indirect cost between traditional OSM and SOM integrated with BIM related to materials handling, BIM tools such as BIM 360 enable to manage job site in terms of prevent rework in production process that can significantly impact to reduce indirect cost.

4.3 Manage the Changes in OSM Integrated with BIM

With BIM platforms, the changes are entered into the model and updated erection and shop drawings are produced almost automatically.

The benefit is enormous in terms of time and effort required to properly implement the change.

By operating BIM in OSM the changes that have been made are displayed in three dimensions and in all views of the project. This approach can switch views and understand the impact of design decisions will be improve really quickly. BIM tools can analyze the impact of the changes for different involved group in OSM process to manage time, cost and quality of these changes related to their activities. For example, if the materials of specific wall of OSM have to change, BIM tools such as Revit enable to analyze the new model in terms of cost, schedule, and energy saving very shortly and share the results of this change between different participants such as mechanical, electrical, plumping, and owners to better making decision and rethink abbot the different aspects of the project. This approach has significant benefits for all participants in order to reduce probably problems that usually happen in traditional construction.

Some changes maybe need to occur during construction process. BIM 360 application as a BIM tools enable to connect entire project team and streamlines BIM project workflows from pre-construction through construction execution. With virtually anywhere, anytime access to the most recent project models and data throughout the project lifecycle, BIM 360 Glue helps to review projects and resolve coordination issues related to probably changes faster. BIM tools enable to manage the changes in design phase, during construction and maintenance period that will be introduced in the following:

Autodesk Revit: The Revit platform for building information modeling is a design and documentation system that supports the design, drawings, and schedules required for a building project. Building information modeling (BIM) delivers information about project design, scope, quantities, and phases when you need it(Architecture, 2011).

In the Revit model, every drawing sheet, 2D and 3D view, and schedule is a presentation of information from the same underlying building model database. As you work in drawing and schedule views, Revit collects information about the building project and coordinates this information across all other representations of the project. The Revit parametric change engine automatically coordinates changes made anywhere in model views, drawing she ets, schedules, sections, and plans(Architecture, 2011).

Autodesk Navisworks Simulate: Autodesk Navisworks Simulate software provides advanced tools for reviewing, analysis, simulation, and coordination of project information. Comprehensive 4D simulation, animation and photorealism capabilities enable the demonstration of design intent and simulation of construction to provide better insight and predictability. Real-time navigation combines with review toolsets to support collaboration among the project team

Autodesk BIM 360: The Autodesk BIM 360 Field iPad application is a field mobility tool that is designed to enable field level access to information and to collaborate on issues, inspections, equipment, and tasks to be performed.

4.4 BIM function for OSM barriers

4.4.1 High Initial Cost

The biggest challenge that consumers face when building a modular home is finding a company that can do the financing.

OSM need to be built with a corresponding finance plan that will differ from the mortgage plan associated with traditional homes. The manufacturers will want to be paid in full before the home is finished, and will often want periodic payments to finance the building process. The clients need to get a construction loan to first pay the builder. On the other side, banks are generally unfamiliar with the modular home construction process and the fact that most payments are required to be made upfront. Banks have been known to deny some people the mortgage required to support this process and clients have had to look at various options before being able to continue with the construction of their OSM.

By considering a flexible approach and adopt a constructive interaction between banks and owners, awareness of the progress of the project at different levels is provided. Thus, Owners can notify banks from progress according to prepared component at different stages of the project in production line at the factory. Because of parts and structural components are unique, Therefore, banks can have constructive interaction with employers by controlling and ensure the construction process, allocate credit to the owner or builder before shipment and installation at the project site. This approach can reduce the initial cost pressure of prefabricated and Owners and investors will be encouraged the use of prefabricated elements. In addition, by applying BIM tools such as Revit Architecture, owners can control and monitor the costs processes and also control cash flows in regard with construction processes by selecting appropriate components base on budgets (Ezcan et al., 2013).

4.4.2 Lack of Experience

4.4.2.1 Lack of Experiences from Local Projects

Since construction projects require a significant investment for its owners, Therefore, Confidence of quality and reduce costs for owners is as a key priority. The use of prefabricated largely improved project performance in quality, schedule, and cost (Zhang et al., 2016). But this requires that facilities be provided, in the absence of experience, owners and investors will be defeated. According to BIM approach that enhances cooperation and coordination between the different teams involved in the project and Reduces risks and also according to create a database of all elements and specifications And simulate different stages of the project such as construction processes in the factory and transported and installed at the site, All stakeholders will achieve the ability by exploring similar models, will be informed the progress of the project on the basis of pre-defined targets. BIM by creating a virtual model and simulate real conditions Provides admission for less experienced or inexperienced people to learn necessity training. Engineers, designers and project managers will be able to provide educational films by using new technologies such as Quad Copter to improve executive capabilities of sub-contractors and contractors.

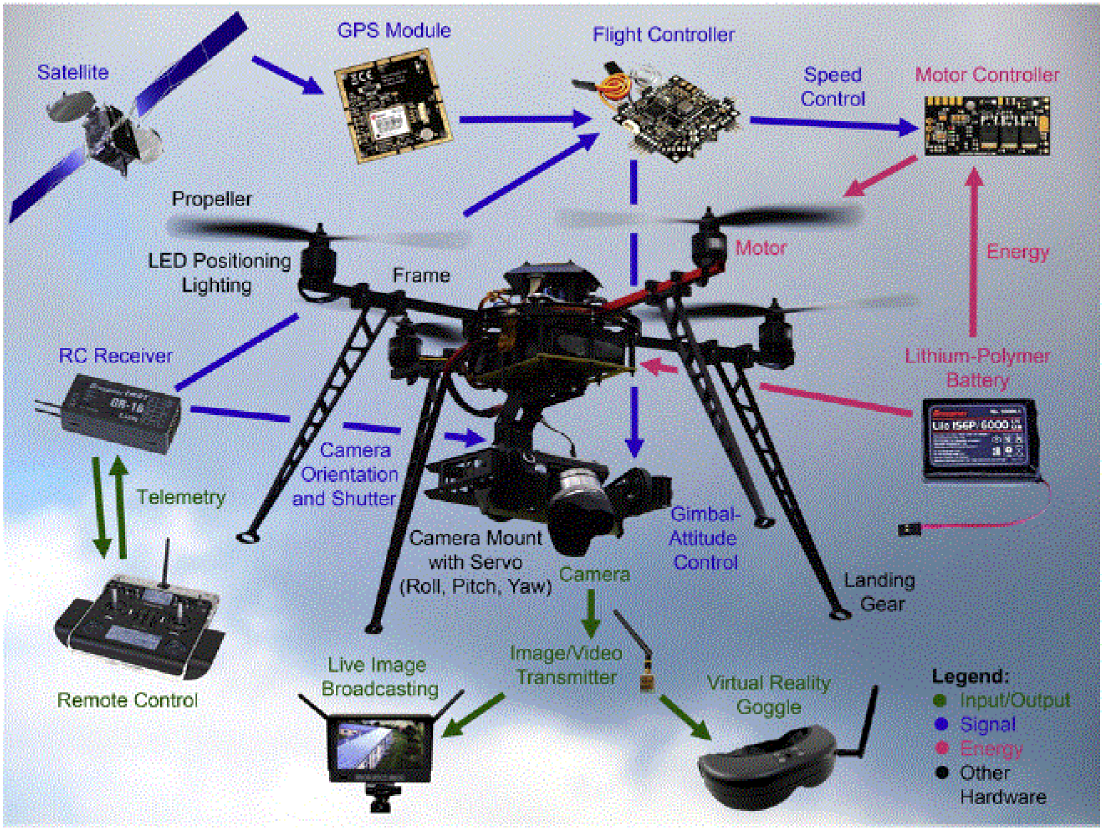

Figure 13: Mobile 3D mapping for surveying earthwork projects using an

4.4.2.2 Shortage of Qualified Contractors for Prefabrication

BIM model-based simulations for training can be used to improve the limited experience of the parties (Ezcan et al., 2013). On the other side, due to the increasing demand from homeowners and builders for operating BIM, demand for contractors and skilled specialists will also increase. Training to contractors will be facilitated and therefore the number of specialists will increase.

4.4.2.3 Shortage of Qualified Designers

Due to the nature of prefabricated parts that need to be produced in factories and then installed onsite, need to be considered more carefully for producing details and elements. As a result, the role of designers and consultants will be bold. Designers or construction management is not necessary to be present onsite to create a virtual model of the project. In fact, designers and consultants get the necessary information in order to create a virtual model of the building. The model can be created by teleworking method and then be placed in the hands of owners. Owners and investors can also employing the best designers and consultants by using modern communication technology in order to use their experience and knowledge of them. In fact communication throughout BIM tools will overcome the lack of local skilled workers. For example, by using 3D scanner, designers and consultants can generate an as-built construction data and comparing them by real condition. If there is any discrepancy between plan and implementation, warnings will be issued for reform.

4.4.3 Monotony of Structure

When speaking of prefabricated buildings, the opinion found that the buildings are structurally simple and so soulless. It is believed that prefabricated are structures with sharp corners and have a linear structure. This impression is strengthened by considering the lack of diversity in prefabricated structure Due to the lack of modern technology. But today, thanks to huge advances achieved in technology, this possibility is provided for designers who design and implement complex architectures buildings, moreover, This has been possible by connecting cutting machines to the latest software such as AutoCAD, Revit,… enabling the cutting had been made available in various forms.

Figure 14: Fabricating walls in Revit

For instance, BIM tools such as Revit, Morphosis and Bentley Triforma due to ability to describe of complex geometry, allows designers or planers to analysis the most complex components of prefabricated structures (Eastman & Liston, 2011).

4.4.4 Disinclination to Innovation

As mentioned in the previous section, Thanks to advances in today's modern manufacturing machinery and digital world and also BIM that provide to analyze the building for various materials, Lack of creativity will be eliminated for Prefabricated. Due to the lack of restrictions on the choice of variety of materials in BIM tools to analyze and the rapid growth of communications, manufacturers are thinking to offer the best materials to buyers and will have no restrictions in this regard. Today, many countries are members of the World Trade Organization and Iran is also seeking to join the World Trade Organization, Hence, manufacturers take advantage of the benefits of global trade to compete with similar products have no choice unless that with creativity and innovation in production of building materials to satisfy their buyers. BIM has made this opportunity to analyze several productions of different producers in other countries in order to select the best choices.

4.4.5 Transportation of Prefabricated Elements

One of the main problems in OSM is related to transportation of prefabricated elements and access to the building site that it cause to change one's mind to plan, using Modular Construction. Stakeholders would not be encouraged to assemble prefabricated homes. These problems will be significant when the distances between off-site manufactures and site of construction are far from each other. In addition, due to traffic roads the risks will be increased. By adoption BIM, due to create a virtual models of road by tools such as Autodesk Vehicle Tracking, it is possible to analysis all components of roads such as distances, barriers on way, Width of the road and measure the speed of vary vehicles that is determined for transporting elements to site. Other BIM tools potential that can be mentioned to it is the power of manage and arrange components and elements on the site and identify the detections by using Autodesk Naviswork Manager Software in order to reduce risks.

Figure 15: Site Safety Visualization (Hardi & McCoo, 2015)

4.4.6 Fragmented Structure

One of the main problems in OSM is related to fragmented structure that it cause to confuse all team in construction. For example a lots of documents should be prepared for different parts and vary pieces. These problems show itself when stakeholders work on infrastructure such as airport, tower or a huge bridge.

By adoption BIM, due to a virtual model of all details and components is created, different included parts such as owners, project managers, engineers and contractors in construction will be able to arrange and manage all details and share it among themselves. For example by searching the code of each piece in BIM tools such as Revit, they will be able to accurate analysis the pieces such as position, location and several other benefits that all cause to reduce cost, time and improve qualities.

Figure 16: Superintendent using BIM Anywhere to scan QR codes for quality control

Chapter 5

RESEARCH METHODOLOGY

5.1 Introduction

This chapter will describe the research methodology that was adopted to meet the purpose of this study. As it already mentioned, this research is a study to survey the power of BIM to overcoming OSM barriers. The Questionnaire survey was prepared to distribute among the experts related to the construction industry in Iran. The statistical method is used to describe and validate the results by applying program SPSS.

5.2 Questionnaire survey

In most of researches, the questionnaire survey would be adopted as a reliable source for collecting. Glasow (2005) mentioned the closed-ended questions will be simple to respond and also easy to analyze. Therefore, as it will be discussed in detail in the following, questionnaire survey was determined as a suitable technique in this research. For this research two questions form are designed as follows:

5.2.1 Questionnaire A

Questionnaire A is designed in order to determine critical barriers of OSM that is prevent to effectively utilize this modern technique with multifaceted benefits in construction industry. The elementary of OSM barriers that was introduced in Table 2 in chapter 3 section 3.5 has been coded in Table 6.

Table 6: Coding the Critical Factors Preventing the Utilization of OSM

Code	Elementary list of OSM Barriers and Limitation
FA 1	High Initial Cost
FA 2	Incertitude of Market Request
FA 3	Lack of Technologies and Testing Institute
FA 4	Doubt about Stability of Prefabricated
FA 5	Shortage of Governmental Rules and Motivations
FA 6	Transportation of Precast Elements
FA 7	Dependence of Traditional Construction Method
FA 8	Shortage of manufacturers of Precast Components
FA 9	Shortage of Qualified Designers
FA 10	Unable To Modify Design Scheme
FA 11	Difficulty to the maintenance of Precast Elements
FA 12	Shortage of Qualified Contractors for Prefabrication
FA 13	Monotony of Structure
FA 14	Shortage of Skilled and Qualified Collaboration Groups
FA 15	Disinclination to Innovation
FA 16	Shortage of Experience from Local Jobs
FA 17	Shortage of Skilled Fabricators/Installers
FA 18	Shortage of Qualified R&D Institution
FA 19	High Cost Pressure without Economics Scale Effect
FA 20	Fragmented Structure
FA 21	Longer Lead-In Time during Design Stage
FA 22	Shortage of Guidelines for Precast Components

Questionnaire A divided to three parts. Part A is included four general questions in regarding the professional field, education, the amount of years' experience in construction and also in off-site construction. Part B is included to six questions to determine benefits of using OSM in construction. And finally, in Part C, twenty two of OSM barriers which were collected from different sources such as books, articles, seminar papers, and journals were considered in order to determine the critical factors of OSM barriers in Iranian construction industry. It is necessary to mentioned all of questions was designed closed-ended formats (Strongly agree; Agree; Neutral; Disagree; and Strongly Disagree).

