# A Study on the Critical Success Factors using BIM for Precast Structures in the UAE's Construction Industry

**دراسة عن عوامل النجاح الحرجة باستخدام( بيم) نمذجة معلومات المباني للهياكل سابقة الصب في صناعة البناء في دولة الإمارات العربية المتحدة**

**by**


## Muneera AbdulKarim Ahmed


**A dissertation submitted in fulfilment**

**of the requirements for the degree of**

**MSc CONSTRUCTION MANAGEMENT**

**at**

**The British University in Dubai**

## Dr. Khalid Almarri

**June 2017**

# DECLARATION

I warrant that the content of this research is the direct result of my own work and that any use made in it of published or unpublished copyright material falls within the limits permitted by international copyright conventions.

I understand that a copy of my research will be deposited in the University Library for permanent retention.

I hereby agree that the material mentioned above for which I am author and copyright holder may be copied and distributed by The British University in Dubai for the purposes of research, private study or education and that The British University in Dubai may recover from purchasers the costs incurred in such copying and distribution, where appropriate.

I understand that The British University in Dubai may make a digital copy available in the institutional repository.

I understand that I may apply to the University to retain the right to withhold or to restrict access to my thesis for a period which shall not normally exceed four calendar years from the congregation at which the degree is conferred, the length of the period to be specified in the application, together with the precise reasons for making that application.

________________________

Signature of the student

# Abstract

Building Information Modeling (BIM) is useful for construction industry in the UAE but the process of adoption is very low and slow, and it might be because of lack of studies and researches in this area conducted in the UAE. In this study, several areas of adoption related challenges examined in this study, which creates issues to adopt BIM for precast structures. This study also investigated critical success factors that influence implementation of construction projects in the UAE. As per literature review findings, the best practice is BIM for precast structure in various nations and regions. Engineers and contractors also considered the critical success factors and benefits of BIM so they can adopt successfully. The conceptual framework consists of BIM for precast adoption, the best practices, and critical success factors. In this study, the qualitative and quantitative approach including suitable tools and techniques applied. In addition, in this study, the data collection methods used was 8 interviews, 44 surveys, and 5 pilot testing. Accordingly, these methods used were also conducted to ensure the validity and reliability of an instrument. Qualitative data analysis applied with the use of summarizing, categorizing, and structuring data gathered for analysis using narrative forms. Quantitative data analysis applied with the use Question Pro analytical tools. There are various ethical considerations mentioned during conducting research followed by data analysis. The respondents participated are from the public and private sector, and they possess good knowledge about precast structure use and the implementation of BIM. There is a positive impact and CSFs includes various positive relationships. The data showed that time, quality and cost factors are important for the implementation of BIM and in the use of precast structures. By the end of this study, the recommendations were for policy-makers and project managers to implement BIM. Another recommendation includes for policy makers, so they should emphasize widely on challenges faced towards BIM implementation at both project and strategic level. While, project managers should select suitable BIM software based on suitable specifications and characteristics.

**Keywords:** Information Technology, Building Information Modelling (BIM), 3D Modelling, Precast Structures, UAE Construction Industry, Critical Success Factors, Construction Management, Interviews and Surveys.

## ملخص البحث:

يعد استخدام نظام نمذجة معلومات البناء مفيد جداً لسوق الإنشاءات في دولة الإمارات العربية المتحدة، لكنه لا يجد رواجاً كبيراً ويواجه تدني وبطء نوعاً ماً في عملية تبنيه والعمل به، وقد تعود الأسباب إلى قلة الدراسات والأبحاث المنفذة على بيئة الأعمال في دولة الإمارات في هذا الشأن. ومن خلال هذه الدراسة فإننا نستعرض بعضاً من جوانب التحديات المدروسة حول إمكانية تبني هذه التقنية، مما يخلق فرصة لتطبيق وتبني التقنية على الهياكل الخراسانية سابقة الصب. أيضاً من خلال هذه الدراسة سوف نسلط الضوء على عوامل النجاح التي من شأنها أن تؤثر على تنفيذ المشاريع الإنشائية في دولة الإمارات. ووفقاً للنتائج التي تمت الإشارة إليها في ملخص البحث، فإن استخدام تقنية نمذجة معلومات البناء هي الممارسة الأفضل تطبيقاً للعناصر الخرسانية سابقة الصب في دول ومناطق مختلفة. والجدير بالذكر أن الكثير من المهندسين والمقاولين قد لاحظوا فوائد وعوامل نجاح استخدام هذه التقنية مما سيسهل تقبلهم واعتمادهم لها بنجاح.

بالمجمل فإن الإيطار النظري للدراسة يشتمل على المحاور التالية: شرح اعتماد تقنية نمذجة معلومات البناء في العناصر الخرسانية سابقة الصب، استعراض أفضل الممارسات وعوامل نجاح التقنية. كما أننا من خلال هذه الدراسة أيضاً سنستعرض كيفية تطبيق التقنية وفق المنهج الكمي والنوعي وباستخدام الأدوات والتقنيات المطبقة. إضافة إلى ذلك، فإن طريقة جمع المعلومات والبيانات تنوعت بين المقابلات الشخصية وإجراء عدد 8 مقابلات، وعدد 44 استبيان، و5 اختبارات تجريبية. مما ساهم في إثبات توفر وواقعية استخدام التقنية. تم تطبيق التحليل النوعي للبيانات باستخدام التلخيص والتصنيف وهيكلة البيانات عن طريق ربط المعلومات وخلق العلاقات بين كل منها حيث تم جمعها بعد ذلك وعرضها في صورة سرد مبسط. تم تنفيذ هذا النوع من التحليل باستخدام الأدوات الاحترافية للأسئلة التحليلية. هنالك العديد من الاعتبارات الأخلاقية تمت مراعاتها خلال هذا البحث وتم تدعيمها بالبيانات التحليلية. تنوعت الفئات المشاركة في البحث بين القطاعات الحكومية والخاصة. حيث تبين امتلاكهم معرفة جيده حول استخدام الهياكل الخرسانية سابقة الصب وتطبيق تقنية نمذجة المعلومات بها.

من خلال تطبيق هذه التقنية نتوصل إلى وجود تأثير إيجابي وعوامل نجاح قطعية تتضمن علاقات إيجابية متنوعة، حيث أظهرت البيانات أن عوامل الوقت والجودة والتكلفة مهمة لتطبيق نمذجة معلومات البناء في الهياكل الخراسانية سابقة الصب. وفي ختام هذه الدراسة، جاءت التوصيات موجهة إلى واضعي السياسات ومديري المشاريع لتنفيذ تقنية نمذجة معلومات البناء. كما وجهت توصية أخرى إلى صانعي السياسات، ليتم التركيز بشكل موسع على التحديات التي تواجه تطبيق تقنية نمذجة معلومات البناء على مستوى المشروع والمستوى الاستراتيجي على حد السواء. وفي حين أنه ينبغي على مديري المشاريع اختيار برمجيات نمذجة معلومات البناء المناسبة استنادا إلى المواصفات والخصائص.



كلمات البحث: تكنولوجيا المعلومات، نمذجة معلومات البناء، النمذجة ثلاثية الأبعاد، الهياكل الجاهزة، سوق الإنشاءات في دولة الإمارات العربية المتحدة، عوامل النجاح القطعية، الإدارة الإنشائية، المقابلات والمسوحات.

# Table of Contents

# List of Tables

# List of Figures

# Chapter 1.0 Introduction

## 1.1 Background

Precast concrete manufacturing industry consists of precast and prestressed concrete manufacturers producing these products to be used in construction markets. Some of the products are precast concrete panels and slabs, posts, poles, railroad ties, roofing tiles, building boards, prestressed bridge trusses and beams (IBISWorld, 2016). The production of precast concrete takes place through concrete casting and they are for construction of buildings, infrastructure construction and more. The production takes place usually at the construction sites or in the plant. Precast concrete industry globally is improving after a weak fall due to recession. The key players in precast concrete manufacturing industry are Coltman Precast Concrete, CEMEX SAB de CV, CRH PLC, Metromont, Coreslab International, Oldcastle Precast, and many others (Clare, 2016). In 2016, the forecast is at 7 per cent increase in the prestressed, precast and reinforced concrete by bringing total sales volume to USD 22.7billion as per NPCA. Since 2014, precast manufacturers are rising in sales of prestressed, precast and reinforced concrete products. It is expected that the industry will continue to recover with 7 per cent growth in 2016 (see Figure 1) (Whitmore, 2016).

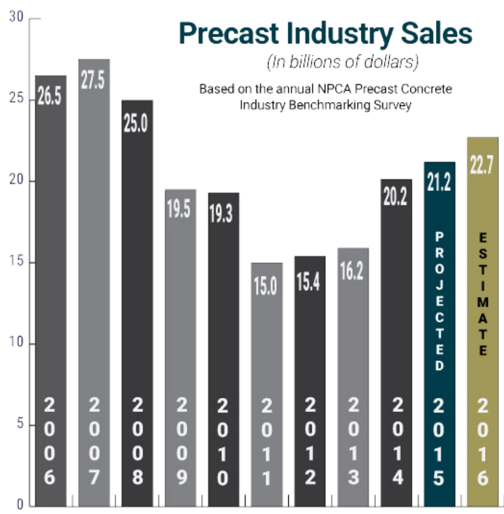



Figure 1: Precast Industry Sales 2006-2016 (Whitmore, 2016)

In GCC countries, there is a direction of massive investment taking place in the construction sector due to precast concrete demand. FIFA World Cup 2022 and Expo 2020 are global events that require large architectural projects so the consumption of precast products shows the boost, as expected in the region. Usage of precast products offers interesting benefits so an increase in demand is likely to continue in the future (AEC Online, 2014). In the UAE, Abu Dhabi is a very attractive market for precast suppliers due to upcoming projects while Dubai sees a surge in 2015. Due to Expo 2020, it is expected that precast industry will positively grow due to use of precast products. The opportunity is based on precast temporary products that can be removed and unassembled once the event is over so it can be transported to different location. Some of the examples are custom bespoke and tilt-up walls and they are forms of precast products so Expo 2020 needs can be catered. In the UAE, major recast manufacturers are Dubai Precast, United Precast Concrete, Emarat Europe, Exeed Precast, Xtramix International Precast, Abu Dhabi Precast Factory, and Gulf Precast Concrete (AEC Online, 2014).