5.2.2 Questionnaire B

The Questionnaire B was designed base on results of Questionnaire A. In the other word, the critical factors of OSM barriers was determined according to the results of Questionnaire A. Questionnaire B is included three parts as same as Questionnaire A, but the number of questions are different. The number of questions of part C of questionnaire B has designed based on the results of part C of Questionnaire A.

Part A of Questionnaire B is included six questions. These questions are related with general information of each participants such as field, education, experience, acknowledge of BIM. Section B of Questionnaire B that included three questions was designed in order to determine the benefits of BIM for construction industry. And finally, as mentioned, part C was designed based on critical factors of OSM barriers that was determined in Questionnaire A. The respondents was requested to rate that what extent BIM can overcome to critical barriers of OSM in construction industry in Iran. Using a five-point scale in which 5 dedicated “Strongly agree,” 4 dedicated “Agree,” 2 dedicated “Disagree,” 1 dedicated “Strongly disagree,” and the middle rank (3) was “Neutral”.

5.3 Population of research

For the Questionnaire A, Members of Teharn Construction Engineering Organization and Khorasan Construction Engineering Organization are participated to answer the questionnaire. They are mainly included faculty member, architecture, civil engineer, contractor, owner/client, manufacturer and construction managers.

For the Questionnaire B, because of the number of BIM experts are low or at least unknown in Iran, it was decided to use snowball sampling technique in order to respond the questionnaire.

5.4 Data Collection

After planning the questionnaire, Google Doc was selected to prepare a web link for questionnaire form. The Questionnaire A was sent to participants by email and manually in March, 2016.

The section B questionnaire was sent between “March, 2016 until May, 2016”.

5.5 Ranking Analysis

This method was applied in some researchers for classification. In this paper, mean score of factors is measured in order to rank them based on responses of participants for both section Questionnaire A and Questionnaire B by considering this issue that between two or more factors with same mean score which one has less standard deviation will be ranked higher.

5.6 Factor Analysis

Factor analysis is recommended for exploration of scale items to see which factors have been emerged by measured items. By using factor analysis, similarities factors will be determined and compress in its related clusters in order to be smaller for better understanding and investigating. Principle component analysis with varimax method is appropriate approach in extraction of factor. The results of this analysis is represented in next chapter.

5.7 Reliability

Cronbach’s coefficient alpha was used to measure internal consistency among the various factors to evaluate the reliability of the five-point scale. Table 7 show interpret of Cronbach’s Alpha based on George and Mallery (2003).

Table 7: Interpret of Cronbach’s Alpha coefficient (George and Mallery, 2003)

Cronbach's Alpha	Internal Consistency
a >= 0.9	Excellent
0.9 > a >= 0.8	Good
0.8 > a >= 0.7	Acceptable
0.7 > a >= 0.6	Questionable
0.6 > a >= 0.5	Poor
a > 0.5	Unacceptable

5.8 Correlation Analysis

The correlation is one of the most common and most useful statistics. Correlation analysis as its name states actually describes the degree of relationship between two variables. In this survey, correlation analysis has been calculated to determine the relationship between performances BIM for OSM barriers.

5.9 Hypothesis

Hypothesis 1: “There is a correlation between the knowledge of BIM and the BIM function in order to overcome OSM barriers”.

Hypothesis 2: “There is a correlation between the knowledge of BIM and OSM Beneficial.”

Next chapter is dedicated to compare the results and will be discussed on results.

Chapter 6

ANALYSIS AND DISCUSSION

In this chapter, based on the results of questionnaire survey, the data will be analyze and discussed. The collected data were analyzed by using the method mentioned in the Chapter 3.

6.1 Questionnaire A

The questionnaire link was sent or asked of 120 stakeholders in Iran construction industry, therefore 71 questionnaires form were filled with valid responses and sent back by civil engineers, construction managers, architectures, faculty members, contractors, owners and manufacturers (59% response rate).

6.1.1 Part A (General Information)

6.1.1.1 Specialized Fields

As shown in Figure 17, the number and percentages of respondents is represented and arranged based on their specialized fields. 44% of participants were civil engineers. The percentages of faculty members and construction managers that participated are the same for both field, 13 %. 6% of respondents were contractors and 8% were architectures. These amount for owners and manufacturers were 7% and 10%, respectively.

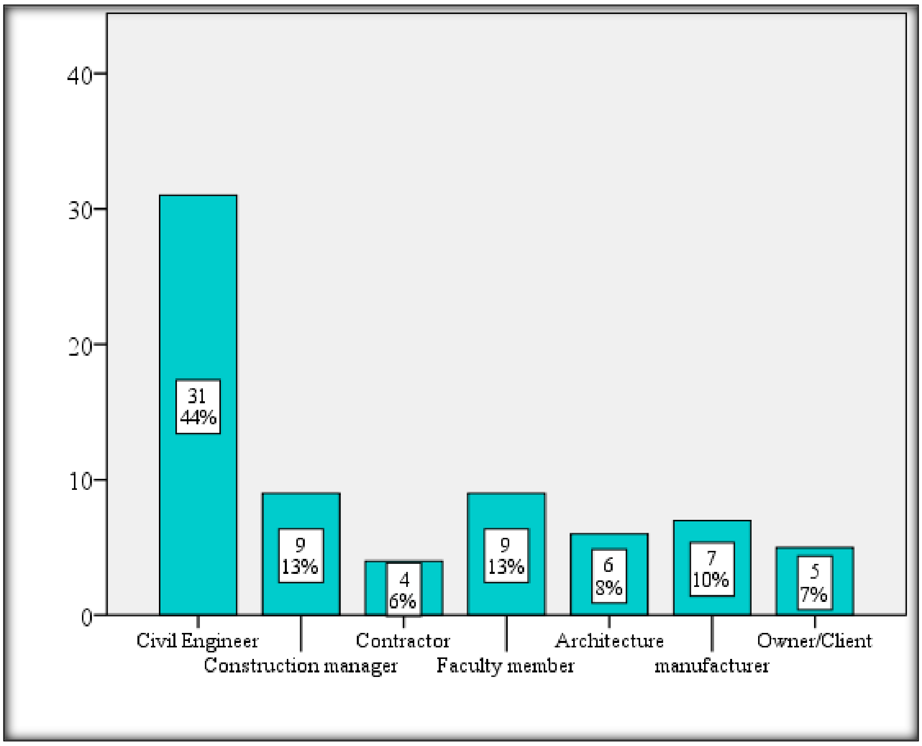

Figure 17: Job Title of Participants

6.1.1.2 Education level

The education level of participants are shown in Figure 18.

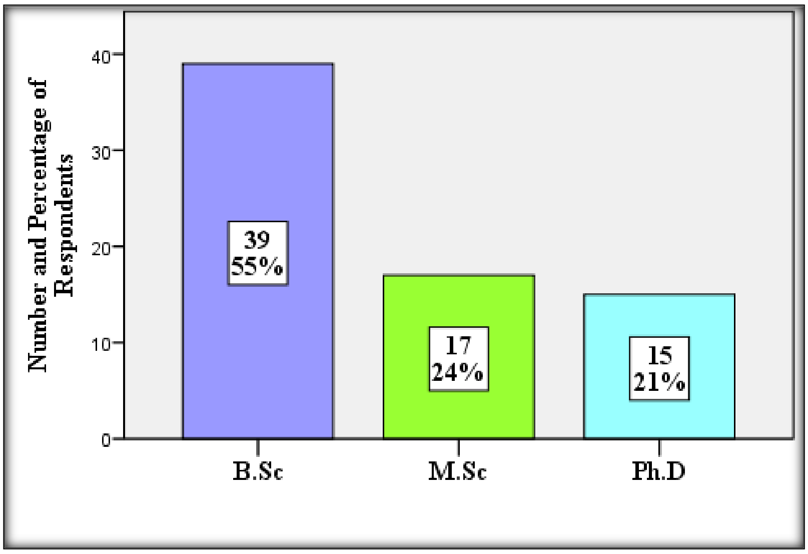

Figure 18: Education Level of Participants

6.1.1.3 Experience in construction industry

As shown in Figure 19, 18% of participants mentioned that they have less than 5 years' experience in construction, 17% have between 5 to 10 years of experience, 23% have between 10 to 15 years and 25% have between 15 to 20 years of experience. The number of participants have more than 20 years working experience is 12 or 17% of respondents.

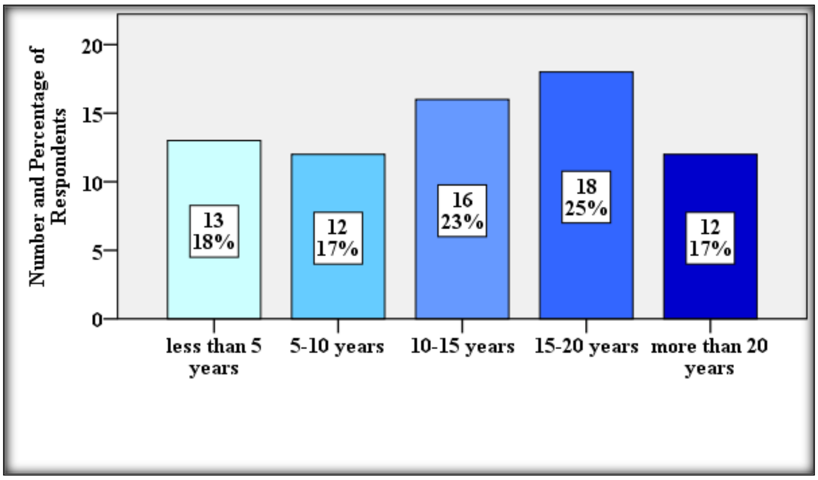

Figure 19: Experience in Construction Industry

6.1.1.4 Experience in OSM

Question 4 of part A of questionnaire A was asked about the years of experience of respondents in OSM (see Figure 20).

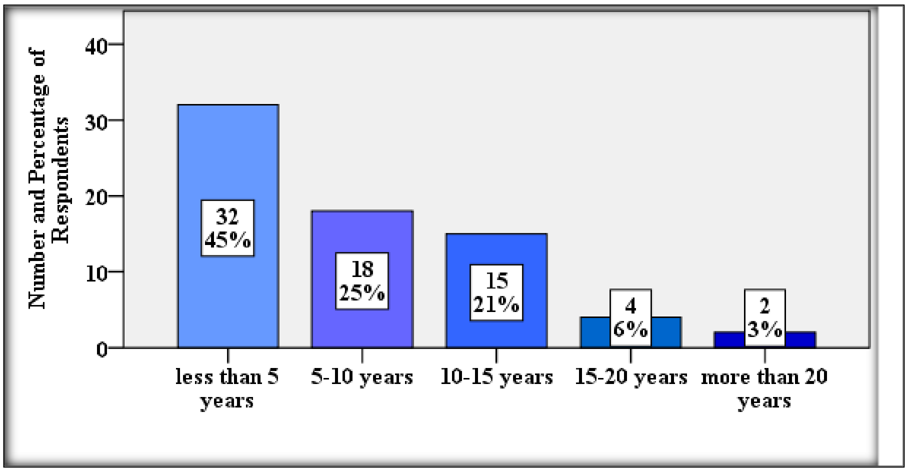

Figure 20: Experience in OSM

6.1.2 PART B (OSM Benefits)

6.1.2.1 Cost Reduction

The first question is about cost saving in OSM method. As it shown in Figure 21, more than three-quarters of participants are agree or strongly agree with this idea that OSM approach will cause to reduce the cost of construction and just 8% were contrary.

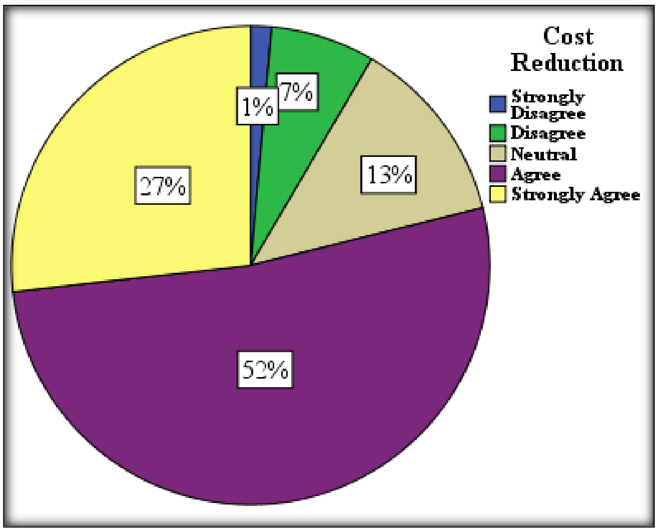

Figure 21: Effect of OSM in Reducing the Cost of Construction

6.1.2.2 Time Reduction

The second question was about time reduction in OSM. As it shown in Figure 22, 60% of participants believe by using OSM method, construction time will be decrease. On the other side only 16% disagree with this idea.

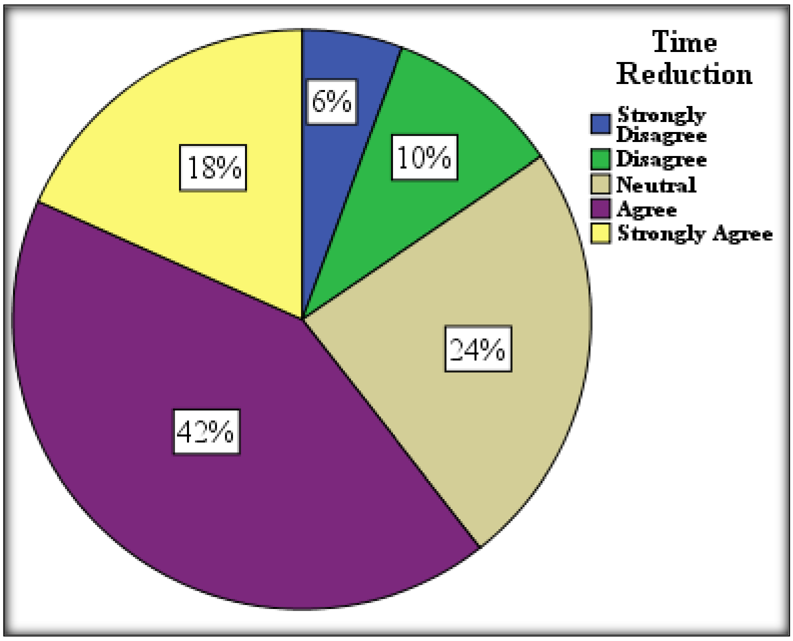

Figure 22: Effect of OSM in Reducing Time of Construction

6.1.2.3 Enhancing Construction Quality

The third question of this part is about construction quality in OSM. 62% of responses represent OSM method will improve construction quality (see Figure 23).

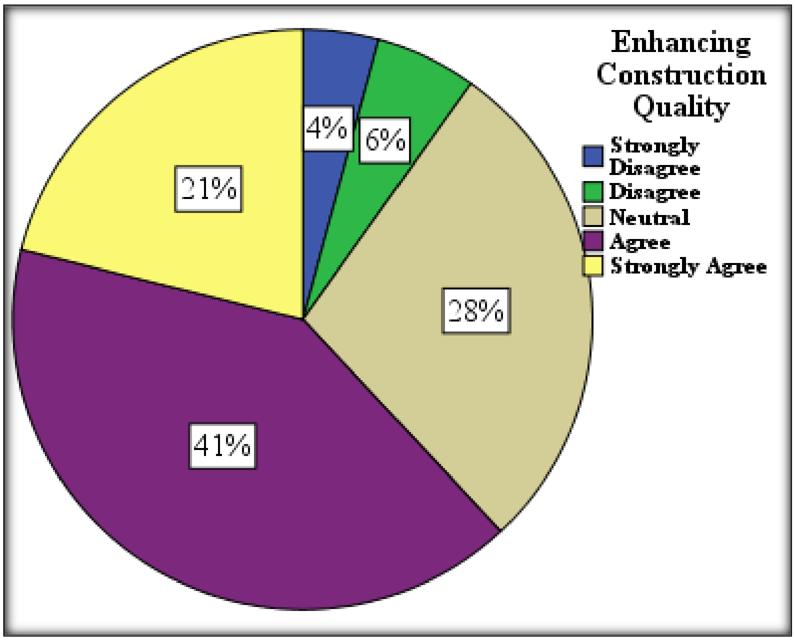

Figure 23: Effect of OSM to Enhancing Construction Quality

6.1.2.4 Non-specialist

One of the most important problems in Iran construction industry is related to low quality of construction due to entrance of non-specialist in construction industry. Fourth question of part B was assigned that OSM execution will prevent or control entrance of non-specialist in construction industry. Nearly half of participants (46%) believe that by using OSM, it is prevented for non-specialist in order to enter in construction industry. On the other side, 33% of respondents have opposite view with this idea.

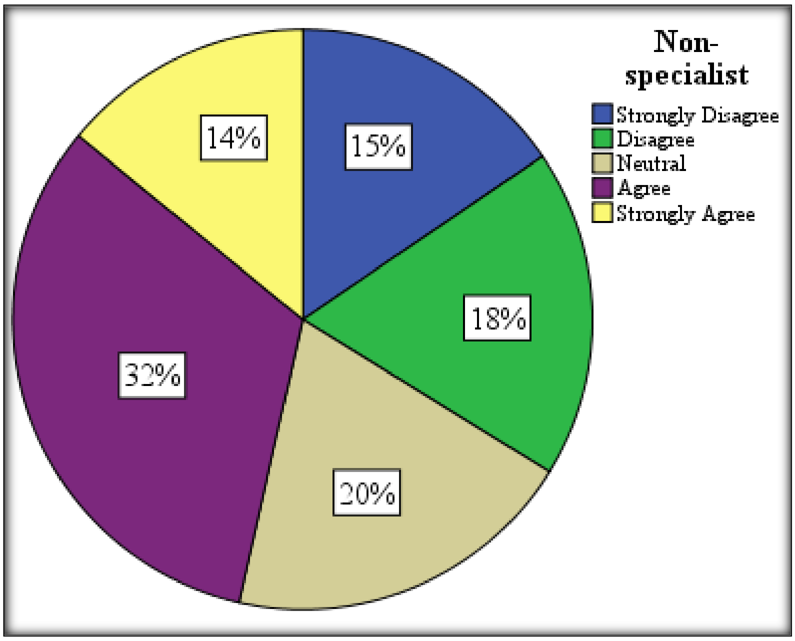

Figure 24: Effect of OSM to Preventing Entrance of Non-Specialist in Construction Industry

6.1.2.5 Labor Productivity

Labor productivity in OSM is the other question was asked in this part. Nearly three quarters of participants acknowledged by adoption OSM method, labor productivity will improve. Only 11% of responses were disagree on strongly disagree with this view (Figure 24).

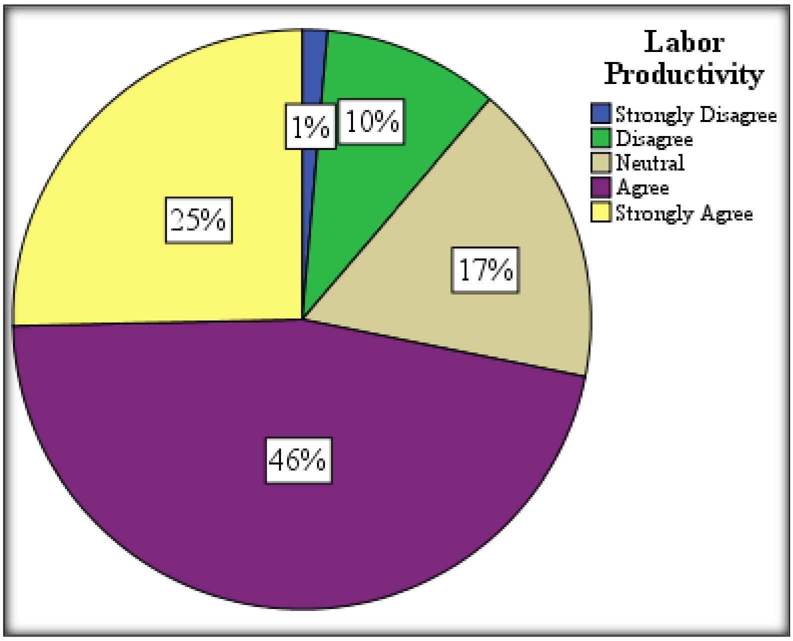

Figure 25: Effect of OSM to Improve Labor Productivity

6.1.2.6 Reduce the legal problems

According to the results of this question, 76% of participants believe that legal problems and related feedback will reduce by executing OSM method in Iranian construction industry. Only 4% of responses disagree with this point-of-view (see Figure 25).

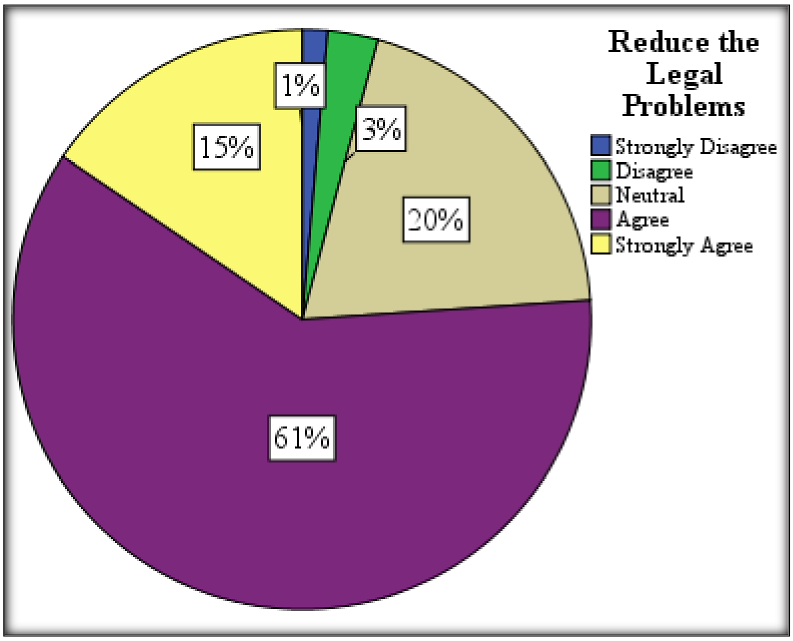

Figure 26: Effect of OSM to Reduce the Legal Problems in Construction Industry

6.1.2.7 Cronbach's Coefficient Alpha (Questionnaire A)

The value of this study's test was 0.883, which was higher than the 0.5. Therefore, the sample based on Table 7 that was represent in chapter 5 (section 5.7) is appropriate to rank factors (Mao, Chao, et al. 2013).

6.1.3 Critical OSM Factors (Questionnaire A)

The main objective of design the questionnaire A as it was mentioned in chapter 5 is to calculate the critical OSM barriers in Iran. Ranking analysis technique was selected to extract them (Mao, Chao, et al. 2013). The results has shown in Table 8.

According to the results, those factors has mean scores bigger than the average total value (3.44) has recognized as critical factors of OSM. Fifteen of OSM barriers have mean score greater than 3.44 as it provided in Table 8. "The shortage of manufacturer of precast components" with mean score 3.85 is the most critical factors that is prevented to performance OSM in Iran. Based on the results of ranking analysis the second critical factor is "the transportation of precast elements" (mean = 3.82). The

“Shortage of Experience from Local Jobs”, “Fragmented Structure” and “Disinclination to Innovation” are the same mean score (3.48). However, the standard deviation of “the lack of practices from local project” is less than two mentioned factors (0.939) and therefore is ranked higher than “fragmented structure” and “Disinclination to Innovation”. This issue is repeated for “Shortage of Skilled and Qualified Collaboration Groups” and “Shortage of Qualified R&D Institution” with same reason are ranked.

As a result, these fifteen factors was extracted as the results of Ranking Analysis of questionnaire A (see Table 8). Radar chart of the results of ranking analysis also has been drawn and shown it in Figure 27.

In Questionnaire B, this fifteen critical factors of OSM will evaluate that what extent BIM can overcome to them.

Table 8: Ranking Analysis of Critical Factors for Preventing the Utilization of OSM

Code	OSM Barriers and Limitation	Mean	Std. Deviation
FA 8	Shortage of manufacturers of Precast Components	3.85	0.951
FA 6	Transportation of Precast Elements	3.82	0.85
FA 1	High Initial Cost	3.79	0.999
FA 17	Shortage of Skilled Fabricators/Installers	3.7	0.947
FA 9	Shortage of Qualified Designers	3.69	0.855
FA 12	Shortage of Qualified Contractors for Prefabrication	3.68	0.997
FA 7	Dependence of Traditional Construction Method	3.55	0.875
FA 5	Shortage of Governmental Rules and Motivations	3.54	1.067
FA 3	Lack of Technologies and Testing Institute	3.52	1.054
FA 16	Shortage of Experience from Local Jobs	3.48	0.908
FA 20	Fragmented Structure	3.48	0.939
FA 15	Disinclination to Innovation	3.48	1.054
FA 22	Shortage of Guidelines for Precast Components	3.46	1.106
FA 14	Shortage of Skilled and Qualified Collaboration Groups	3.45	0.923
FA 18	Shortage of Qualified R&D Institution	3.45	1.08
FA 4	Doubt about Stability of Prefabricated	3.3	1.074
FA 13	Monotony of Structure	3.27	1.195
FA 21	Longer Lead-In Time during Design Stage	3.25	0.937
FA 19	High Cost Pressure without Economics Scale Effect	3.23	1.045
FA 2	Incertitude of Market Request	2.96	1.02
FA 10	Unable To Modify Design Scheme	2.96	1.139
FA 11	Difficulty to the maintenance of Precast Elements	2.83	1.042