## 1.2 Precast Description

### 1.2.1 Relationship between Precast and Steel Concrete

There is a strong relationship between precast and steel structure. When comparing both, structural and production behavior comes together are between beams and columns. Concrete exhibits no strength so it is needed to provide reinforcing material. Accordingly, it shows that the reinforced concrete is composite of two materials, so required performance can be provided. In concrete reinforcement, the most commonly used is steel. Therefore, it shows that precast concretes are similar to steel concrete (Bryan, 2010). The two methods of construction are almost very similar. With certain specifications, the components of either precast or steel are ordered from pilot plant. Before all this, there is need for good schedule and plan. Steel construction is usually employed due to planning reasons. Due to the absence of good planning, there are chances of problems to occur during the process of construction and particularly during the installation of components. There is need for recognizing steel structure design with details such as welding strength, bolt size, connection type, etc. in the finishing part, precast and steel finishing shows not too similar because there is need for steel surface protection from any damage or fire. Therefore, it shows that final product when comparing precast and steel structure, there will be a difference in terms of interface (Abidin, 2007).

### 1.2.2 Precast Support from UAE Government

UAE experiences a significant increase in the use of precast concrete for not only small-scale projects but also large-scale projects. The benefits of precast structure considered are environmental, economic, and logistical benefits. It shows that the use of precast structures will be increasing interestingly during the coming years. According to figures shared by Abu Dhabi Chamber of Commerce and Industry, the precast industry in the UAE is valued at AED 5.87billion. Conventional concrete is not preferred because while using precast fabrications, there is a reduction of nearly 25 per cent of labor costs (Bohlen, 2012). The author can relate expected benefits triggering usage of precast products by UAE and support given with valuation. Sacks, *et al*. (2005) summarizes about various benefits of using precast structure in the construction. Some of the benefits are streamlined procurement, enhanced customer service, eliminated costs of rework, directed information inflow from sales to engineering, reduced lead times, and improved productivity engineering.

Dubai Municipality expanded and enforced Green Building Regulations, which is the latest movement to push the construction sector for sustainable future in long-term from 2014 onwards. It is now mandatory for government buildings to enforce regulations, and it is expected to become mandatory for the private sector as well. Due to this legislation opened opportunities for construction sector and increase in the use of precast products. Now, it is one of the main materials used in buildings and constructions in the region. It is a move towards environmental and sustainability awareness (Waugh, 2013).

Modern Residential City is an example from Green Precast Systems and Technologies and production is worth AED 450million. They are committed in supporting the government to deliver sustainable technologies and environment friendly solutions to the UAE. The quality is high-tech and a method of construction that enables 3D monolithic precast solution to make significant savings from both construction and ongoing costs (Green Precast Systems and Technologies LCC, 2010).

## 1.3 Problem Definition

The precast industry is facing some of the following challenges: (AEC Online, 2014).

- The rising difficulty of projects where in-house expertise works on their needs.
- Locating nearby manufacturers of precast is very important for lower transportation costs.
- Exporting precast products are not considered and neglected, due to high costs transportation.
- Using precast is done when there are a similar shaped and large number of components.
- Competing is not easy, because precast industry is highly competitive marketed.

After knowing these challenges, precast manufacturers are now price conscious and they are establishing mobile precast manufacturing plants so they can be competitive. The estimation is that more than 127 precast concrete players exist in the GCC. The largest presence is in the UAE, Saudi Arabia and Qatar as major suppliers in the region while driving the precast industry's growth (AEC Online, 2014). There are unique problems in precast concrete structures such as lateral bracing in the absence of considerable lateral stability. Therefore, the dealing is in a similar manner for beam and post structures of steel or wood (Ambrose, 1993).

There is need for insight on designing and verifying high-rise buildings with precast concrete as core composition. Even though precast concrete delivers with economy, efficiency and sustainability, there are a number of issues with some misapprehensions about precast concrete. There are concerns over precast concrete looks. Many do not know about the benefits of precast concrete and knowledge is lacking. Another issue is longer lead times when using cast-in-situ. Project communication is inadequate among the structural precast, designer and contractor. Moreover, there is a shortage of precast detailing, design and installation expertise

(Pickup, 2013). There is lack of studies supporting BIM precast solutions in the construction and related critical success factors and problems are not clearly addressed for tackling and solving.

## 1.4 Aim and Objectives of Research

The aim of this research study is to establish about BIM for precast structure use, challenges and critical success factors in the construction industry of the UAE. The aim of this study is determined based on two steps. In the first was detailed and careful literature research to identify the best practices in BIM for precast implementation globally and the establishment of critical success factors and challenges. Second, interview and survey questionnaires designed to gather data for the establishment of critical success factors and challenges that UAE might take advantage or face. Therefore, in order to achieve research aim, the following research objectives are identified:

- To investigate the best practices in BIM precast globally.
- To examine critical success factors for BIM precast in the UAE.
- To identify and investigate challenges in BIM precast that UAE faces.
- To establish critical success factors for the implementation of BIM precast in the UAE.

## 1.5 Significance

The purpose of this research study is to improve knowledge of challenges and critical success factors of BIM in precast structure usage in the UAE. Expo 2020 achievement will speed up the process of precast structure usage so this study outlines factors to ensure success and strategic plan to overcome challenges.

The importance and significance of this research study towards construction industry can increase the level of BIM precast awareness and knowledge by introducing guidelines and policy for effective implementation. From this research study, it is possible to identify critical success factors and challenges hindering the success of BIM for precast.

## 1.6 Scope of Research Study

The scope of this research study is to address issues affecting precast usage and critical success factors for BIM precast manufacturers to embrace precast structures in the construction industry. The study is limited to public sector and private sector in the UAE.

## 1.7 Research Structure

This study intends to examine issues that are creating problems in use of BIM for precast and determine critical success factors that will influence the overall implementation of construction projects in the UAE. Overall, the structure of study consists of six chapters: introduction, literature review, research methodology, discussion and analysis, and conclusion and recommendations.

Chapter 1 presents the first chapter research topic introduction and related background and description. In addition, this chapter includes problem definition, aim and objectives of this research study, and significance and scope of the study.

Chapter 2 provides review of literature with investigation on steel structures, precast structures, BIM for precast, related challenges, and critical success factors.

Chapter 3 presents research methodology implemented in this thesis, which includes a qualitative and quantitative method based on 15 interview and 100 survey questionnaires and their distribution in organizations in the public sector and the private sector.

Chapter 4 details interview and survey findings and results on BIM for precast challenges and success factors. It also provides details on data collection during the research study.

Chapter 5 consists of discussions and investigation of the research topic and limitations of the study along with recommendations for further work.

Chapter 6 concludes the research study through the summary of the findings.  It will also include strategic guide description and recommendations.

# Chapter 2.0 Literature Review

## 2.1 Background

Chapter 2 provides literature review with investigation in the best practices from across the world based on the precast adoption level, BIM for precast, related benefits and critical success factors to overcome challenges in conventional precast concrete structures.

In 2001, the precast Concrete Software Consortium formation took place. It represents building modeling software of three-dimensional (3D) leveraging so competitiveness can be maintained in construction technologies. In order to adopt BIM, benefits and costs were assessed in terms of short-term economic reasons for BIM precast concrete engineering. Proposed methodology reduces in duration and cost based on the estimation on individual and at the level of engineering activities such as design and drafting. The results are assessed collectively in the complete process framework. Usage of the 3D parametric modeling undertook with SDS/2® and Xsteel® applications (Sacks *et al*., 2005).

The consideration of BIM took place based on economical advantageous offered in the steel structural fabrication. The current adoption is in precast concrete capabilities and construction for reinforced concrete cast-in-place development. Promoters and adopters of BIM in engineering, architecture and construction industry where closest to phase in constriction such as contractors, fabricators, etc. rather than generators of information related building. Many prefer to use and introduce BIM because they are useful during design and analysis process. A greater share of the overall workload is reduced on engineers through BIM (Sacks, and Barak, 2006).

BIM software resolves many technical problems during precast processes. The costs of engineering are reduced along with the reduction in errors as well. Moreover, it is support for production automation and engineering lead-time reduction (Sacks *et al*., 2005). BIM for precast such as BIM is widely used and widely accepted. BIM development took place from computer-aided design (Sacks, Kaner, Eastman, & Jeong, 2010).

It consists of BIM for designing and detailing buildings that also includes exchange of building information among project stakeholders and project lifecycle stages based on the computer (Sacks, Kaner, Eastman, & Jeong, 2010). In project data management and design, BIM generates methodology that is essential for project data and building design based on the set of interacting processes, policies and technologies in digital format (Penttilä, 2006). It enables integrated delivery and intelligent simulation of architecture (Eastman, 2008).

Lee, & Ha (2013) describes that BIM offers and meets various customer needs. The walls design can be moveable walls and separate fixed walls. They studied customer satisfaction about new design and model house. According to the results found, BIM provides designs based on changes at an individual level of desire while reducing the need fro designers. Figure 2 illustrates the process of design in five steps. Firstly, the participants are able to see "84 $m^2$ F-type model house". They are able to view 3D images based on new design and alterations can be done immediately.

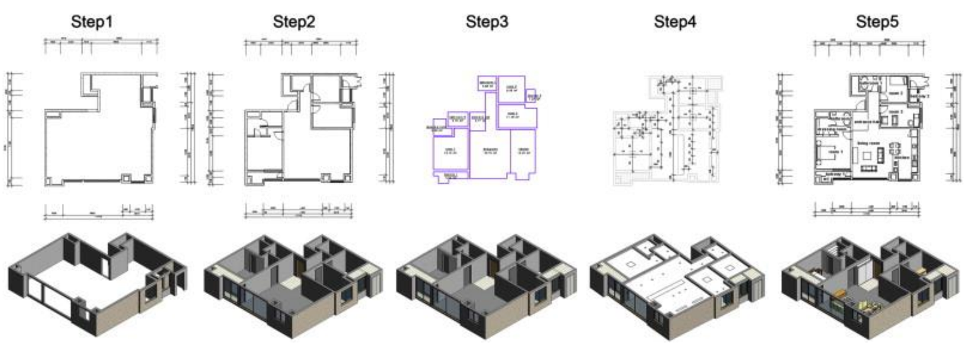



Figure 2: BIM Design Process/Steps (Lee, & Ha, 2013)

BIM is a process to create, use and manage project data and design and it is visualized based on technology and 3D digital models with intelligence (Succar, 2009; Eastman, Teicholz, Sacks, & Liston, 2011). The function of BIM is by attaching relevant information to virtual columns, walls, plumbing, electrics, etc. for defining and controlling their behavior and properties. The inclusions are in the information such as relational geometrical qualities, design performance, geometry, scheduling, supplier, material qualities, and more (Eastman, Teicholz, Sacks, & Liston, 2011).

According to Eadie, et al. (2015), BIM is defined as managed 3D consists of tools with attached data and it is held in separate discipline. Bennett (2012) details the important role of BIM as an intelligent process that is model-based to gain better insight while accelerating management, construction, design, and planning economically with less costs and environmental impact. It consists of design tools with an innovative approach, facilitates in the retrofit, and rehabilitates aging urban infrastructure and transportation projects. Highly detailed BIM are created through BIM and some of the examples are bridge tunnels and utilities, railways, and roads to enable construction, engineering, government, public and business communities to better recognize the plan alternatives and the task. BIM software helps in the identification, diagnoses, the prediction of problems that infrastructure in the city might experience in the future through seismic proceedings and possible impacts.