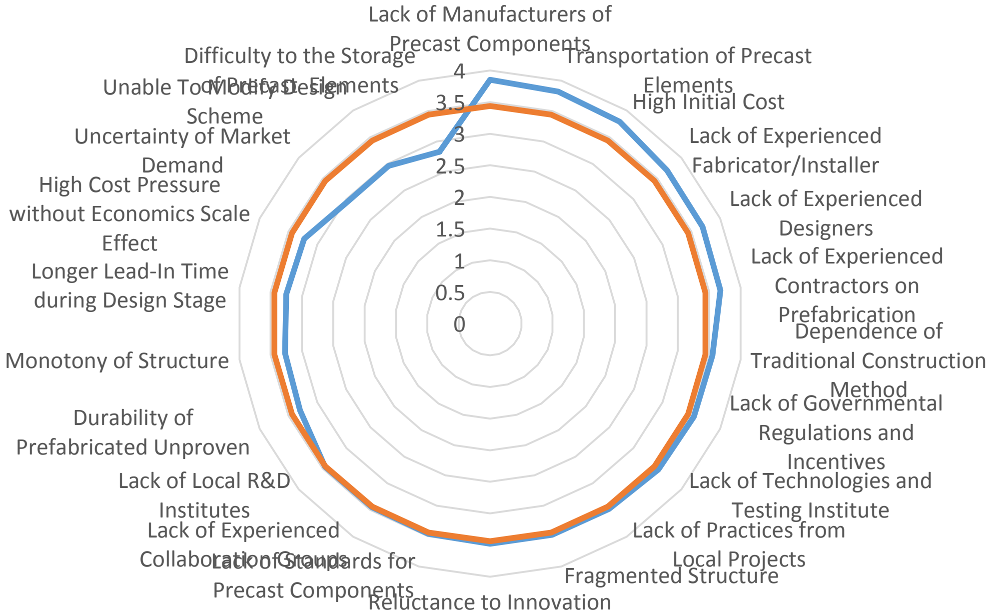

Figure 27: Radar Chart of Critical Factors of OSM Barriers

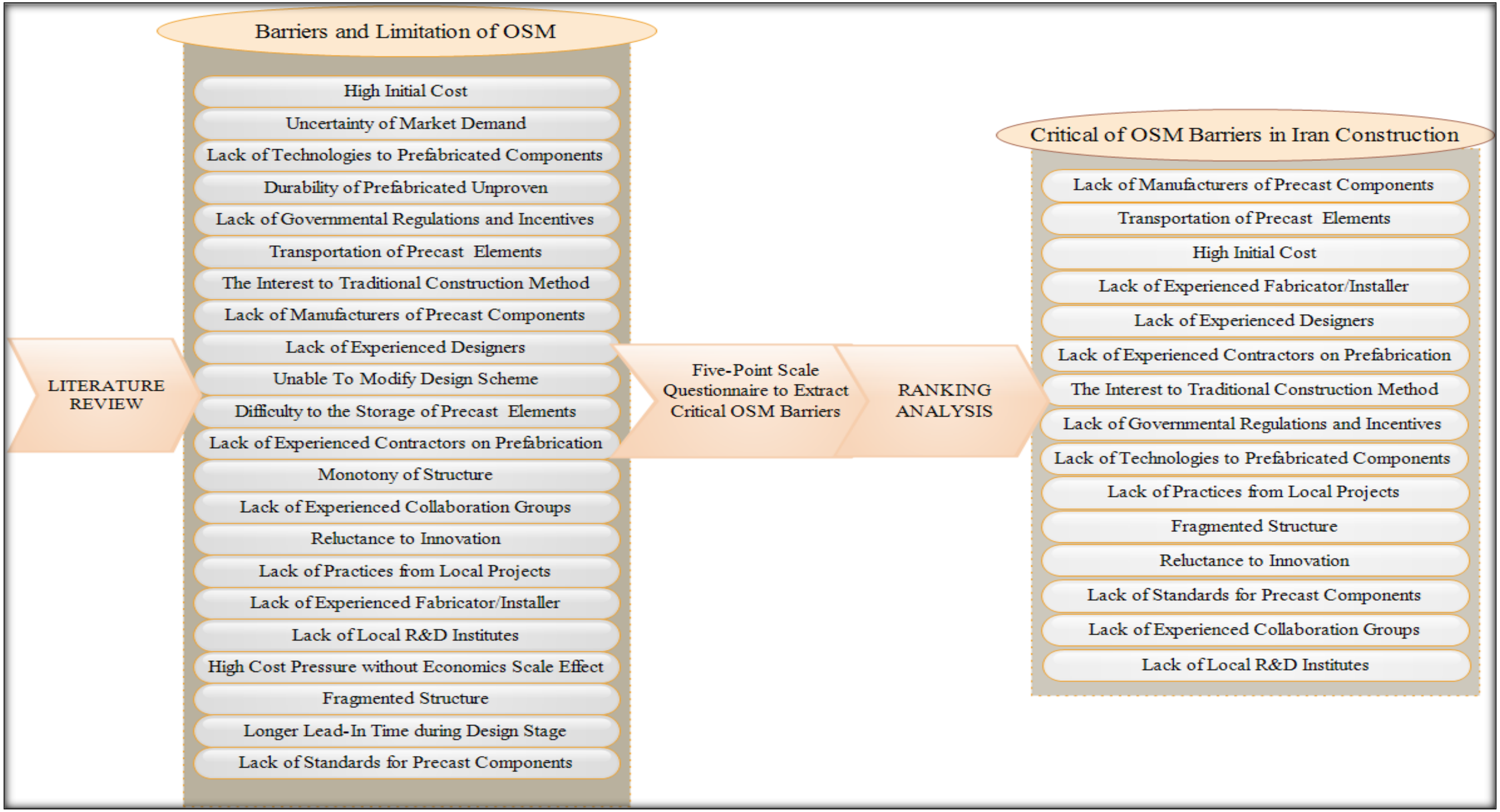

Figure 28: Questionnaire A Process

6.2 Questionnaire B

As it mentioned in chapter 5, BIM is a new approach in Iran construction industry and many firms and construction companies did not operate it yet. As a result, the number of experts or specialists is low or unknown. Therefore, snowball sampling technique was used in order to fill questionnaire form. A questionnaire link is prepared by using Google Doc application and sent to members of Tehran Construction Engineering Organization and Khorasan Construction Engineering Organization and also was asked them to send the questionnaire link for collogues that has knowledge about BIM. 47 questionnaire form were filled with valid responses.

6.2.1 Part A (General Information)

6.2.1.1 Specialized Fields

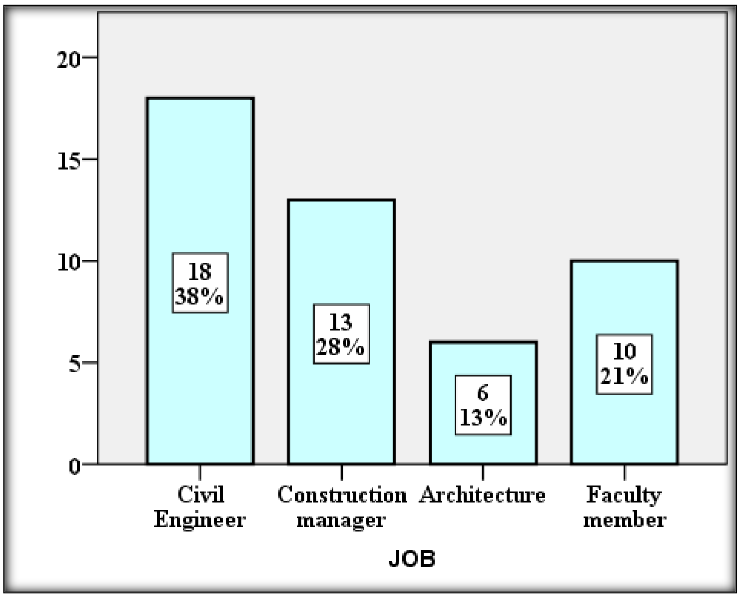

Figure 29: Job Title of Participants

6.2.1.2 Education

Master's degree holders were the highest number of participants in this survey at the rate of 40%. Bachelor's degree holders were 34% and Ph.D. holders were 26% as it shown in Figure 30.

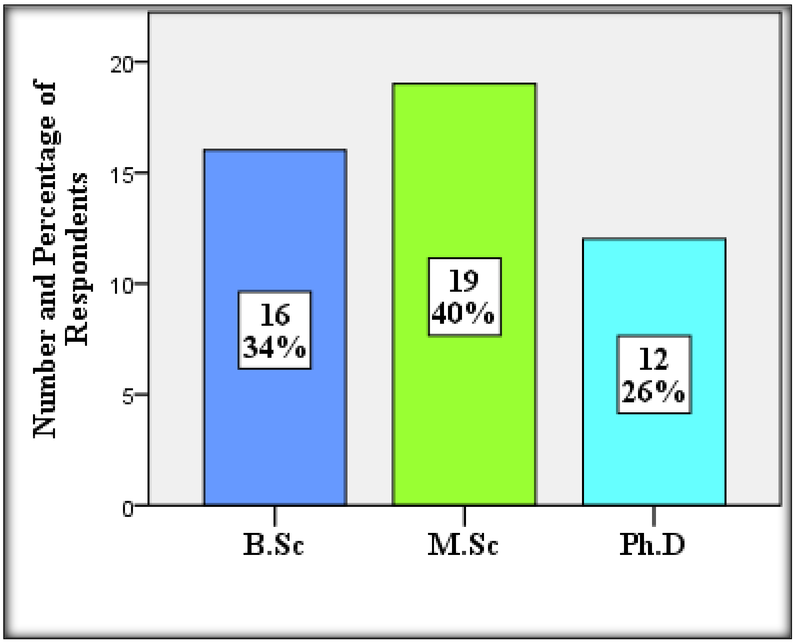

Figure 30: Education of Participants

6.2.1.3 Experience in construction industry

The years of working experience of participants is shown in Figure 31.

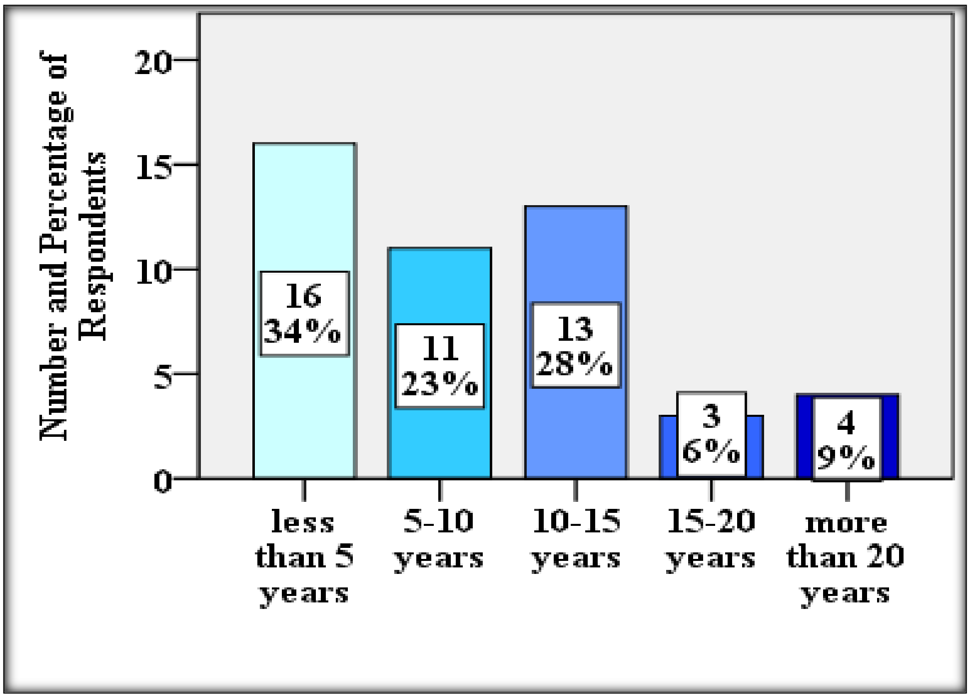

Figure 31: Experience in construction

6.2.1.4 Experience in BIM

As shown clearly in Figure 32, the number and percentage of respondents based on their BIM experience has been represented.

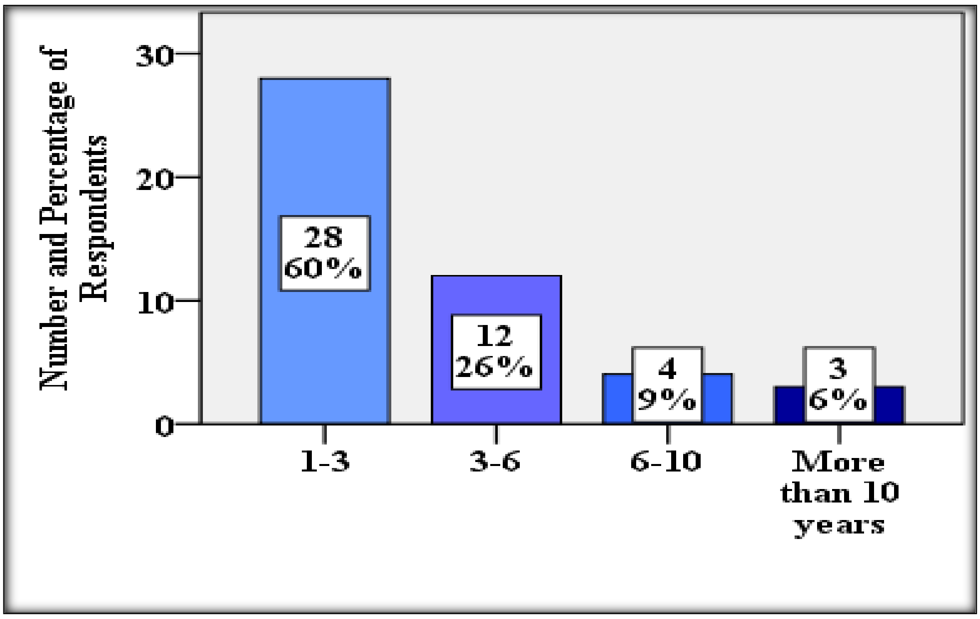

Figure 32: experience in BIM

6.2.1.5 Is it necessary all engineering in construction industry should have be BIM knowledge?

The necessity of BIM knowledge for all engineers in construction has been asked and as shown in Figure 33, 55% of respondents believe that all engineer in construction need to have knowledge about BIM and 45% responded that it is not necessary.

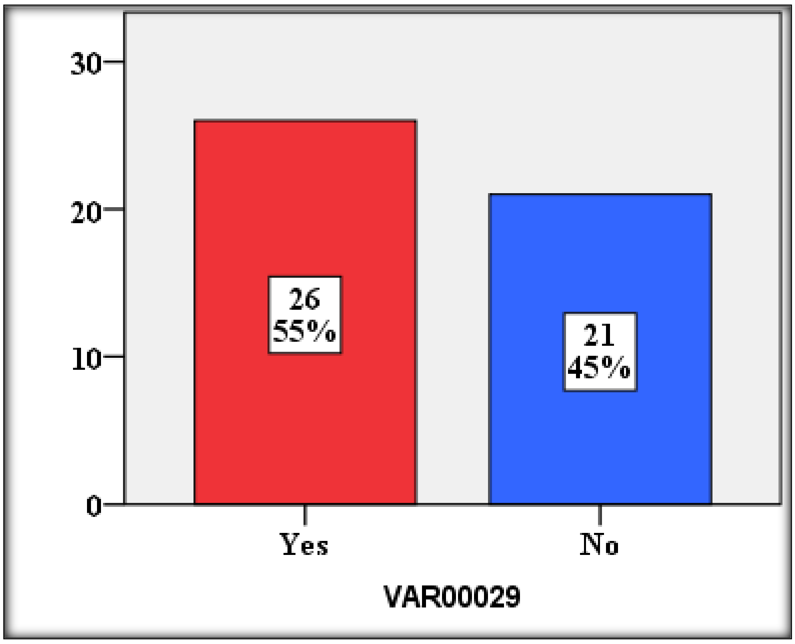

Figure 33: The Necessity of BIM Knowledge for All Engineering

6.2.1.6 Is it necessary the construction manager should be BIM expert?

This question is regarding the necessity of BIM knowledge for construction managers in Iran. As it shown the results, 79% of respondents believe that construction managers should be BIM experts in construction industry and 21% reject this opinion (see Figure 34).

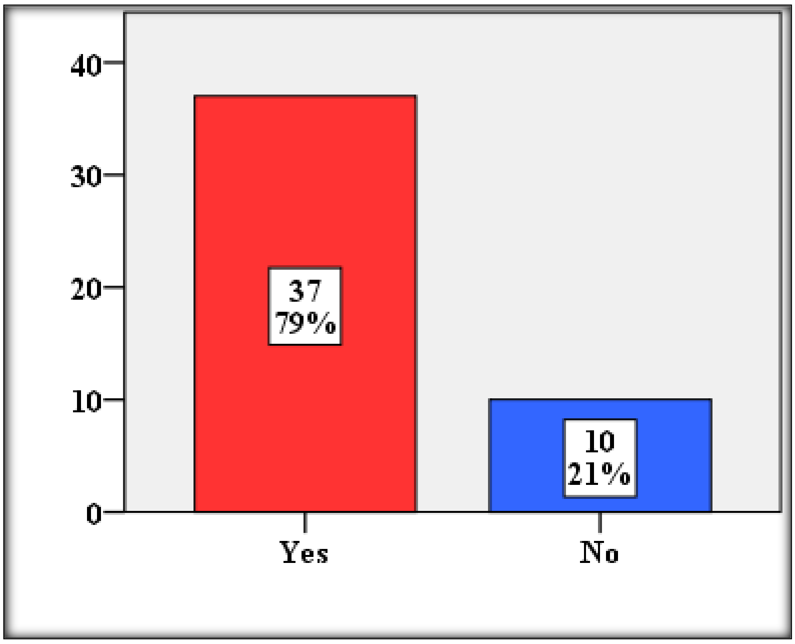

Figure 34: construction manager should be BIM expert

6.2.2 PART B (BIM Benefits)

6.2.2.1 Enhancing Construction Quality

As shown in Figure 35, 63% of participant in the survey believe that by adopting BIM, quality of construction will be improved. 12% of respondents have rejected this.

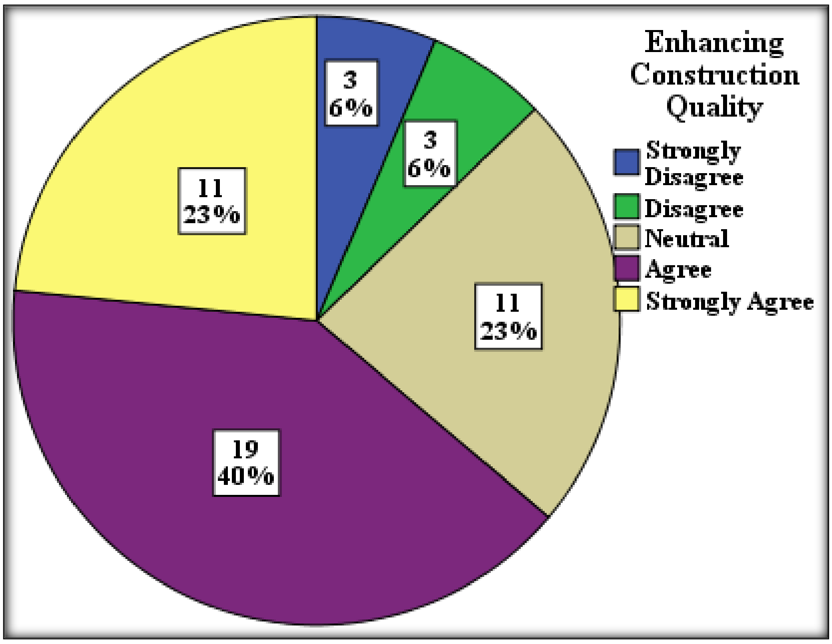

Figure 35: Enhancing Construction Quality by operating BIM

6.2.2.2 Non-specialist

One of the most problems related in Iran construction industry is the entrance of non-specialists in construction. Based on the result of research, three quarters of respondents believe that use BIM is prevented from entering Non-specialist in Iran construction industry.

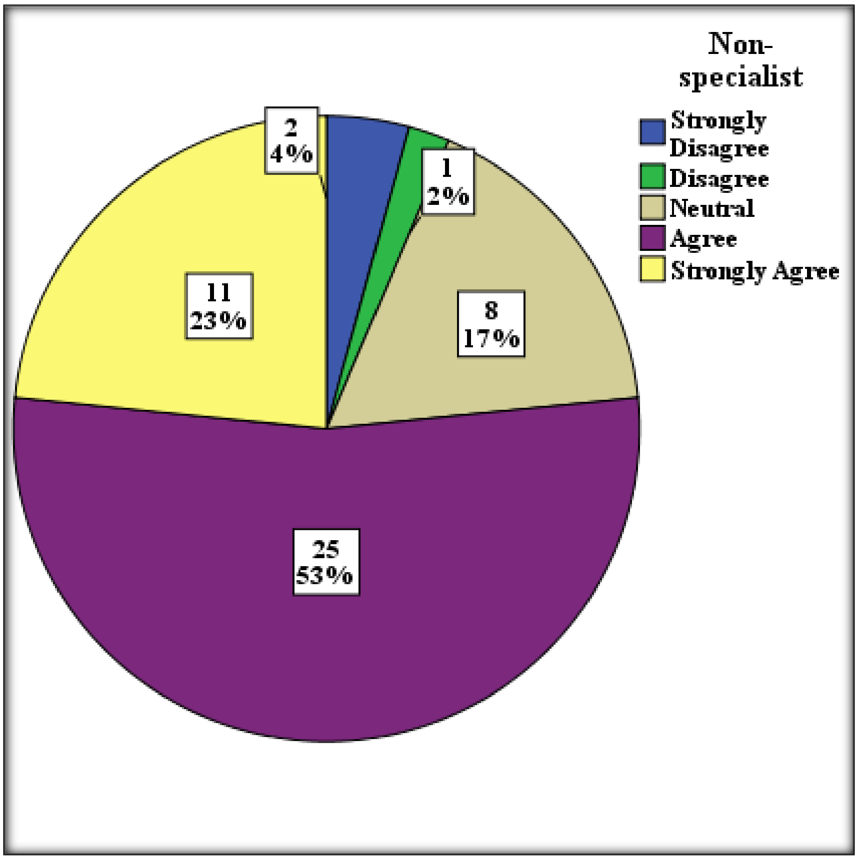

Figure 36: Preventing Of Entrance of Non-Specialist by Operating BIM

6.2.2.3 Reduce the legal problems

Final question of this part is about legal problems in Iran construction industry. 60% of responses confirmed that by adopting BIM the legal problems will be reduced. On the opposite side %13 were strongly disagree or disagree with this idea and 28% were neutral.

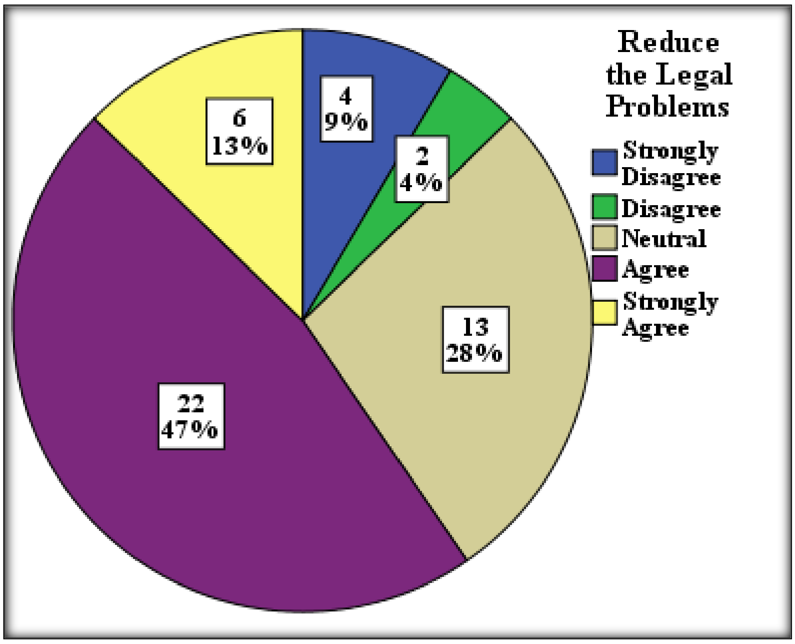

Figure 37: Reduce the Legal Problems by Operating BIM

6.2.3 PART C: Functionality of BIM for OSM Barriers

6.2.3.1 Cronbach's Coefficient Alpha (Questionnaire B)

The value of this study's test was 0.813, which was higher than the 0.5. Therefore, the sample is suitable for the same reason stated for questionnaire A (see section 6.1.2.7 or section 5.7).

6.2.4 Ranking Analysis Technique

Functionality of BIM against Critical OSM Factors (Questionnaire B). The main objective of design the questionnaire A as it was mentioned in chapter 5 is to calculate the critical OSM barriers in Iran construction industry.

Table 9: Critical Factors Hindering the Utilization of OSM in Iran

Code	OSM Barriers and Limitation
FA 8	Shortage of manufacturers of Precast Components
FA 6	Transportation of Precast Elements
FA 1	High Initial Cost
FA 17	Shortage of Skilled Fabricators/Installers
FA 9	Shortage of Qualified Designers
FA 12	Shortage of Qualified Contractors for Prefabrication
FA 7	Interest to Traditional Construction Method
FA 5	Shortage of Governmental Rules and Motivations
FA 3	Shortage of Technologies for Prefabricated Components
FA 16	Shortage of Experience from Local Jobs
FA 20	Fragmented Structure
FA 15	Disinclination to Innovation
FA 22	Shortage of Guidelines for Precast Components
FA 14	Shortage of Skilled and Qualified Collaboration Groups
FA 18	Shortage of Qualified R&D Institution

Ranking analysis technique was selected to extract them (Mao, Chao, et al. 2013). The results has shown in Table 9. Factors have mean scores bigger than the average total value (3.31) were recognized as factors that BIM approach can overcome them as obstacles of OSM implementation in Iran. The results of ranking analysis of the 15 barriers and limitation of OSM that BIM can overcome them are shown in Table 10 .As shown in Table 10 , 8 barriers out of 15 barriers have mean bigger than 3.31, and are therefore adjudged as factors that by operating BIM can overcome them in Iran. “Dependence of Traditional Construction Method” and “Shortage of Skilled and Qualified Collaboration Groups” have the same mean scores (3.79).

Table 10: Ranking Analysis for Functionality of BIM for Critical Factors Hindering the Utilization of OSM in Iran

BIM Function	The Functionality of BIM for OSM barriers	Mean	Std. Deviation
BIM Function on FA7	BIM can overcome the Interest in Traditional Construction Method	3.79	0.883
BIM Function on FA14	BIM can overcome the Shortage of Skilled and Qualified Collaboration Groups in OSM	3.79	0.931
BIM Function on FA6	BIM can overcome the problem associated with Transportation of Precast Elements in OSM	3.6	0.851
BIM Function on FA20	BIM can overcome Fragmented Structure in OSM	3.57	1.016
BIM Function on FA12	BIM can overcome the Shortage of Qualified Contractors for Prefabrication	3.47	0.804
BIM Function on FA16	BIM can overcome the Shortage of Experience from Local Jobs in OSM	3.38	1.095
BIM Function on FA9	BIM can overcome the Shortage of Qualified Designers in OSM	3.32	0.755
BIM Function on FA17	BIM can overcome the Shortage of Skilled Fabricators/Installers in OSM	3.32	1.045
BIM Function on FA15	BIM can overcome Disinclination to Innovation in OSM	3.23	1.068
BIM Function on FA1	BIM can overcome High Initial Cost in OSM	3.21	1.062
BIM Function on FA22	BIM can overcome the Shortage of Guidelines for Precast Components in OSM	3.11	1.108
BIM Function on FA3	BIM can overcome the Lack of Technologies and Testing Institute in OSM	3.09	1.12
BIM Function on FA18	BIM can overcome the Shortage of Qualified R&D Institution in OSM	2.94	1.051
BIM Function on FA8	BIM can overcome The shortage of manufacturers of Precast Components in OSM	2.91	0.929
BIM Function on FA5	BIM can overcome the Shortage of Governmental Rules and Motivations in OSM	2.79	1.16

Therefore, each one has lower standard deviation "Dependence of Traditional Construction Method= 0.883" is ranked first and "Shortage of Skilled and Qualified Collaboration Groups=0.931" is ranked second (Mao, Chao, et al. 2013).