## 2.2 BIM Precast Adoption Levels

BIM modeling was first introduced before 15 years but very few organizations are using for precast. It can be applied in Architecture, Engineering, and Construction sectors in production. This pioneering development is by the Precast Concrete Software Consortium (PCSC) for the BIM precast modeling system. The major precast producers are in the US and Canada (Lee, et al., 2004). BIM are potentials in producing precast (McCraven, 2010). Figure 3 illustrates BIM modeling for precast buildings that consists of internal exchanges, enterprise applications, design stage and production stage. All these are brought together with BIM within BIM.

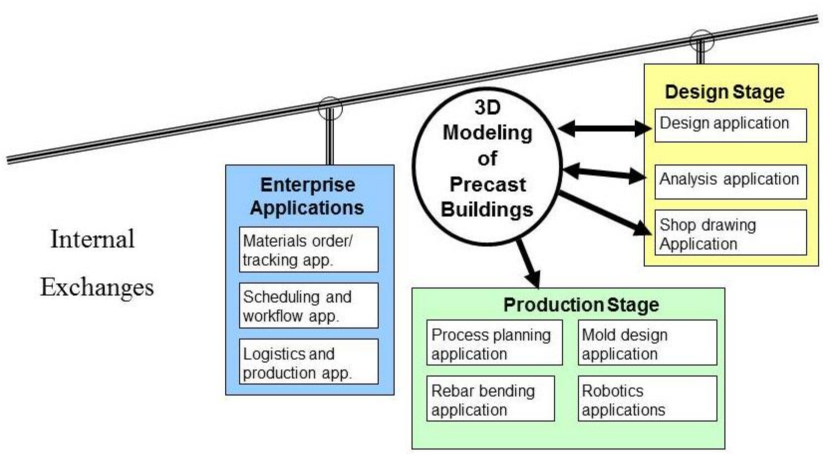


Figure 3: BIM Modeling for Precast Buildings (Eastman, and Sacks, 2002)

In 2001, the Precast Concrete Software Consortium formation took place. It represents BIM software of three-dimensional (3D) leveraging so competitiveness can be maintained in construction technologies. In order to adopt BIM, benefits and costs were assessed in terms of short-term economic reasons for BIMprecast concrete engineering. Proposed methodology reduces in duration and cost based on the estimation on individual and at the level of engineering activities such as design and drafting. The results are assessed collectively in the complete process framework. Usage of BIM parametric modeling undertook with SDS/2® and Xsteel® applications (Sacks *et al*., 2005).

Howard and Björk (2008) recommend that BIM implementation is of great potential in the development of project team role while coordinating the use of project models throughout the project cycle. In contrasts, Broquetas (2011) states that project managers should be proficient in BIM so they can be in charge of overall management in BIM and this is as per findings and respondents.

In the recommendation by Froese (2010) also suggests that BIM practices are advancing so it is necessary to exploit advantages offered during the evolution of project management practices. The findings conclude that the implementation should be unified the project management approach because BIM is collaborative in nature and does not require project work division into disparate tasks. Kymmell (2007) also argues that new roles are already created by BIM such as BIM manager to synchronize with the project team, the BIM facilitator and the BIM operator to create and assist in 3D model creation and simulations.

According to a survey conducted by McGraw Hill Construction (2012), it shows that use of BIM increased from 28% to 71% from 2007 to 2012 in North America. At the same time, the adoption levels in the UK also increased from 13% to 39% between 2010 to 2012. It indicates that in order to industrialize BIM, there are many efforts made by the Government of the UK.

Eadie, et al., (2015) studied BIM adoption in the current status of the UK. From 2016, the UK government mandated the use of BIM for government related projects. The findings made shows the adoption took place due to technical aspects of BIM and client demand is boosting adoption of BIM. However, there is need for structural changes due to effect on consultant fees.

China adopted and made BIM initiative with 5 years plan from 2013. The efforts started with national guidelines in the development of BIM (Hong Kong Construction Industry Council, 2013). In Finland, it is a requirement by the government to meet the IFC standard since 2007 in all projects. The objective is to integrate BIM model to design, build, service, and maintain property in not many years. Singapore also worked towards the application of BIM to mandate, which is part of government development from 2015 (buildingSMART Australasia, 2012).

Rogers, Chong, & Preece (2015) point out that BIM is well received in Malaysian construction industry, but the rate of adoption is tremendously slow. They found that BIM concepts exist in firms but there is lack of training in the industry with little governmental support and guidance indicating as the main barriers to adopt BIM. However, the firms are ready to adopt BIM when there are competitive advantage and market demands within two years.

McGraw Hill Construction (2014) details that in various regions and countries, it shows that BIM is rapidly expanding around the world, but there are major differences in BIM benefits and experience. Figure 4 shows the percentage of contractors' implementation levels by the country with comparison of 2013 and 2015. At 79% and 55%, US contractors are leading in the implementation of BIM with the increase of 24% in 2015. Brazilian contractors rank second with 73% and 24% with an increase at 49% in 2015.

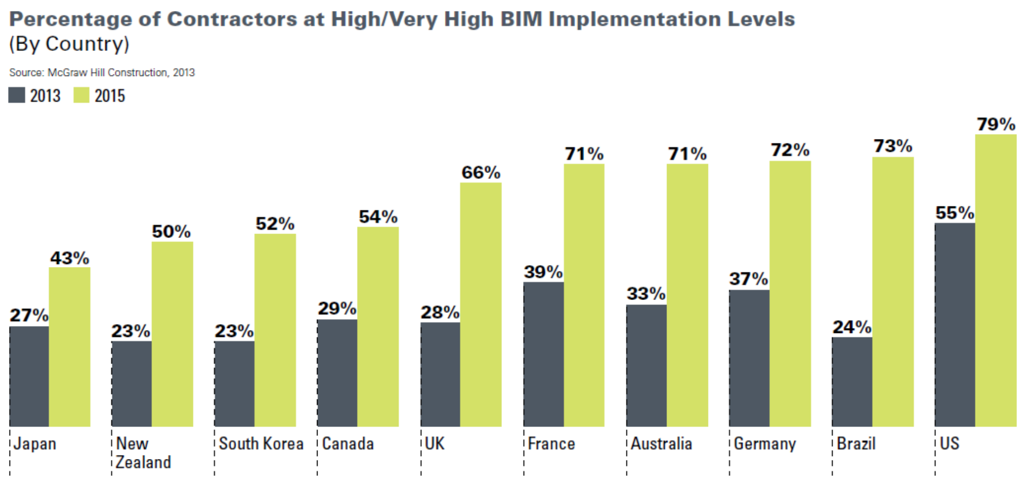



Figure 4: BIM Implementation by Country 2013 vs. 2015 (McGraw Hill Construction, 2014)

## 2.3 Researches in BIM for Precast Structures

Current approaches in BIM is possible to summarize in five domains and they are project lifecycle stages with information management, lifecycle information assessment and management, enhanced communication and coordination for collaborative working, simulation and analysis and modeling. Through BIM approaches, BIM helps in the improvement of lifecycle stages in the construction project. Therefore, it shows that BIM is the main enabler for BIM related knowledge integration (Cavieres, Gentry, & Al-Haddad, 2011). Through collaborative BIM, it is possible for communication and coordination because of BIM that is network-based, integrated and library management (Steel, Drogemuller, & Toth, 2012). In building model, all parts operate interactively such as readjustment is done to the external wall piece, then all related and connected vertical walls to this original wall movement takes place correspondingly and related affected objects in the model. This research shows that BIM underlines with significant performance to solve problems in complex design of building projects. The differences also exist in different models of structural, architectural, and services parts within the building models. The results also shows that a large number of parts incorporation in the assembly is also possible with relationships for coordination between parts of the model, which are restricted to each other (Sacks, Eastman, & Lee, 2004). In addition, in different levels of complexity, there are different types of models used such as the level of detail to facilitate various purposes present in BIM approach (Gruen, Behnisch, & Kohler, 2009).

## 2.4 BIM Modeling Techniques

The construction process comes with a difficult working environment so there are risks during construction. In order, to deal and handle these risks in a better way, the solution is the use of precast because it is cost effective, safe, more sustainable, and higher quality when comparing with traditional solutions such as in-situ or rock armour. The design issues worked on through precast units. Figure 5 shows case study for the innovation register. The innovative techniques used were precast concrete with the combination of others (Ozorhon, Abbott, Aouad, and Powell, 2014). Therefore, it shows that through BIM software for precast solution, the innovative process in the construction is possible.

| RELEVANCE | Modern methods of construction | Community engagement |
|---|---|---|
| TYPE of INNOVATION | Process & Product | Service |
| DRIVERS<br>Problem & need | Client's persistence on quality, safety, cost effectiveness, and sustainability<br>Client's aim to achieve demonstration project | Regeneration of the area<br>Client vision to provide a public space besides coastal defense |
| INPUTS<br>Resources | Idea introduced by the contractor<br>1 year of planning and R&D by the client and contractor<br>In-house (environmental design) team of the client | 1.5 years of planning and R&D<br>In-house team of the client |
| INNOVATIVE ACTIVITIES | Precast concrete with vacuum lifter<br>Panel columns for stabilization<br>Digital camera system for performance monitoring<br>Low energy and renewable technologies<br>Waste minimization<br>Local materials and workforce<br>Green infrastructure and biodiversity | Partnering with wider community throughout the whole process<br>Public consultation/exhibitions to determine final design |
| TOOLS | Toolbox talks<br>Conferences<br>Weekly and monthly meetings<br>Web site<br>Tide tables<br>Monitoring of sea movement<br>Live quality alert system | Seafront partnership<br>Weekly and monthly meetings<br>Guest books<br>Web site<br>Local press and radio |
| ENABLERS | Early contractor involvement<br>Partnership with the supplier, designer<br>Understanding client requirements<br>Support of the funders<br>Local suppliers<br>JIT and lean construction | Willingness of the community<br>Integrated teams<br>Support of the funders |
| BARRIERS | Soft ground<br>Unexpected tides<br>Budget limitations | No barriers were indicated |
| OUTPUTS<br>Achievements & KPIs | Improved KPIs; reduction in completion time, cost savings, better health and safety, environmental, and quality results | Public feedback and satisfaction<br>Good and safe neighborhood |
| IMPACTS<br>Benefits | Example scheme (best practice) with 18 awards<br>Income generation<br>Tourist attraction<br>Future collaboration along supply chain<br>Client satisfaction | |
| LESSONS LEARNT<br>Lessons & Recommendations | Planning and regular meetings bring success<br>Early contractor involvement lead to shared goals<br>Community engagement brings ideas<br>Collaborative approach will be used in future projects | |

Figure 5: The Innovation Register for Case Study (Ozorhon, Abbott, Aouad, and Powell, 2014)

The focus of this research study is on the critical success factors using BIM for precast structures in UAE's construction industry in order to investigate the possible challenges and success factors required survive. The author suggests some possible solutions and recommendations for minimizing or eliminating challenges and issues and maximizing success factors in precast industry.

## 2.5 BIM Benefits and Cases

Various cases exist in precast research with the use of modeling. Liu, Guo, Li, & Li (2014) present the landscape bridge case project “Loukouni Bridge in Project II of Congo State Route I”, which is a typical arch bridge. In this case, a large amount of precast components was involved so BIM was considered to streamline the process of construction to aid in construction project management. The project included building modeling, construction monitoring, construction simulation and analysis, and design detection. BIM helps in the design improvement of bridge construction projects. The bridge was designed with the application of BIM involved detections of collision and scheme tests based on design drawings to sustain construction simulation and design optimization. The construction process of Loukouni Bridge was done visually and creatively based on the use of BIM. Therefore, BIM helps project manager with schedule support and safety training and construction management of the Loukouni Bridge project (Liu, Guo, Li, & Li, 2014).

The BIM based solution was developed based on the Loukouni Bridge project with characteristics and analyses of problems related to design and improvement of construction that can be applied in real-life cases and researches. Therefore, the Loukouni Bridge project case shows that BIM includes potential to improve not only effectiveness but also efficiency, which can be applied in mega-complex projects. With the help of this research and findings, it shows that BIM application is possible with success. However, in this case, participants lack BIM knowledge so quality and progress of implementation might be affected. Accordingly, it is necessary that BIM training is given for each party involved in the Loukouni Bridge project (Liu, Guo, Li, & Li, 2014)

In the research study by Sacks, et al. (2005), a total sample of six projects was applied in the three different precast companies (see Table 1). These models were developed with the use of BIM software. It indicates that BIM can be applied not only in complex projects but also small, medium and large as well. The sample illustrates various information essential for project managers to have an idea about the floor area, the number of pieces, marks, modeling hours and hours per square feet. The description also includes various types of researches and cases such as parking deck, office and parking structure, office building structure, office building with parking, parking deck, and three-level parking deck.

Table 1: Six Project Samples from Different Precast Companies (Sacks, et al., 2005)

| Code | Description | Floor area, sq ft [m²] | Size classification | No. of pieces | No. of piece marks | Piece mark ratio | Modeling hours | Hours per 1,000 sq ft [1,000 m²] |
|---|---|---|---|---|---|---|---|---|
| QE2 | Three-level parking deck | 137,000 [12,728] | Medium | 567 | 242 | 2.3 | 75 | 0.55 [5.9] |
| COL | Parking deck | 60,672 [5,637] | Small | 249 | 68 | 3.7 | 32 | 0.53 [5.7] |
| Y | Office building with parking basement and steel atrium structure | 480,320 [44,623] | Large | 1700 | 125 | 13.6 | 34 | 0.07 [0.8] |
| X2 | Office building structure | 272,736 [25,338] | Medium | 930 | 396 | 2.3 | 127.5 | 0.46 [5.0] |
| PEN | Office and parking structure with facades | 167,918 [15,600] | Medium | 976 | – | – | 87.5 | 0.52 [5.6] |
| OO2 | Parking deck | 285,000 [26,477] | Medium | 563 | 300 | 1.9 | 60 | 0.21 [2.3] |

The major benefit offered by BIM modeling for precast are accuracy in parts representation within a data environment exhibiting integration. The other benefits are better design in building proposals, more effective and faster processes, control in whole-life environmental data and costs, better quality of production, the possibility for automation in assembly, better lifecycle of data, and better customer service (Azhar, 2011).

BIM offers data capture with better accuracy showing every element included in precast production to decrease design time significantly (McCraven, 2010). It also improves communication and coordination between various stakeholders of a project. In order to ensure greater client satisfaction, there is an improvement in coordination and efficiency (InfoComm International, 2011). Usually, BIM usage goals are automation and integration of production, engineering and construction operations so the project can gain market share through productivity (Lee, et al., 2004).

The consideration of BIM took place based on economical advantageous offered in the steel structural fabrication. The current adoption is in precast concrete capabilities and construction for reinforced concrete cast-in-place development (see Figure 6). Promoters and adopters of BIM in engineering, architecture and construction industry where closest to phase in constriction such as contractors, fabricators, etc. rather than generators of information related building. Many prefer to use and introduce BIM models because they are useful during design and analysis process. A greater share of the overall workload is reduced on engineers through BIM models (Sacks, and Barak, 2006). BIM software resolves many technical problems during precast processes. The costs of engineering are reduced along with the reduction in errors as well. Moreover, it is support for production automation and engineering lead-time reduction (Sacks *et al*., 2005).

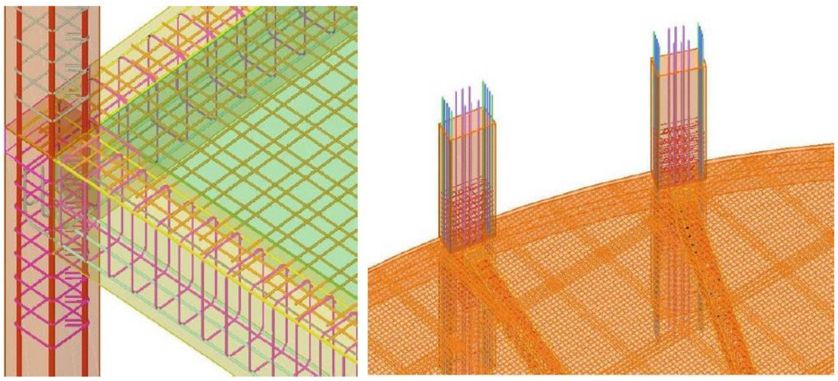


Figure 6: 3D Parametric Models (Sacks, and Barak, 2006)

BIM for precast allows structural engineers to not only build projects accurately, efficiently, and competitively but also design, simulate, visualize, analyze and document (Autodesk, 2012a; Autodesk, 2012b). The most important benefits that structural engineer enjoys are data consistency, coordination and productivity that comes with improved simulation and visualization of problems and situations in the construction project (Sacks, et al., 2005). Table 2 outlines benefits of adopting BIM in precast engineering and construction projects. The benefits realized by them are improvement such as the definition of the project, enhanced accuracy of cost estimation, the reduction in the cost of engineering, improved customer service, the reduction of drafting and design errors, production automation, streamlined logistics, BIM direct costs, determination of indirect costs, replacement costs, and the reduction in the rate of overhead cost.

Table 2: Cost or Benefits of BIM for Precast Implementation (Sacks, et al., 2005)

| Benefit or cost | Description | Estimate |
| --- | --- | --- |
| Improved project definition at time of sales | Early modeling and presentation of project proposals to clients result in better-defined projects. | |
| Enhanced cost estimating accuracy | Projects can be estimated with more detail and accuracy and at lower cost, both at early stages and for procurement, than can be done at present, resulting in reduced contracting risk. | |
| Reduced cost of engineering | The range of productivity gains for architectural projects are engineering (46 to 51 percent) and drafting (80 to 84 percent), and for structural projects are engineering (35 to 46 percent) and drafting (82 to 84 percent). | 2.6 to 6.7 percent of total project cost (including erection) |
| Reduction of design and drafting errors | Assessment of data for a sample of over 32,500 pieces from numerous companies revealed engineering related errors in: assembly design (0.19 percent of total project cost), drafting (0.12 percent), piece detailing (0.08 percent) and design coordination (0.18 percent). | 0.40 to 0.46 percent of total project cost |
| Improved customer service | Significantly shortened lead time between contract and production, and increased responsiveness to clients' requests for changes. | |
| Streamlined logistics | Integration of 3D models with Enterprise Resource Planning Systems, reducing internal communication costs and errors, increased management control and smaller inventories of components and finished pieces. | |
| Production automation | Provision of data for laser layout projection systems and for computer controlled machines such as reinforcing bar benders, welding machines, milling and/or laser cutting machines for production of styrofoam mold parts, wire mesh bending machines and robotic applicators for sandblasting and acid etching. Automation of cranes and other piece-handling equipment. | |
| Reduced overhead cost rates | Reduced overhead cost rate per unit of product as a result of increased capacity utilization due to increased sales. This excludes any direct reduction of overhead costs. (At 67 percent capacity utilization, average industry overhead rates reported are 24.9 percent.[14]) | |
| Direct costs of 3D BIM stations | Direct costs for purchase of software, hardware, installation, training, maintenance contracts, and for salary growth for employees trained to operate the systems. The estimate is an annual equivalent cost per work station based on a five-year cycle. | $11,390 to $20,165 |
| Replacement cost of existing systems | This annual benefit is derived through replacement of existing CAD stations. | $3,488 to $5,774 per station |
| Indirect costs through adoption phase | Management resources and time, personnel turnover, reduced productivity during adoption (at the start of the learning curve), business process re-engineering and organizational restructuring. | |

Hergunsel (2011) details BIM use and benefits. BIM was used as coordination, construction planning, cost estimation, the record model, visualization, and prefabrication. BIM is potential to help owners in renovation and maintenance. Costs can be avoided during construction planning and any schedule delays. It not only saves time but also labor in the field. Materials acquiring can be higher and faster. There are no additional costs and it can be avoided through BIM. In addition, needs and expectancy of the project can be visualized collaboratively.

McGraw Hill Construction (2014) reports BIM benefits enjoyed by various contractors across the globe (see Figure 7). According to responses from contactors, the top three BIM benefit is reduced omissions and errors at 41%, collaborating with design firms or owners at 35%, enhancing organizational image at 32%, reducing rework at 31%, reducing the cost of construction at 23%, better predictability or cost control at 21%, reducing the duration of the overall project at 19% and new business marketing at 19%.

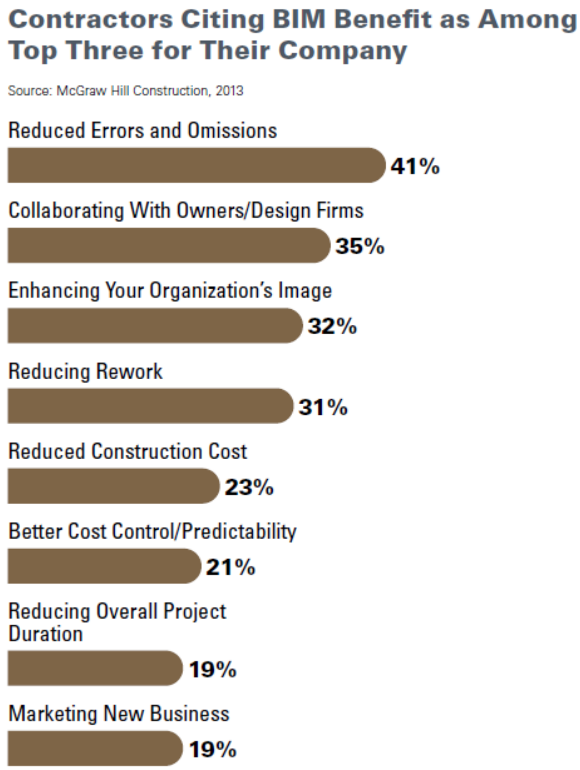



Figure 7: BIM Benefits as per Contractors across the Globe (McGraw Hill Construction, 2014)

## 2.6 BIM Limitations, and Risks

Even though, there are numerous benefits offered by BIM for precast structure use, there are a number of limitations as well. The cost of hardware and software, the cost of training and transition from drafting to modeling are some of the BIM limitations (InfoComm International, 2011). Azhar (2011) states, there are two risks such as contractual or legal and technical risks. BIM data ownership is at risk and there is need to protect with legal channels and copyright laws. There is need for strategies, well-defined process for transactional construction, and digital data requirement to ensure meaningful integration to avoid technical issues.