According to the research results, Participants of the survey believe that 8 limitation of OSM will be obviated by adoption BIM approach that are as follows:

1) Interest in Traditional Construction

2) Shortage of Skilled and Qualified Collaboration Groups

3) Problems of Transportation of Precast Elements

4) Fragmented Structure

5) Shortage of Qualified Contractors for Prefabrication

6) Shortage of Experience from Local Jobs

7) Shortage of Qualified Designers in OSM

8) Shortage of Skilled Fabricators/Installers

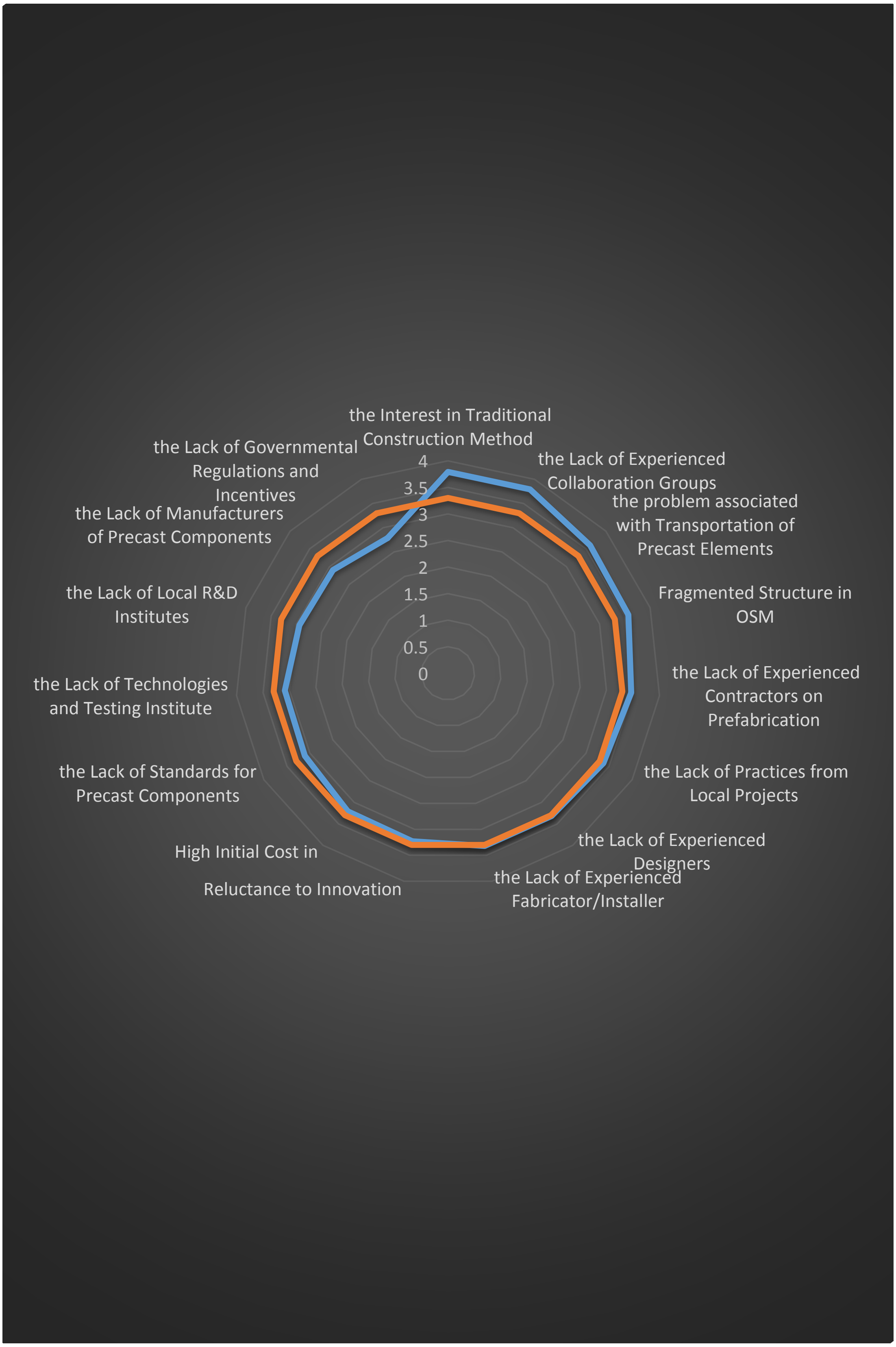

Figure 38: Radar chart of functionality of BIM for OSM barriers

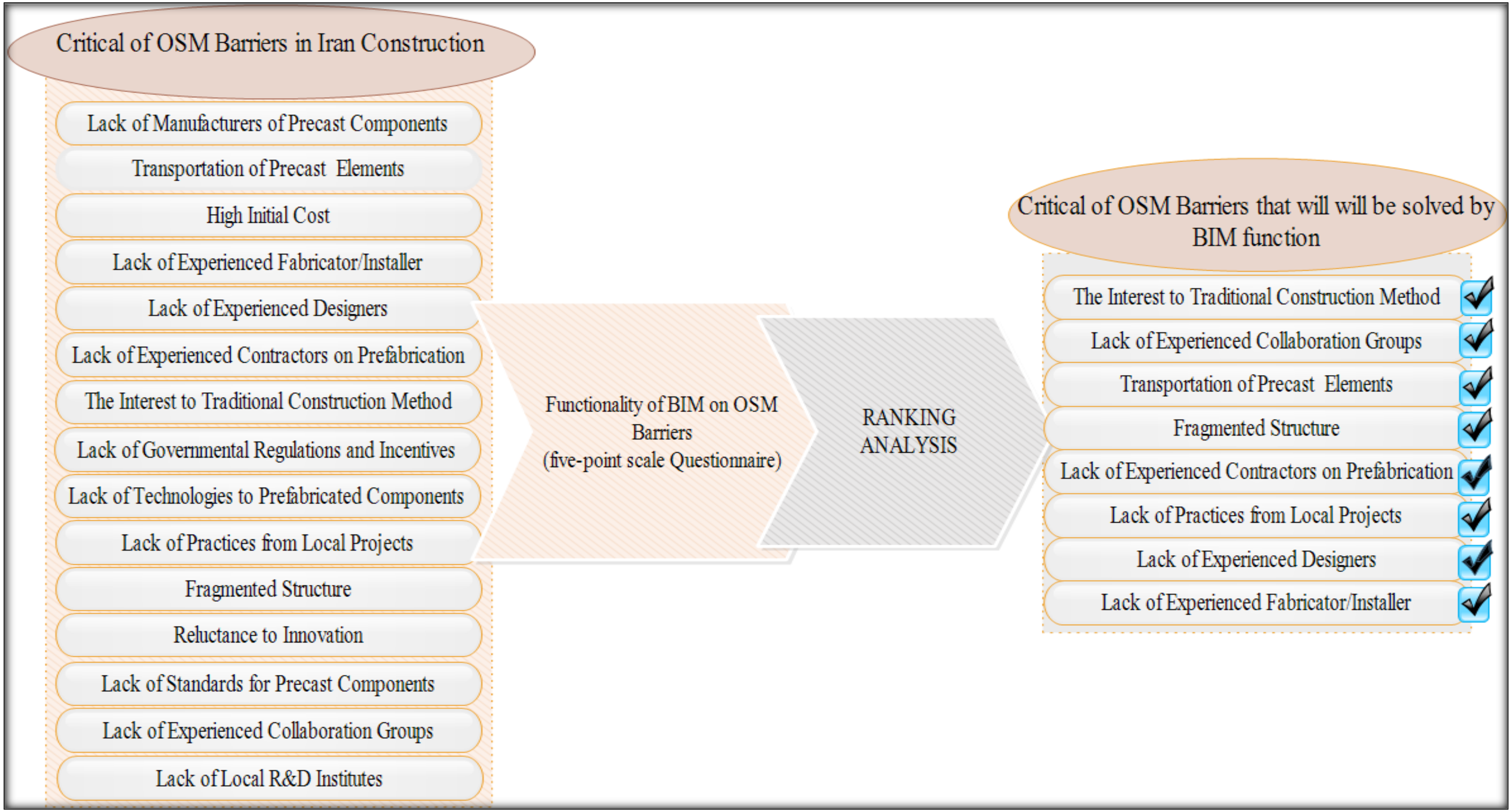

FIGURE 39: QUESTIONNAIRE B PROCESS

6.2.5 Result of Factor Analysis

Kaiser-Meyer-Olkin (KMO). Mao et al (2013), cited that "The range of KMO statistic is between 0 and 1. Hence values greater than 0.5 is appropriate for Factor Analysis and the specimen is suitable."

The KMO value for Questionnaire B is 0.631, more than 0.5. The results indicate that the data is suitable for factor analysis.

Three clusters were extracted through principal component analysis. 65.98% of variation of these eight barriers of OSM can be explained by these three clusters that includes eight items of BIM functionality and the factor loading value are more than 0.50. (Mao, Chao, et al. 2013).

Table 11: Variance of Critical Factors

Cluster	Initial Eigenvalues		
	Total	**% of Variance**	**Cumulative %**
1	2.603	32.533	32.533
2	1.494	18.673	51.206
3	1.182	14.78	65.986

Table 12: Cluster Matrix after Varimax Rotation

Code	Functionality of BIM	Cluster 1	Cluster 2	Cluster 3
F1	BIM can overcome the Interest in traditional construction	0.813	-	-
F2	BIM can overcome the problems associated with Transportation of Precast Elements in OSM	0.800	-	-
F3	BIM can overcome the Shortage of Skilled and Qualified Collaboration Groups in OSM	0.778	-	-
F4	BIM can overcome the Shortage of Skilled Fabricators/Installers in OSM	-	0.809	-
F5	BIM can overcome the Shortage of Qualified Designers in OSM	-	0.778	-
F6	BIM can overcome Fragmented Structure in OSM	-	0.751	-
F7	BIM can overcome the Shortage of Experience from Local Jobs in OSM	-	-	0.720
F8	BIM can overcome the Shortage of Qualified Contractors for Prefabrication	-	-	0.706

Each of the 8 functionality of BIM on OSM barriers belonged to one of the three clusters (see Table 12). Also loading factor of each factors is more than 0.50. According to the results of factor analysis (Table 12) between eight important factors, the contribution of each cluster are as follows:

Cluster 1 and cluster 2 are included three factors each one, and cluster 3 is included two factors. As a results, these three cluster can be named as follows and is discussed in the following section:

Cluster 1: Supply chain

BIM can overcome:

- The Interest in Traditional Construction Method
- The problems associated with Transportation of Precast Elements in OSM
- The Shortage of Skilled and Qualified Collaboration Groups in OSM

Interest in Traditional Construction Method. According to the results, BIM has the abilities and capabilities in order to overcome the interest in traditional construction. BIM can create a virtual model before construction and subcontractor and contractor can use this virtual model in order to estimate cost based on information output that provided by BIM digital model to win more work (Hardin & McCool, 2015).

Owners can walk in their virtual model of their project in order to watch all details and decide to change the component location or not. BIM tools has a high potential in order to detect clashes between varieties of component in virtual model.

Project information is stored on papers that it is difficult to use and human mistake cause to increase cost in traditional construction that BIM approach has solved this errors (Arayici, 2015).

Transportation of Precast Elements. Second limitation of OSM that located in this cluster is Transportation of component from factory to on-site construction. BIM tools such as Civil 3D can support all the process of manufacturing such as logistics, stocking, packaging and transportation to the construction site(Zhang et al., 2016).

By adopting BIM waste of material is reduced and cause to stop overproduce material that means lower cost to transfer components to construction site (Mordue et al., 2015).

Shortage of Skilled and Qualified Collaboration Groups. Third barriers and limitation that prevented to use OSM in Iran construction industry and belong in this cluster is that by using BIM can solve it is the Shortage of Skilled and Qualified

Collaboration Groups. Azhar et al (2009), cited “The foundations of BIM are laid on two pillars, communication and collaboration”

Cluster 2: Design and Execution

BIM can overcome:

- The Shortage of Skilled Fabricators/Installers in OSM
- The Shortage of Qualified Designers in OSM
- Fragmented Structure in OSM

The Shortage of Skilled Fabricators/Installers. Due to the nature of BIM technology that has a high potential to readily share data among different participant in construction processes, who technicians or installer with lower experience can extract their required information from virtual model or be taught by experienced fabricators at another location without considering distances thanks to BIM capabilities in communications.

Deutsch (2011), mentioned that BIM allows all stakeholders to readily share information earlier in the initial stages of construction.

Chen and Luo (2014), cited “BIM is most frequently perceived as a tool for visualizing and coordinating work, avoiding errors and omission.”

Shortage of Qualified Designers. The second factor in cluster two is “the Shortage of Qualified Designers” in OSM and participants believed that will be solved by operating BIM in OSM. Teleworking as a new approach to working can be led by BIM. BIM thanks to have high power in order to readily share information between designers, construction managers and owners can apply the best expertise in assisting to designing modular construction without considering distances.

Deutsch (2011), cited that with considering collaborative tools, distances is wasted in today’s world.