## 2.7 Challenges of Precast Structure

### 2.7.1 Additional Costs in Precast Concrete

The determination of the precast component is usually by cost, performance and speed benefits so precast structure can compete against traditional practices. Despite of proven precast structure benefits, there are transportation costs challenges with weight limitations. Controlled factory conditions are required to manufacture and it affects cost because of defects and wastes during the production process while trying to meet expectations of clients and customers. Moreover, due to lack of knowledge on precast concrete, it also increases costs of training and development (Glass, 2000).

Many owners and architects do not consider precast concrete and prevents possible consideration. Additional costs incurs for heavy precast units so enhanced craneage are required, which seems extra and additional costs preventing implementation of precast concrete (Park, 2003).

Pheng and Chuan (2001) states individual pieces of production are feasible technically before delivery. However, the common practice is six months before delivery rather than two days and longer duration means additional costs. General contractors or owners pay more than 90% of the cost during the production time while retaining remainder parts until the completion of the project. Consequently, clients or customers usually finances the production costs of precast units. Sacks, Akinci, and Ergen (2003) mentions incentive is given to the manufacturer during large inventory buffering from the time of design and production of precast operations.

### 2.7.2 Long Lead Time in Precast Concrete

Longer lead-times are one of the challenges in precast concrete for construction projects and the range is usually from two to six months. When clients or customers prefer custom made precast units and pieces, then lead-times are affected while embedding because of time spent on exhaustive and demanding engineering design. (Sacks, Akinci, and Ergen, 2003).

Production planning is done in three levels. Firstly, plant capacity is reserved when the contract is signed. Secondly, within two weeks of time, there is medium-term planning conducted. In the last level, before two days, short-term production planning is conducted for each of the production day (Sacks, Akinci, and Ergen, 2003). Scheduling is challenging due to inadequate planning. Poor communications take place and defective components are delivered to the site. The role players in good communication are structural engineers and precaster. It is important to conduct proper planning and communication to avoid challenges in scheduling (Polat, 2008; Ergin, Arditi, & Günhan, 2000). It shows that due to improper planning, it leads to delays in the construction projects and affects overall project schedule.

### 2.7.3 Quality in Precast Concrete

Quality is a challenge in precast concrete where clients or customers are not happy. According to Glass (2000), factory conditions leads to poor quality production during precast units' production. The working environment is unsafe, unhealthy and unpleasant and does not meet the needs of the precast construction industry. In addition, another challenge in the quality of precast concrete is from an unfamiliar installation where joining precast elements as construction techniques are poor quality monitoring and unfamiliar (Park, 2003; Glass, 2000). Furthermore, structural design firms' shows lack of expertise in precast. The current levels of planning and communication are inadequate required during input and design stages of precast concrete (Polat, 2008; Ergin, Arditi, & Günhan, 2000). All these challenges show results in construction documentation errors and affects quality of the precast concrete production.

## 2.8 Critical Success Factors for BIM Precast

Sacks *et al*. (2005) describes BIM software makes it possible to resolve various technical challenges and difficulties in the precast construction projects and processes. With the adoption and help of BIM, it is easy to eliminate challenges of increased cost, poor quality, and increased and delay schedule or time. There is support for production automation and drastic reduction in lead-time.

Omar, Nawi, & Nursal (2014) details BIM software as a solution in precast construction industry to various problems and issues such as increased costs, increased lead in times, and increased delays. The characteristic and concept of BIM reshapes precast construction projects.

Project manager and teams work together so productivity increases and the final project outcome improves such as maintenance, functionality, safety, quality, time, cost, etc. Therefore, precast construction industry witnesses BIM software available in the market. At the same time, each of the BIM software available in the market offers different features and functions and not the same. However, in order to adopt BIM software, there is need for a high amount of investment in the software that also includes hardware investments and training and development expenses. Depending on the project needs, the decision and selection of suitable BIM software should be made so needs can be fulfilled.

Sanchez, Hampson, and Vaux (2016) explains the benefits of BIM for precast adoption based on 32,500 data assessments from various companies in 2005. During the assembly of design, drafting, coordination of design and piece detailing, the study revealed the reduction of 46% project cost. By using BIM, it is possible to eliminate 60% of errors that is causing an increase in the project costs.

When adopting critical success factors identified are clear goals, IT capabilities, mitigate resistance to change, culture of sharing, training and development, BIM team, managers, and management participation, support, a pilot project, adoption strategy, and metrics (Bender, 2010; CURT, 2010; Won, & Lee, 2010; Gu, & London, 2010; Khosrowshahi, & Arayici, 2012; Arayici, et al. 2011). For project managers, BIM shows potential to reengineer projects processes for better integration of different project related stakeholders. The basic criteria for success of the project is time, quality and cost (Albert, 2004; Harris, 2013). It is also considered the most important aspect of construction management for a successful project due to impact from safety, quality and environmental (Datta, & Koehn, 2003). The adoption of BIM and related new technologies provide success in timesaving, cost saving, and quality assuring with safety during the process of construction (Bosché, 2010).

Wang (2015) summarize that construction process with BIM comes with early detection of defects and real-time quality control. These are very important to reduce the overall schedule of projects along with cost overrun. The approaches other than BIM are time-consuming to conduct quality control with ineffectiveness on construction sites. Quality managers are not able to make use of data from specific times and locations and the process during identification of defects and management is not easy.

Ku, & Taiebat (2011) details that BIM application is increasing rapidly due to cost reduction, time reduction and quality enhancement. Therefore, the construction industry is embracing BIM application for environmental sustainability as well. Several firms in the construction industry are gaining experience through the application of new processes and tools. However, it is important to understand BIM impact on the practice and operations of construction firms. In order to gain BIM skills and knowledge, there is need for BIM implementations, strategies of construction firms, training requirements, organizational structures, and examining expectations. Luth, Schorer, & Turkan (2014) mentions that BIM is a common practice is the facilities, construction, engineering, and architectural management industry. This industry recognizes BIM benefits for utilizing in construction projects such as schedule, and costs coordination in construction and design phases. Omar, Nawi, & Nursal (2014) also state that BIM is a solution for various problems in the construction industry. Hamdan, Barkokebas, Manrique, & Al-Hussein (2015) also reports that BIM facilitates inventory management and provides better quality within less cost and time. The data exchange is made possible with comprehensive and convenient means across different environments.

BIM helps in cost management and scheduling because data retrieval and comparison is easy. It also helps in comparison of the planned budget and schedule where managers are able to get a constant update. Nevertheless, the progresses of construction varies due to decision making or standards and rules, constantly changing conditions, safeness of the construction site, quality of component, etc. Stakeholders want to gain economic profits from construction projects. The important issues for stakeholders are saving costs and progress speed. With the establishment of BIM models, it makes potential to manage costs, schedule and quality with priorities.

Table 3 outlines list of critical success factors and their literature sources. Around 22 critical success factors are identified for this study, which are essential for the success of BIM system use.

Table 3: Critical Success Factors for BIM and Literature Sources

| No. | The List of Critical Success Factors | Literature Sources |
|---|---|---|
| 1. | BIM adoption strategy, | Messner, et al. (2013) |
| 2. | BIM economic impact | Won, and Lee (2010) |
| 3. | BIM functions and features | Gilligan and Kunz (2007), D'Agostino et al. (2007), Young et al. (2009) cited in Messner, et al. (2013) |
| 4. | The project manager and team | Won, and Lee (2010) |
| 5. | Web-based quality, costs, time and project management | Morlhon, Pellerin, & Bourgault (2015), Park, (2009), Zhang (2012), Epstein & Books24x7 (2012), McCuen (2008), |
| 6. | Clear business strategy and goals | Won, and Lee (2010) |
| 7. | Clients' request for BIM | Won, and Lee (2010) |
| 8. | Construction location site | Won, and Lee (2010) |
| 9. | Culture of sharing and communicating | Brewer, and Gajendran (2011) |
| 10. | Employees' expertise in BIM system | Won et al. (2008), Young et al. (2009), Gilligan and Kunz (2007), D'Agostino et al. (2007), Young et al. (2009) cited in Messner, et al. (2013) |
| 11. | Interest and the willingness for BIM system | Won, and Lee (2010) |
| 12. | Investment in BIM costs | Bernstein et al. (2012), Gilligan and Kunz (2007), Eastman et al. (2008), Yan and Damian (2008), D'Agostino et al. (2007), Young et al. (2009) cited in Messner, et al. (2013), Won, and Lee (2010) |
| 13. | IT capabilities technical support | Won, and Lee (2010) |
| 14. | Learning curve | Bernstein et al. (2012), Gilligan and Kunz (2007), Eastman et al. (2008), Yan and Damian (2008), D'Agostino et al. (2007), Young et al. (2009) cited in Messner, et al. (2013) |
| 15. | Long-term strategy of BIM provider | Won, and Lee (2010) |
| 16. | Management commitment, participation, and support | Bernstein et al. (2012), Gilligan and Kunz (2007), D'Agostino et al. (2007) cited in Messner, et al. (2013), Won, and Lee (2010) |
| 17. | Mitigate resistance to change | |
| 18. | Performance metrics | Won, and Lee (2010) |
| 19. | Pilot project | Won, and Lee (2010) |
| 20. | Quality of BIM | Won, and Lee (2010), Morlhon, Pellerin, & Bourgault (2015), Mom, Tsai, & Hsieh (2014) |

| Table 3: Critical Success Factors for BIM and Literature Sources | | |
|---|---|---|
| No. | The List of Critical Success Factors | Literature Sources |
| 21. | Safety, and environmental | Ding, et al. (2015) |
| 22. | Training and development | Morlhon, Pellerin, & Bourgault (2015), Won, and Lee (2010) |

### 2.8.1 Costs and Productivity

Productivity increases due effective cost estimation because BIM software consists of built-in cost estimation features. When there are any changes, quantities of materials are automatically updated after extraction. Controlled environmental data and whole-life costs are better understood through BIM. There is accurate cost estimation within 3% when comparing with traditional forms of estimations (Taihairan, and Ismail, 2015; Azhar, 2011; Ren, Skibniewski, & Jiang, 2012).