Fragmented Structure. The last factor of Cluster 2 is related to fragmented structure of OSM. BIM tools such as Revit or Naviswork software have a high potential in order to manage and control components during production processes in off-site or on-site. Moreover, by adopting BIM can prevent overproduce components based on virtual model of building and thanks to BIM tools capabilities in order to link with other production equipment such as laser cutting machine, productivity is improved and probable errors is reduced.

On the other hand, Radio-frequency identification (RFID), Quick Response codes (QR) and Barcode Technology allow information of each component save in a database in order to re-call them in appropriate time, control the details and match them in BIM model and also manage by mobile scanning device in prefabrication factories (Arayici, 2015).

ND design capabilities of BIM tools offer an automated design environment, which can reduce errors (Singh, Sawhney, & Borrmann, 2015).

Cluster 3: Skill and Experience

BIM can overcome:

➢ The Shortage of Experience from Local Jobs in OSM

➢ The Shortage of Qualified Contractors for Prefabrication

Shortage of Experience from Local Jobs. First factor in this Cluster is the lack of practices from local project that the respondents of the research believed BIM approach can overcome it. As it mentioned above and Deutsch (2011), cited by using BIM and collaborative tools, the distances between prefabricated factories, on-site installation and consultants will be disappeared.

Lack of Experienced Contractors on Prefabrication. The second and last factor that belong to cluster 3 is the lack of experience contractors for OSM implementation. As it mentioned in chapter 4 part 4.3.2 “BIM model-based simulations for training can be used to improve the limited experience of all parties involved in a construction project. (Ezcan et al., 2013).”

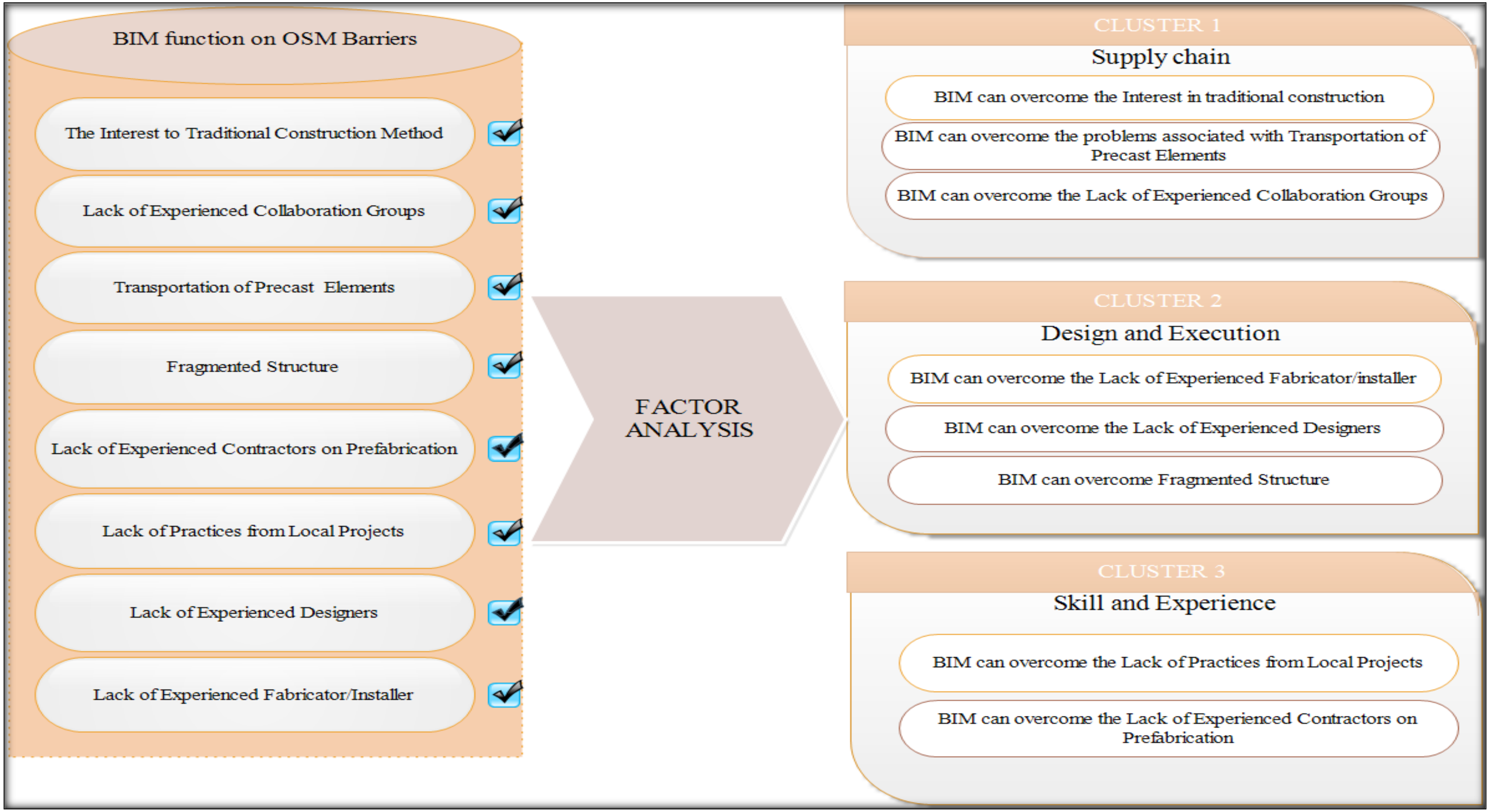

Figure 40: Factor Analysis Diagram

6.2.6 Correlation Analysis

As it shown in Table 13 Correlation between different factors is mentioned and is determined some factors are positively correlated. For example:

There is a significant and positive correlation between the Knowledge of BIM and Benefits of BIM ($r=.80$, $p< 0.01$), Or, Increases the Knowledge of BIM were correlated with increases in the Benefits of BIM.

There is a significant and positive correlation between the OSM beneficial and Benefits of BIM ($r=.57$, $p< 0.01$), Or, Increases the OSM beneficial is correlated with increases in the Benefits of BIM in Iran.

There is not a significant correlation between the Experience in BIM and BIM Function for critical factors hindering the utilization of OSM in Iran. ($r=.27$, $p= 0.07$).

Table 13: The Result of Correlation Analysis

Item		Experience in BIM	Knowledge of BIM	OSM Beneficial	BIM Beneficial	BIM function for OSM Barriers
Experience in BIM	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	47				
Knowledge of BIM	Pearson Correlation	.312*	1			
	Sig. (2-tailed)	.033				
	N	47	47			
OSM Beneficial	Pearson Correlation	.302*	.338*	1		
	Sig. (2-tailed)	.039	.020			
	N	47	47	47		
BIM Beneficial	Pearson Correlation	.401**	.798**	.568**	1	
	Sig. (2-tailed)	.005	.000	.000		
	N	47	47	47	47	
BIM function for OSM Barriers	Pearson Correlation	.266	.361*	.442**	.564**	1
	Sig. (2-tailed)	.071	.013	.002	.000	
	N	47	47	47	47	47

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed)

6.2.7 Hypothesis

In this section the results of testing hypothesis are presented. To test hypotheses, correlation was used (Table 13). Results of correlation revealed that:

Hypothesis 1: It is hypothesized that the knowledge of BIM will be positively correlated with the BIM function in order to overcome OSM barriers ($r=.36$, $p< 0.05$).

Hypothesis 2: It is predicted that the knowledge of BIM will be positively correlated with OSM Beneficial ($r=.34$, $p< 0.05$). In the other word, Increases the Knowledge of BIM were correlated with increases in OSM Beneficial.

6.2.8 Comparing the Literature Review and Questionnaire Results

According to the literature review that was mentioned in chapter 4 and the results of questionnaire survey, certain OSM barriers that will be solved by integrating BIM for OSM are in common for both section. These common factors are as follows:

1. Problems of Transportation of Precast Elements
2. Fragmented Structure
3. Shortage of Qualified Contractors on Prefabrication
4. Shortage of Experience from Local Jobs
5. Shortage of Qualified Designers in OSM

In addition, the results of literature review confirm that BIM integration for OSM have high potential in order to obstacles OSM barriers in Iran construction industry such as:

1. High Initial cost
2. Monotony of structure
3. Disinclination to Innovation

On the other side, the results of questionnaire survey approve that by BIM integration for OSM can overcome on these critical factors of OSM in Iranian construction such as:

1. Interest in Traditional Construction
2. Shortage of Skilled and Qualified Collaboration Groups
3. Shortage of Skilled Fabricators/Installers

Moreover, the results of questionnaire survey in comparison with literature review that was discussed above is represented in Figure 41.

In addition, by attention to the results of hypothesis test is cleared that by increase the BIM knowledge, demand for OSM construction will be increase. It means by developing BIM tools and consider training courses to increase aware of BIM, OSM construction as a sustainable approach could find its position in Iranian construction to build new units in existing cities or useful method in order to create new cities.

Figure 41: The Results of Questionnaire Survey in Comparison with Literature Review

Chapter 7

CONCLUSION

In this study, to meet the growing demand for housing in Iran, the use of prefabricated building was proposed as a method with indicators of sustainable development. Prefabricated construction has a great potential to reduce costs, reduce time, reduce risks, increase quality and sustainability for the environment. But because of some barriers, prefabricated has failed to achieve its position in the building industry in Iran.

In this study, the major obstacles to the implementation of prefabricated construction were collected from Different scientific resources. Then in the first stage, prepare a questionnaire survey and after analyzing the results, the most important critical barriers of OSM were identified in Iran, which includes 15 factors is respectively as follows:

- The shortage of manufacturers of Precast Components
- Transportation of Precast Elements
- High Initial Cost
- The Shortage of Skilled Fabricators/Installers
- The Shortage of Qualified Designers
- The Shortage of Qualified Contractors on Prefabrication
- The Dependence of Traditional Construction Method
- The Shortage of Governmental Rules and Motivations
- The Lack of Technologies and Testing Institute
- The Shortage of Experience from Local Jobs

- Fragmented Structure
- Disinclination to Innovation
- The Shortage of Guidelines for Precast Components
- The Shortage of Skilled and Qualified Collaboration Groups
- The Shortage of Qualified R&D Institution

BIM due to its ability to create a virtual model of the building with all the characteristics of real buildings, have great potential for increased cooperation and coordination among various groups of the project. BIM can reduce the cost, reduce the time, reduce risks, increase productivity and provide suitable condition for education as well as tracking activities and components during construction.

According to the above, in the second phase of the research, second questionnaire was prepared to evaluate the role of BIM in reducing restrictions and obstacles to the implementation of prefabricated. The results of this study showed, BIM can overcome to the eight barriers out of fifteen critical factor in Iran, which is respectively introduced as follows:

- The Interest In Traditional Construction Method
- The Shortage of Skilled and Qualified Collaboration Groups
- The Problem Associated With Transportation Of Precast Elements
- Fragmented Structure In
- The Shortage of Qualified Contractors On Prefabrication
- The Shortage of Experience from Local Jobs
- The Shortage of Qualified Designers
- The Shortage of Skilled Fabricators/Installers

The results of the study demonstrated that, with the increasing knowledge of BIM can be overcome on some obstacles of prefabricated construction in Iran. Moreover, the results proved that, with increasing awareness of BIM, the interest to use of OSM increases.

As a result, it is expected, according to the increasing development of knowledge and communication, BIM tools have a high potential to overcome to all barriers and constraints of prefabricated in Iran.

Hence, it is recommended to the organizations and governments to prepare proper condition in order to integration these kind of modern construction approach in the building industry in Iran.

7.1 Recommendation for future research

There is a long way to win over all OSM barriers by adoption BIM at least by existing BIM tools. Therefore, by considering one by one OSM limitations and also BIM capabilities of compatibility and extensibility, the researches focus on BIM tools defects with aim to improve tools and give offers is recommended. Moreover, in future research the challenges and barriers to implementation of BIM can be studied in Iran. Also according to the different types of climates in Iran, further research will be useful to choose the best kind of prefabricated construction systems.

REFERENCE

Agur, M., Thom, G., Chipato, F., Breuer, Z., & Hope, H. (2015). Evaluation of UK Futures Programme: final report on Productivity Challenge 1: Offsite Construction.

Alazzaz, F., & Whyte, A. (2014). Uptake of Off-Site Construction: Benefit and Future Application. *World Academy of Science, Engineering and Technology, International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, 8(12), 1168-1172.

Arayici, Y. (2015). *Building Information Modeling* (1st ed., p. 10). Retrieved from http://bookboon.com/en/search?q=building+information+modeling

Arif, M. and C. Egbu (2010). Making a case for offsite construction in China." *Engineering, Construction and Architectural Management* 17(6): 536-548.

Azhar, S., Khalfan, M., & Maqsood, T. (2015). Building information modelling (BIM): now and beyond. Construction Economics and Building, 12(4), 15-28.

Blismas, N. G., Pendlebury, M., Gibb, A., and Pasquire, C. (2005). Constraints to the use of off-site production on construction projects. Archit. Eng. Design Manage. 1(3), 153–162.

Blismas, N., & Wakefield, R. (2009). Drivers, constraints and the future of offsite manufacture in Australia. Construction Innovation, 9(1), 72-83.

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International journal of project management*, 31(7), 971-980.

Chen, L., & Luo, H. (2014). A BIM-based construction quality management model and its applications. Automation in Construction, 46, 64-73.

Deutsch, R. (2011). *BIM and integrated design: strategies for architectural practice*. John Wiley & Sons.

Eastman, C., Eastman, C. M., Teicholz, P., & Sacks, R. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.

Elhag, T., & Al-Sharifi, M. (2014, May). The viability of BIM for UK contractors. In Proceedings of International Conference on Construction in a changing World (pp. 4-7).