Many efforts are made to apply BIM so construction project execution can be done successfully. According to Cha, and Lee (2015) BIM application process is proposed as a useful took for project management efficiently. Among activities, BIM identifies work items recognizes relationships among tasks and activities. Cost analysis takes place without human error and with increased work efficiency.

Guo, Qian, & Li (2014) state that the advantages for using BIM technology in terms of reducing costs. The demand increases for precast concrete buildings and there is need for energy conservation that results in costs reduction. The complete process of production can be given with the use of BIM. This study also analyzed the application of BIM in precast structure with the prospects during the use of BIM in precast industry.

McGraw Hill Construction (2014) reports that omissions and errors were eliminated through BIM. Therefore, BIM decreases rework that reflects in overall project cost. Better predictability and cost control is important for project improvement and delivery. Sacks, et al. (2005) mention BIM offers long-term benefits and reduced costs. Table 4 shows the benefits and estimations of costs over a period of four years. On a annual basis, net benefits increases as net annual direct benefit. The most important contribution from BIM software is productivity increase based on engineering viewpoint, and particularly in construction documents production (Sacks & Barak, 2007).

In large scale or any structural engineering firms, it is common that project teams are from different geographical locations. The expectation is that project team members will help in different projects based on the needs of the firm. The entire process is easier than before due to new technologies such as cloud servers. Everyone in the project team is able to access all information required in an online platform under a single hard drive. Everyone or anyone will be able to work on the project by accessing and modifying despite significant distance among project team members. BIM software includes this concept, so it provides a database with data rich benefiting greatly on productivity and communication (Nawari, 2012).

Table 4: Costs and Benefits assessed by Large Precast Company (Sacks, et al., 2005)

| Activity | Year 1 | Year 2 | Year 3 | Year 4 |
|---|---|---|---|---|
| Annual predicted cost of sales | $40,000,000 | $42,000,000 | $44,100,000 | $46,305,000 |
| **Direct benefits** | | | | |
| Engineering productivity | $216,000 | $680,400 | $952,560 | $1,000,188 |
| Error reduction | $45,000 | $141,750 | $198,450 | $208,373 |
| **Costs** | | | | |
| Equivalent CAD work stations required | 18 | 19 | 20 | 21 |
| CAD stations saved | 0 | 4 | 9 | 20 |
| 3D modeling work stations | 3 | 6 | 12 | 13 |
| Added work station costs | $45,000 | $45,000 | $90,000 | $15,000 |
| Indirect 3D costs | $30,000 | $31,500 | $33,100 | $34,800 |
| **Net benefits** | | | | |
| Net annual direct benefit | $186,000 | $745,650 | $1,027,910 | $1,158,761 |
| **Indirect benefit** | | | | |
| Potential annual volume/overhead gain | $0 | $247,291 | $532,294 | $859,492 |

Return on investment (ROI) analysis is to evaluate investment proposed. The comparison is about gain achieved or anticipated from investment costs and the formula is ROI equals earning divided by cost. BIM consists of ROI feature to evaluate various corporate investments in fixed asset purchases, training programs, and research and development projects (Autodesk 2007 cited in Azhar, 2011). Table 5 provides BIM ROI in various projects along with cost, savings, and scope.

Table 5: BIM ROI (Azhar, 2011)

| Year | Cost ($M) | Project | BIM scope | BIM cost ($) | Direct BIM savings ($) | Net BIM savings ($) | BIM ROI (%) |
|---|---|---|---|---|---|---|---|
| 2005 | 30 | Ashley Overlook | P/PC/CD | 5,000 | (135,000) | (130,000) | 2600 |
| 2006 | 54 | Progressive Data Center | F/CD/FM | 120,000 | (395,000) | (232,000) | 140 |
| 2006 | 47 | Raleigh Marriott | P/PC/VA | 4,288 | (500,000) | (495,712) | 11560 |
| 2006 | 16 | GSU Library | P/PC/CD | 10,000 | (74,120) | (64,120) | 640 |
| 2006 | 88 | Mansion on Peachtree | P/CD | 1,440 | (15,000) | (6,850) | 940 |
| 2007 | 47 | Aquarium Hilton | F/D/PC/CD | 90,000 | (800,000) | (710,000) | 780 |
| 2007 | 58 | 1515 Wynkoop | P/D/VA | 3,800 | (200,000) | (196,200) | 5160 |
| 2007 | 82 | HP Data Center | F/D/CD | 20,000 | (67,500) | (47,500) | 240 |
| 2007 | 14 | Savannah State | F/D/PC/VA/CD | 5,000 | (2,000,000) | (1,995,000) | 39900 |
| 2007 | 32 | NAU Sciences Lab | P/CD | 1,000 | (330,000) | (329,000) | 32900 |
| Total all types | | | | 260,528 | 4,516,620 | 4,256,092 | 1633% |
| Totals without planning/VA phase | | | | 247,440 | 1,816,620 | 1,569,180 | 634% |

Source: Holder Construction Company, Atlanta, GA.

Note: CD = construction documentation; D = design; F = feasibility analysis; FM = facilities management; GSU = Georgia State University; NAU = Northern Arizona University; P = planning; PC = preconstruction services; ROI = return on investment; VA = value analysis.

McGraw Hill Construction (2014) reports that positive ROI is found based on contractors surveyed (see Figure 8). Estimates made were between 10% and 25% on BIM investments. The top ROI investments in BIM were Japanese, German and French contractors followed by Canada, Brazil and New Zealand. UK, South Korea and the US are lowest when comparing with other contractors. Financial metrics such as higher profitability, reduced cost, and higher productivity were generally considered for ROI measurement as BIM investments.

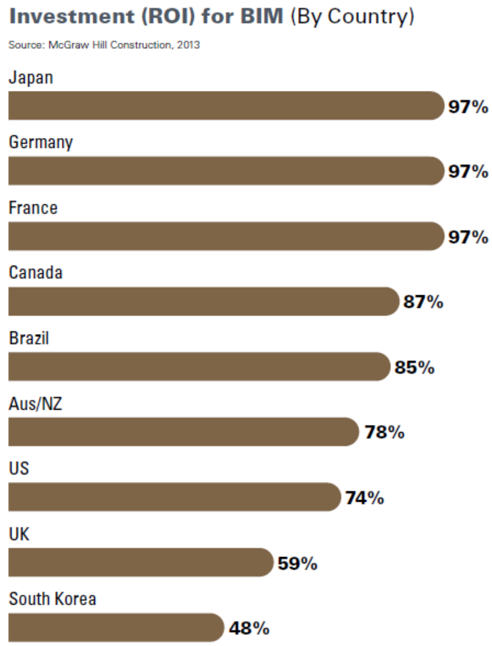



Figure 8: ROI for BIM (McGraw Hill Construction, 2014)

Sacks & Barak (2007) states construction documents production is very labor intensive, which is part of structural engineering. BIM software completely automates the process with important sections such as numbering schedules, rebar schedules, reinforcement detailing, automatically generated, and saves lots of effort and time. According to McGraw Hill Construction (2012), BIM software offers the most important benefits for firms and contractors. Both firms and contractors agree for 45% benefits of marketing new business. While, contractors usually anticipates at 51% for overall better project outcomes and firms shows lesser at 38%. Reduce errors in documents in almost similar for firms and contractors (42% and 41%, respectively). Figure 9 illustrates the value that engineering and architectural firms put on BIM. The value varies differently for each in the project phase. The data shows 44% of owners anticipate planning, 59% firms anticipate design and 53% anticipate construction documentation (see Figure 10). It indicates that BIM offers various benefits for firms, contractors and owners.

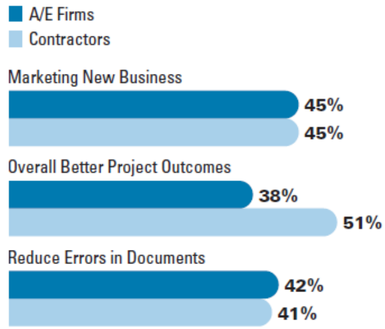



Figure 9: Top Internal Benefits for Using BIM (McGraw Hill Construction, 2012)

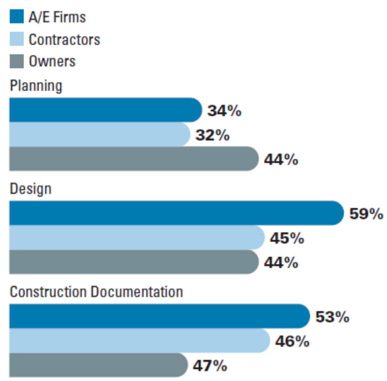



Figure 10: BIM Value for Infrastructure (McGraw Hill Construction, 2012)

### 2.8.2 Time and Coordination

Azhar (2011) finds that due to BIM software use, up to 80% time is reduced in cost estimation generation. Moreover, up to 7% project time is reduced as well. The use of BIM software creates collaboration among project team members and accelerates better communication. Therefore, BIM software eventually leads to reduced costs and improved profitability due to better time management where customer and client relationships are also improved.

Cha, & Lee (2015) makes similar findings about BIM software usage in terms of time analysis with efficiencies in work and project related areas. Omar, Nawi, & Nursal (2014) also states that BIM solves various problems about increased lead in times and improve the final project outcomes in terms of time as well.

McGraw Hill Construction (2014) finds that BIM ensures reduced cycle time for project delivery and activities, which was higher in Canada at 48%. The promises that BIM technology makes are to deliver construction information and coordinated design in visual environment. The industry is still learning about BIM and projects are delivered on time. The model of the building is designed and developed on time with BIM.

Collins (2016) emphasizes that digital model offers various construction related benefits. Some of the examples of benefits are assembly sequencing confirmation, detections of clash, and verification of as-built dimensions. Preparing and customizing construction models requires a large amount of time, which does not also assure actual building construction with the modeled one but digital models lowers time required and provides the guarantee for clients or customers. Wang, Cheng, & Sohn, (2016) confirms that BIM shows and enables less construction time.

Nissilä, et al. (2014) describes schedule control and development for the precast supply chain can be studied. BIM model helps the structural engineer to control schedule, time-saving, different status information, the real-time schedule situation, site erection, and delivery, etc. through the cloud-based BIM model in networked service.

In order to ensure timeliness, the essential part of BIM is good coordination across various projects (Migilinskas, Popov, Juocevicius & Ustinovichius, 2013). Single BIM is enough for documentation phases and analysis of the project, which contributes for better coordination across the results of structural analysis and increases the entire project consistency in overall design. It becomes easy for structural engineers to spend extra time in project coordination than performing structural analysis (Schinler & Nelson, 2008). It indicates that due to BIM time is saved and reduces any delays and time spending in various works of the project.

McGraw Hill Construction (2012) confirms that there is a reduction in coordination time spending while allowing structural engineers to focus on problem solving efforts. According to Schinler & Nelson (2008) the more complex and bigger the project is, then the more coordination is required. BIM is very important and valuable to deal with complex and bigger projects. BIM makes possibilities for better design decisions and coordination during the project process.

McGraw Hill Construction (2012) reports that BIM use offers coordination tools so engineers can better manager projects effectively. Engineers are able to make the layout around the structural model in BIM so they can improve coordination. It also helps in clash detection so errors can be reduced automatically while checking for inferences and collisions between plumbing, ducts and structural system. In the design phase, any issues related to coordination can be identified and solved easily. Therefore, BIM saves time through the process of reducing errors and improving accuracy in construction projects.

Schinler & Nelson (2008) reports that production coordination is possible effectively through BIM, as it improves communication, connects structural design with fabrication, and shares information between contractors, fabricators and detailers. The time need to construct steel and concrete structures are reduced and decreased eventually.

### 2.8.3 Quality and Visualization and Simulation

BIM is flexible and offers better quality of production through documentation output, and automation (Azhar, 2011). Omar, Nawi, & Nursal (2014) states that due to various problems it affects quality and BIM enables the final project outcomes with quality assurance.

Seo, Kim & Kim, (2012) describes that BIM offers quality checking and through the software it is possible to perform quality checks so zoning legislation, building codes and other requirements are satisfied in terms of quality. In the design phase, the process of quality checking is conducted, and it improves quality of design by detection of errors and detection of omissions.

In addition, in the construction phase, BIM improves the feasibility of construction based on conflicts detection between many building systems or elements. Accordingly, BIM's quality checking ensures safety because it enables fast decision-making and improves quality and design of construction projects. Many researchers suggested that quality control solutions are essential in safety management of projects (Zhang *et al.*, 2013; Yanagida, et al., 2012; Sugiyama, & Mito, 2014).

In precast production, quality control is an integral part. Therefore, there is need for an efficient quality system so precast components can be checked and used in any mass production. Under a contract, the precast factory sets up manufacturing location for tunnel segments in large quantity. In the quality inspection plan, the processes and control procedures are discussed in the precast manufacture. The roles of inspectors, standard tests involved and corrective actions were on focus. Review is conducted on critical issues related to the quality and productivity of production. It includes the quality of maintenance, and staff, which affects quality system efficiency. There is need to provide some considerations to improve the productivity and workflow of the plant (Cheong, Kwan, & Hariyanto, 2005).

The quality of BIM data is considered and basic BIM guidelines for architectural design use based on proposed requirements. BIM based safety management solutions, methods were proposed in the identification, and the collection of critical safety management factors was limited. (Seo, Kim & Kim, 2012; Eastman, Lee, Jeong & Lee, 2009; Guo, Qian, & Li, 2014).

The platform consists of validating designs, and construction and BIM models related phases from the quality control point of view. BIM is a formal and rich model that provides automated quality inspections. It can execute and interpret various criteria such as construction regulations, building design, safety codes, health codes and client requirements. In addition, the process of quality inspection consists of various phases such as project scope and objectives. The process consists of four phases and they are interpretation of rule, preparation of BIM model, execution of rule, and reporting rule checking (Seo, Kim & Kim, 2012; Eastman, Lee, Jeong & Lee, 2009; Guo, Qian, & Li, 2014).

Wang, Cheng, & Sohn, (2016) describes that BIM enables higher construction quality. There is need for assessing individual precast concrete elements prior to transportation of units to construction location. BIM consists of laser scanning options so precast concrete elements can be scanned and dimension quality assessment takes place. This study validated this proposed technique because they have conducted scanning experiment on small-scale testing. The results from this experiment showed that BIM ensures efficiency and accuracy.

In the findings by McGraw Hill Construction (2014), it shows that contractors increased quality and safety, which are outstanding benefits for them. More teams acknowledged their quality and efficiency. BIM activities are specialized for sustainability and the use of BIM supports goals of sustainability, which are valuable for contractors. The quality is improved due to tools for simulation and analysis, which helps professionals and contractors to generate design solutions and leverage models. The promises that BIM technology makes are for design coordination and information related to construction projects in the modeling environment, as high quality.

The implementation of BIM helps in creative and new solutions for various problems (Bynum, Issa & Olbina, 2013). It is easy for engineers to filter and isolate any element or area of especial interest from the precast structure while being able to have modeling visualization. Accordingly, BIM provides in depth insight into the project with facilitating and understanding enhancement in the problem solving process while generating ideas (Autodesk, 2012a; Autodesk, 2012b).

Bennet, (2012) describes that BIM improves planning based on testing scenarios and improving different settings. Before the beginning of the work, the quality can be assured through simulations of design clashes, installation conflicts and management of workflow. Effective and quick decision-making can be facilitated for simulation of construction sequences by project team working on designs. In addition, navigation with real-time is also possible to support simulations so exploration can be enhanced. The possible impact from seismic events can be determined with the use of BIM. Future infrastructure challenges are also mitigated with the help of BIM through simulations, visualizations and analysis.

## 2.9 Conclusions

Review of the literature provides comprehensive literature conduced for this research study. This chapter presents and discusses about the best practices in BIM for precast globally in various regions and nations that includes some cases as well. The concepts and definitions were clearly introduced on BIM software. The benefits and critical success factors of BIM for precast must be considered to eliminate impact from precast concrete challenges that engineers and contractors are facing nowadays. These challenges of precast concrete should be considered so benefits and success factors of BIM for precast where BIM can be maximized.

Research and cases conducted in the area of BIM BIM for precast was examined. According to examination conducted, it showed that there were good benefits findings made along with limitations and challenges. This chapter introduced information, which will help in the identification, selection, and analysis of BIM best practices across the globe so objectives of this study can be achieved. It is also to recognize and make use of BIM precast benefits and critical success factors, which are essential for precast construction industry.

The benefits of BIM and success factors identified in this chapter will help in overcoming precast concrete challenges related to quality, time and costs. The critical success factors identified as the best practices were good quality control, lower scheduling time, and control in costs due to BIM. All these factors are related to benefits of BIM for precast and helps in overcoming challenges.

The UAE precast construction industry will be able to apply BIM for precast without any risks affecting construction projects while project managers and the team are working with good communication and coordination level. At the same time, there will be no reworks, defects or errors resulting from quality issues. In addition, the long-lead time and lengthy scheduling and planning will come to an end. Furthermore, the costs increase and expenses unexpected will not take place with the use of BIM for precast with ROI.

# Chapter 3.0 Conceptual Framework

## 3.1 Background

From the literature review, the researcher identified four Hypotheses that will be tested during data analysis from online surveys.

**Hypothesis 1 (H1):** There is a positive relationship between Building Information Modeling and reduced cost for precast structure.

**Hypothesis 2 (H2):** There is a positive relationship between Building Information Modeling and timesaving for precast structure.

**Hypothesis 3 (H3):** There is a positive relationship between Building Information Modeling and better quality for precast structure.

**Hypothesis 4 (H4):** There is a positive relationship between Building Information Modeling, CSF and success criteria for precast structure (time, cost, and quality).

Chapter 3 provides the conceptual framework (see Figure 11) of this study. The focus of this research is to establish critical success factors for using BIM precast in the UAE’s construction industry. These critical success factors were realized after identifying and analyzing challenges of precast structures without the use of BIM system and with the use of traditional methods. Once investigated and examined, the critical success factors will help and support organizations in the construction industry of the UAE to excel in the use, adoption and application of BIM for precast structures.

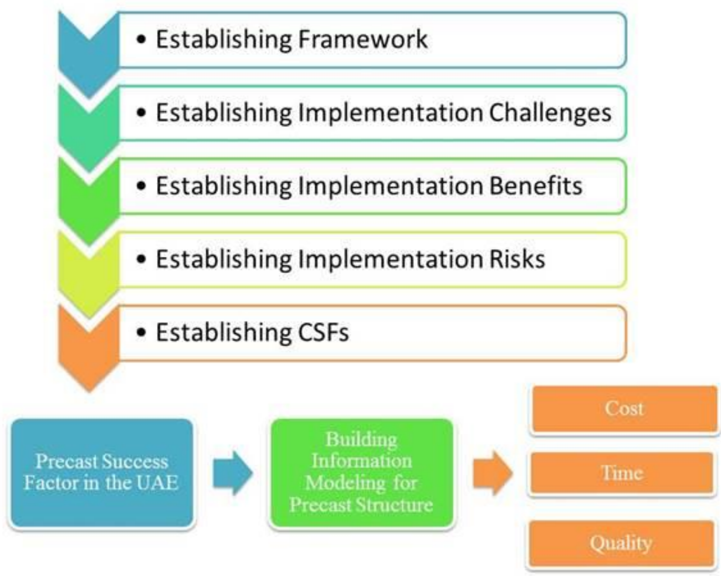



Figure 11: Conceptual Framework

In the precast success factors, many concepts are related such as adoption or application of the BIM system for precast, best practices, critical success factors, and the classification of these factors. Volk et al. (2014) details the BIM system for precast consideration, so it is increasing and growing, since the past decades. It is because of resources savings and various benefits during new project buildings planning, designing, and constructing. Since 1970s, the development of BIM was based on computer-aided design and development of various object-based parametric modeling, and integrated analysis tools took place such as the basic concept of BIM. In the early 2000s, BIM was introduced in pilot projects for improvement in design, preplanning, visualization, clash detection, data management, costing management, and quantification. The application was also done for complex structures.

According to the American Institute of Architects (2008), BIM is with advances in hardware and software consists of three-dimensional representation realistic. BIM provides coordination advantages because all the views can be done from a single model. In various fields, 3D is applied for construction and engineering as it consists of 3D imaging characteristics. Smith and Tardif (2012) also describes 3D with representation of buildings that enables project teams to achieve higher mutual understanding and communicate effectively. BIM was suggested and described as the next generation software for planning and designing building projects.

BIM is a 3D digital model with simple geometric shapes such as cones, arcs and cylinders. It consists of intelligent objects with real-world counterparts such as walls, windows and doors depicting actual components of buildings. This software includes an understanding that window is the part of the wall only and the wall is important based on the size of the width. Objects may have non-geometric or geometric attributes with the semantic, functional or topologic information. BIM model includes building element properties and holds information about project schedule, material inventories, cost estimates, quantities and spatial relationships. BIM allows stimulation of the construction process and demonstrates entire lifecycle of the building in a virtual environment to facilitate in the building model and design (Azhar, 2011; Smith and Tardif, 2012). The BIM concept application in different phases during the life cycle of building project.