Emmitt, S., & Gorse, C. (2010). *Barry's advanced construction of buildings*. John Wiley & Sons.

Ezcan, V., Isikdag, U., & Goulding, J. S. (2013). BIM and off-site manufacturing: recent research and opportunities. In 19th CIB World Building Congress Brisbane, Australia.

Fazli, A., Fathi, S., Enferadi, M. H., Fazli, M., & Fathi, B. (2014). Appraising Effectiveness of Building Information Management (BIM) in Project Management. Procedia Technology, 16, 1116-1125.

Ganiron Jr, T. U., & Almarwae, M. (2014). Prefabricated technology in a modular house. *International Journal of Advanced Science and Technology*, 73, 51-74.

George, D. and Mallery, P. (2003). SPSS for Windows step by step. *A simple guide and reference*. 11.0 update (4th ed.). Boston: Allyn & Bacon.

Goodier, C., and Gibb, A. (2004). Barriers and opportunities for offsite in the U.K., Loughborough Univ, Loughborough, U.K.

Hardin, B., & McCool, D. (2015). *BIM and construction management: proven tools, methods, and workflows*. John Wiley & Sons.

Jaillon, L. C. (2009). The evolution of the use of prefabrication techniques in Hong Kong construction industry (Doctoral dissertation, Department of Civil and Structural Engineering, The Hong Kong Polytechnic University).

Jalaei, F., & Jrade, A. (2015). Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings. Sustainable Cities and Society, 18, 95-107.

Kamali, M., & Hewage, K. (2016). Life cycle performance of modular buildings: A critical review. Renewable and Sustainable Energy Reviews, 62, 1171-1183.

Kamar, K. A. M., Alshawi, M., & Hamid, Z. (2009, January). Barriers to industrialized building system (IBS): The case of Malaysia. In BuHu 9th Int. Postgraduate Research Conf.(IPGRC) (pp. 471-484). University of Salford, Salford, UK.

Khalfan, M., & Maqsood, T. (2014). Current State of Off-Site Manufacturing in Australian and Chinese Residential Construction. *Journal of Construction Engineering*, 2014.

Kim, M. K., Cheng, J. C., Sohn, H., & Chang, C. C. (2015). A framework for dimensional and surface quality assessment of precast concrete elements using BIM and 3D laser scanning. Automation in Construction, 49, 225-238.

Kolo, S. J., Rahimian, F. P., & Goulding, J. S. (2014). Offsite Manufacturing: The Way Forward for Nigeria's Housing Industry. ALAM CIPTA, *International Journal of Sustainable Tropical Design Research and Practice*, 7(1), 35-40.

Krug, D. & Miles, J. (2013). Offsite Construction: Sustainability Characteristics (1st Ed.). London. Retrieved from http://www.firstpenthouse.com/wp-content/uploads/Offsite-Construction.pdf

Lawson, M., Ogden, R., & Goodier, C. (2014). *Design in modular construction*. CRC Press.

Lovell, H., & Smith, S. J. (2010). Age cement in housing markets: the case of the UK construction industry. Geoforum, 41(3), 457-468

Mao, C., Shen, Q., Pan, W., & Ye, K. (2013). Major Barriers to Off-Site Construction: The Developer's Perspective in China. *Journal of Management in Engineering*.

Miles, J., & Whitehouse, N. (2013). Offsite Housing Review. *Department of Business, Innovation & Skills and the Construction Industry Council, London*.

Moghadam, M., Alwisy, A., & Al-Hussein, M. (2012, May). Integrated BIM/Lean Base Production Line Schedule Model for Modular Construction Manufacturing. In Construction Research Congress, ASCE (pp. 1271-1280).

Molavi, J., & Barral, D. L. (2016). A Construction Procurement Method to Achieve Sustainability in Modular Construction. Procardia Engineering, 145, 1362-1369.

Mordue, S., Swaddle, P., & Philp, D. (2015). *Building Information Modeling for Dummies*. John Wiley & Sons.

Mullens, M. A. and M. Arif (2006). Structural insulated panels: Impact on the residential construction process. *Journal of construction engineering and management* 132(7): 786-794.

National Building Specification. (2016), 21 April 2016, from https://www.thenbs.com/periodic-table-of-bim

Nawari, N. O. (2012). BIM standard in off-site construction. *Journal of Architectural Engineering*, 18(2), 107-113.

NBIMS. (2012). National BIM Standard - United States TM Version 2. National Institute of Building Sciences building SMART Alliance TM.

Norusis, M. J. (2008). SPSS 16.0 *advanced statistical procedures* companion, Prentice-Hall, Upper Saddle River, NJ.

O'Connor, J. T., O'Brien, W. J., & Choi, J. O. (2014). Critical success factors and enablers for optimum and maximum industrial modularization. *Journal of Construction Engineering and Management*, 140(6), 04014012.

Pan, L. (2008). Study on the restricting problems and countermeasures of housing industrialization of China. M.Sc. thesis, Chongqing Univ., Chongqing.

Pan, W., Gibb, A. G., & Dainty, A. R. (2007). Perspectives of UK house builders on the use of offsite modern methods of construction. Construction Management and Economics, 25(2), 183-194.

Ramaji, I. J. (2016). An Integrated Building Information Modeling (BIM) Framework for Multi-story Modular Buildings (Doctoral dissertation, Architectural Engineering).

Reddy, K. P. (2012). *BIM for building owners and developers: making a business case for using BIM on projects*. John Wiley & Sons.

Rogan, A. L., Lawson, R. M., & Bates-Brkljac, N. (2000). Value and benefits assessment of modular construction. The Steel Construction Institute, Ascot.

Singh, M. M., Sawhney, A., & Borrmann, A. (2015). Modular coordination and BIM: Development of rule based smart building components. Procedia Engineering, 123, 519-527.

Succar, B. (2009, May). Building Information Modelling framework: a research and delivery foundation for industry stakeholders. *Automation in Construction, 18*(3), 357-375.

Wong, J. K. W., & Zhou, J. (2015). Enhancing environmental sustainability over building life cycles through green BIM: A review. Automation in Construction, 57, 156-165.

Zhang, J., Long, Y., Lv, S., & Xiang, Y. (2016). BIM-enabled Modular and Industrialized Construction in China. Procedia Engineering, 145, 1456-1461.

Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C. M., & Teizer, J. (2015). BIM-based fall hazard identification and prevention in construction safety planning. Safety Science, 72, 31-45.

Zhang, S., Teizer, J., Lee, J. K., Eastman, C. M., & Venugopal, M. (2013). Building information modeling (BIM) and safety: Automatic safety checking of construction models and schedules. Automation in Construction, 29, 183-195.

APPENDIX

Appendix A: Questionnaire A

The Benefits of Off-Site Manufacturing and Measure the Critical Barriers of OSM

I am a student in construction management at Eastern Mediterranean University, Famagusta, Cyprus. This survey questionnaire is a part of the dissertation project. Thank you for participating in my survey. Your feedback is important.

For more information, please contact me on:
Hassan Nejat
Phone: + (90) 5338335807
Email: hassan.nejat@students.emu.edu.tr

Section 1- General Information

1. Which of the following best describe your job function?

- ☐ Faculty member
- ☐ Architecture
- ☐ Construction manager
- ☐ Civil Engineer
- ☐ Owner
- ☐ Supplier / Manufacturer
- ☐ Contractor

2. Your education?

- ● Bachelor Degree
- ● Master Degree
- ● PhD

3. How many years do you have experience in construction industry?

- Less than 5 years
- 5-10 years
- 10-15 years
- 15-20 years
- More than 20 years

4. How many years do you have experience in off-site construction industry?

- Less than 5 years
- 5-10 years
- 10-15 years
- 15-20 years
- More than 20 years

Section 2- The Benefits of Off-Site Manufacturing

Utilization of prefabricated structures is increasing due to have the benefits for sustainable development in developed countries. Thus, according to this approach, this section is designed in order to examine some of the benefits and advantages of off-site manufacturing in Iran

5- The use of offsite manufacturing reduces the project construction cost in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

6- The use of offsite manufacturing reduces the project construction time in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

7- The use of offsite manufacturing will increase consumer confidence in the quality of construction in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

8- The use of offsite manufacturing will prevent the entry of non-experts in construction industry in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

9- The use of offsite manufacturing will increase more productivity of human resource in construction in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

10- The use of offsite manufacturing will decrease legal problems in construction industry in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

Section 3 - Measure the Critical Off-Site Barriers in Construction Industry In Iran

11- What extent can effect high initial cost on non-use of prefabricated construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

12- What extent can effect Incertitude of Market Request on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

13- What extent can effect Shortage of Technologies for prefabricated components on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

14- What extent can effect Doubt about Stability of Prefabricated on non-use of offsite construction in Iran?

- Very Low
- Low

- Average
- High
- Very High

15- What extent can affect the Shortage of Governmental Rules and Motivations on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

16- What extent can effect Transportation of prefabricated elements problems in offsite construction on non-use of them in Iran?

- Very Low
- Low
- Average
- High
- Very High

17- What extent can affect the interest to traditional construction method on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

18- What extent can affect the shortage of manufacturers of prefabricated components on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High

- Very High

19- What extent can affect the Shortage of Qualified Designers in offsite construction on non-use of them in Iran?

- Very Low
- Low
- Average
- High
- Very High

20- What extent can effect Unable to modify design scheme on non-use of offsite manufacture in Iran?

- Very Low
- Low
- Average
- High
- Very High

21- What extent can effect Difficulty to the storage of prefabricated elements on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

22- What extent can affect the Shortage of Qualified Contractors on prefabrication on non-use of them in Iran?

- Very Low
- Low
- Average
- High
- Very High

23- What extent can effect Monotony of structure on non-use of prefabricated construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

24- What extent can affect the Shortage of Skilled and Qualified Collaboration Groups on non-use of offsite construction in Iran?

- Very Low
- Low
  - Average
- High
- Very High

25- What extent can effect Disinclination to Innovation in offsite construction on non-use of them in Iran?

- Very Low
- Low
- Average
- High
- Very High

26- What extent can affect the Lack of practices and experiences from local projects on non-use of prefabricated construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

27- What extent can affect the Shortage of Skilled Fabricators/Installers on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

28- What extent can affect the Shortage of Qualified R&D Institution and services on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

29- What extent can effect High cost pressure without economics scale effect on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

30- What extent can effect Fragmented industry structure on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

31- What extent can effect longer lead-in time during design stage on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

32- What extent can affect the Lack of standards for prefabricated components on non-use of offsite construction in Iran?

- Very Low
- Low
- Average
- High
- Very High

Appendix B: Questionnaire B

Implementation of BIM for off-site manufacturing

I am a student in construction management at Eastern Mediterranean University, Famagusta, Cyprus. This survey questionnaire is a part of the dissertation project. Thank you for participating in my survey. Your feedback is important.

For more information, please contact me on:

Hassan Nejat

Phone: + (90) 5338335807

Email: hassan.nejat@students.emu.edu.tr

Section 1- General Information

1. Which of the following best describe your job function?

- ☐ Faculty member
- ☐ Architecture
- ☐ Civil Engineer
- ☐ Owner
- ☐ Manufacturer
- ☐ Construction manager
- ☐ Other: ______

2. Your education?

- Bachelor Degree
- Master Degree
- PhD

3. How many years do you have experience in construction industry?

- Less than 5 years
- 5-10 years
- 10-15 years
- 15-20 years
- More than 20 years

4. How many years do you have experience in BIM?

- 1-3
- 3-6
- 6-10
- More than 10

5. Is it necessary that all engineering in construction industry should have be BIM knowledge?

- YES
- NO

6**.** Is it necessary the construction manager should be BIM expert?

- YES
- NO

7. How much is your awareness about BIM?

- Very poor
- Poor
- Fair
- Good
- Very good

Section 2- Building Information Modeling

The aim of this section is to investigate benefits and advantages of BIM function in Iran.

8- BIM function will prevent to entrance Non-experts in construction industry in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

9- BIM function will increase consumer confidence in the Quality of construction in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

10- BIM function will decrease Legal Problems in construction industry in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

Section 3 – Functionality of BIM for OSM Barriers and Limitation

Thanks to technological advances in recent years, building information modeling have been proposed as a new approach in the construction industry. Therefore, according to the abilities and capabilities of this method for simulation, analysis and modeling of buildings is expected using this approach and integration with Off-Site Construction can resolve the challenges and limitations in prefabricated application. Questions this section has been set in order to this issue.

11- BIM function can resolve the shortage of manufacturers of precast components in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

12- BIM function can resolve Transportation of prefabricated elements problems in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

13- BIM function can resolve High Initial Cost problem in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

14- BIM function can resolve the Shortage of Skilled Fabricators/Installers for offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

15- BIM function can resolve the Shortage of Qualified Designers in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

16- BIM function can resolve the Shortage of Qualified Contractors in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

17-BIM function can resolve the Interest to traditional construction method in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

18- BIM function can resolve the Shortage of Governmental Rules and Motivations in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

19- BIM function can resolve the Shortage of Technologies for prefabricated components in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

20- BIM function can resolve the Shortage of Experience from Local Jobs problem in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

21- BIM function can resolve Fragmented industry structure in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

22- BIM function can resolve Disinclination to Innovation problem in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

23- BIM function can resolve the Lack of standards for prefabricated components in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

24- BIM function can resolve the Shortage of Skilled and Qualified Collaboration Groups in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

25- BIM function can resolve the Shortage of Qualified R&D Institution and services in offsite manufacturing in Iran.

- Strongly Disagree
- Disagree
- Neural
- Agree
- Strongly Agree

26- What is your opinion about benefits of offsite construction by integration BIM and use this method for future projects?

- Not at all beneficial
- Slightly beneficial
- No opinion
- Beneficial
- Very beneficial