Barlish and Sullivan (2012) states that various studies were dedicated for BIM concept to search and define with consistent definition. It is found that BIM concept is interpreted differently and not the same across different discipline, such as technical aspects, design perspectives, etc. However, BIM is gaining popularity rapidly and various building professors are in doubt about specific benefits for their building projects. At the same time, BIM benefits are not established fully and consists of mixed opinions and perspectives showing misunderstanding on expected outcomes.

Bryde, Broquetas, & Volm (2013) suggest that BIM is about geometric modeling and assists in various construction and management of projects. According to the definition by Succar (2009), BIM is a project management tools and processes, and it is not only a software but also input information and geometrical modeling. The potential use of BIM is collaboration improvement, time reduction, project documentation and overall beneficial outcomes in projects.

Sheth, and Malsane (2014) describes BIM as one tool that supplies useful information, facility design and development, information generation, scheduling, the process of fabrication, etc. BIM approach can also be applied for the green built environment and green building development. The National Institute of Building Sciences defines BIM as a digital representation of functional and physical characteristics related to the facility (American Institute of Architects, 2008).

Sacks, et al. (2005) explains in the construction industry, the adoption of information technologies (IT) is generally argued about benefits offered rather management willingness and quantified benefits, which are necessary for the initial decision on investments. The companies in the construction industry conducts very low investments in research and development so precasting companies are not exempted either. The adoption and application of IT is complex because it involves role and personnel changes with the reorganization of engineering departments, intensive training, changes in relationships with clients and alignment of IT procedures with the company. In order to succeed, the idea of adoption should not only be managed carefully but also planned as well, and it requires progress measurement periodically. The long-term benefits of BIM can be projected to four years scenario of adoption by construction companies. As per business and engineering managers of companies in North America, the adoption of advanced IT in engineering is important to fully adopt BIM application and usage.

Haron (2011) states that BIM application in the construction industry provides many advantages and implementation of application comes in four phases (see Figure 12). The most important part is to understand the reason behind BIM application and set adoption objectives to plan, design, construct and operate. Throughout the phases, they are connected and interrelated with predecessors and dependencies on each. It also shows that various tasks are continuous until operate phase.

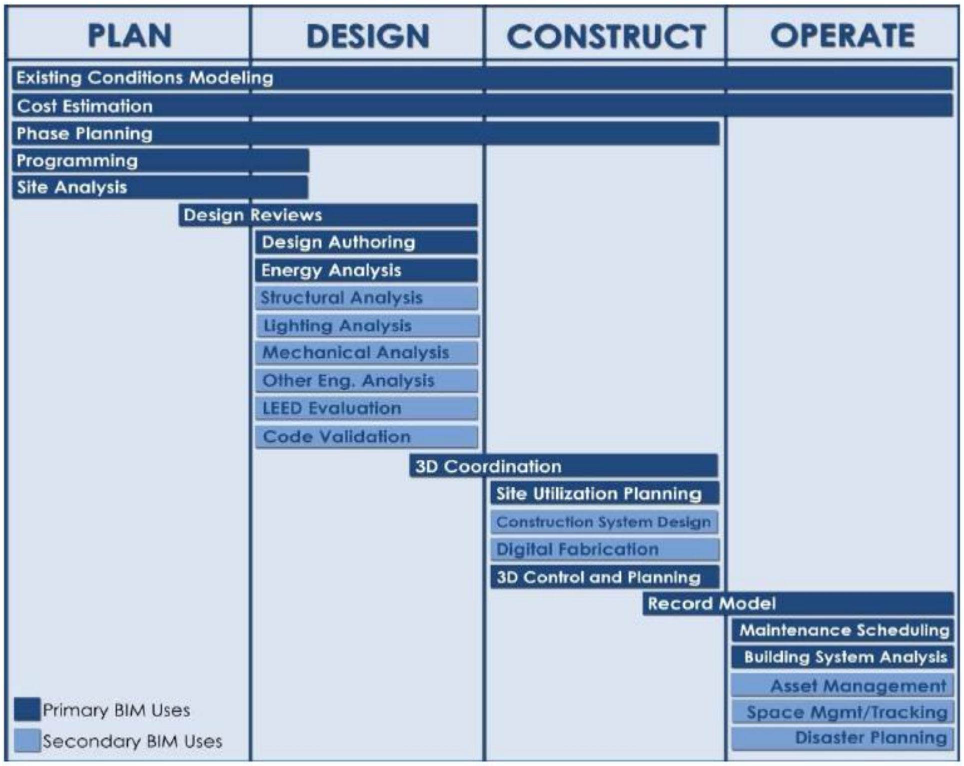



Figure 12: BIM Application throughout Project Lifecycle (Haron, 2011)

One of the best practices of BIM implementation is in the construction industry of Malaysia, Hong Kong, and Singapore. Government and industry players play an important role in BIM implementation, promotion and communication of BIM importance (Zahrizan, et al., 2012; Kamar, et al., 2012). Lee, et al. (2004) states the key success factors are important to determine the success of the BIM adoption and application. The success factors supports in the improvement and implementation of the BIM system.

BIM application and adoption is one of the best practices so use and benefits can be achieved while identifying critical success factors and needs during the implementation process. Critical success factors are essential for BIM implementation and various studies conducted to realize benefits and success factors so it can be carried out in the construction industry. There are possibilities for obstacles during implementation of BIM, but critical success factors helps eliminate these obstacles (Harona, et al., 2015; Yan & Damian, 2008; Eastman, et al., 2011; Eastman, Teicholz, Sacks, & Liston, 2011).

Zahrizan, et al. (2013) mentions the recognition of critical success factors is to ensure BIM implementation success in the Malaysian construction industry. Projects cannot be successful without considering success factors.

The best practice is for development of organizations so they can excel. McArthur, & Sun (2015) points out various best practices to apply. These best practices help to adopt BIM in construction, design and operations. Morlhon, Pellerin, & Bourgault (2015) confirms that in order to support adoption and application of BIM in the construction industry, there is need to establish best practices. Messner, et al. (2013) also states the best practices are to identify limitations and barriers affecting BIM adoption in the various project.

Abubakar, et al. (2014) explains that organizations achieve continuous improvement through best practices. At global level, best practices are adopted to acclaim benefits of BIM technologies. Therefore, not only organizations but also industry is able to operate and deliver projects with global best practices with efficiency and success to benefit.

For the best practice, critical success factors assists in application and continuous improvement. Morlhon, Pellerin, & Bourgault (2015) find that depending on critical success factors, the activities identified and implemented helps organizations. At the same time, success factors come with actions and various weaknesses should be found as well affecting associated actions with critical success factors. Therefore, for BIM implementation, there is need to establish a list of critical success factors.

The organization in the construction industry might face limited resources to adopt all critical success factors. However, at this point, the organization’s top management priority should be focusing on critical success factors based on project selection, BIM services, and a suitable BIM for organization as a whole. Accordingly, critical success factors are used to evaluate and manage the level of BIM adoption, and they are efficient metrics (Messner, et al., 2013).

Various benefits, functions and values of BIM for BIM should be considered as a part of critical success factors in the use of this software system for UAE construction projects. This study consists of two main parts and they are the application of the BIM and improvement of construction projects. The improvement areas are the benefits that the BIM can offer for precast structures and minimize the impact of challenges present. With the identification of critical success factors, this study intends to apply BIM for precast that helps in the achievement of success rate in building projects while applying the best practices and considering success factors.

Critical success factors are grouped and categorized for better allocation and analysis. Morlhon, Pellerin, & Bourgault (2015) list success factors identified under technology, people and process. According to this study, they are categorized and grouped so BIM adoption can be improved based on investigation and analysis. While, the list for critical success factors group consists of the system selection process, technical education, education to management of information, standardization, involvement of external stakeholders and business process reengineering.

According to Lee, et al. (2004), the key success factors are suitable BIM system identification, the early replacement of the outdated system, reliable and clear economic impact assessment, the progress fear, project facilitators or coordinators, careful planning with project teams, and effective leadership.

CSFs helps in overcoming factors affecting use of precast structures and these factors complied from literature review given in Table 6. The factors are categorized under cost, quality and time affecting use of precast structures.

Table 6: Factors Affecting Precast Usage

| No. | Cost | Quality | Time |
|---|---|---|---|
| 1. | Material costs | Errors and omissions | Project duration |
| 2. | Transportation costs | Production automation | Delivery speed |
| 3. | Inflation | Design and drafting | Construction speed |

| Table 6: Factors Affecting Precast Usage | | | |
|---|---|---|---|
| No. | Cost | Quality | Time |
| 4. | Cost estimation | Construction documentation | Production planning and scheduling |
| 5. | Engineering cost | Decision-making | Communication |
| 6. | Overhead costs | Quality controlling and monitoring | Time for handling and equipment use |
| 7. | Training costs | Client or customer expectations | Time for sub precast structure |
| 8. | Wastes costs | Defects detection | Time for super precast structure |
| 9. | The erection costs | Quantity of labor and related costs based on project size | Time for finishing work |

## 3.2 Conclusions

The conceptual framework was focused in this chapter, which will be used to conduct this research study so objectives can be achieved and research questions can be answered, as identified and stated in chapter one. The development of the critical success factors list was outlined in this chapter with the conceptual background on various concepts of this study. The concepts included were on BIM for precast adoption, the best practices, and critical success factors. BIM can be adopted and the focus of this study.

In addition, some of the examples of the best practices were also given such as in Hong Kong, Malaysia and Singapore. At the same time, the concept of critical success factors was also explained and described. All these three concepts were defined and described based on the relation to the topic of this study. Chapter four will present research methodology and online survey questionnaire components based on this chapter.

# Chapter 4.0 Research Methodology

## 4.1 Background

The main purpose of this study is to collect data so research questions can be answered. This chapter provides details on research methodology principles and concepts to show adopted methods. Therefore, this chapter specifies research strategy with related tools used to achieve objectives of this study. Firstly, questionnaires were designed based on review of literature. Secondly, in order to conduct interview and survey, organizations in the private sector and the public sector chosen. Lastly, the interview has been conducted and the survey distributed with collection procedures. The research aim and objectives of this study are given in the first chapter.

## 4.2 Research strategy

In the initial phase, a comprehensive literature review was conducted for this research study. In this study, literatures were selected from the various range of the subject for analyses to limit issues with limited access to particular researches, studies and publications. These sources were consulted including journals, articles, books, reports, conference papers, and case studies. Research related to precast structures and the BIM system in the past has used mostly case studies, surveys and interviews as research methodologies.

Figure 13 illustrates the research approach summary for this study. In interviews, open-ended format, which were designed and determined and it is the most suitable and effective research methodology for adding greater context and initiating relevant concepts to literature. After literature and interview analysis, an online survey questionnaire was designed and determined so it can be the suitable method for data collection from users in the private and public sector about precast structure challenges. Results will be analyzed from private and public sector users, which will be compared and analyzed for the determination of CSFs for BIM implementation in precast industry in the UAE.

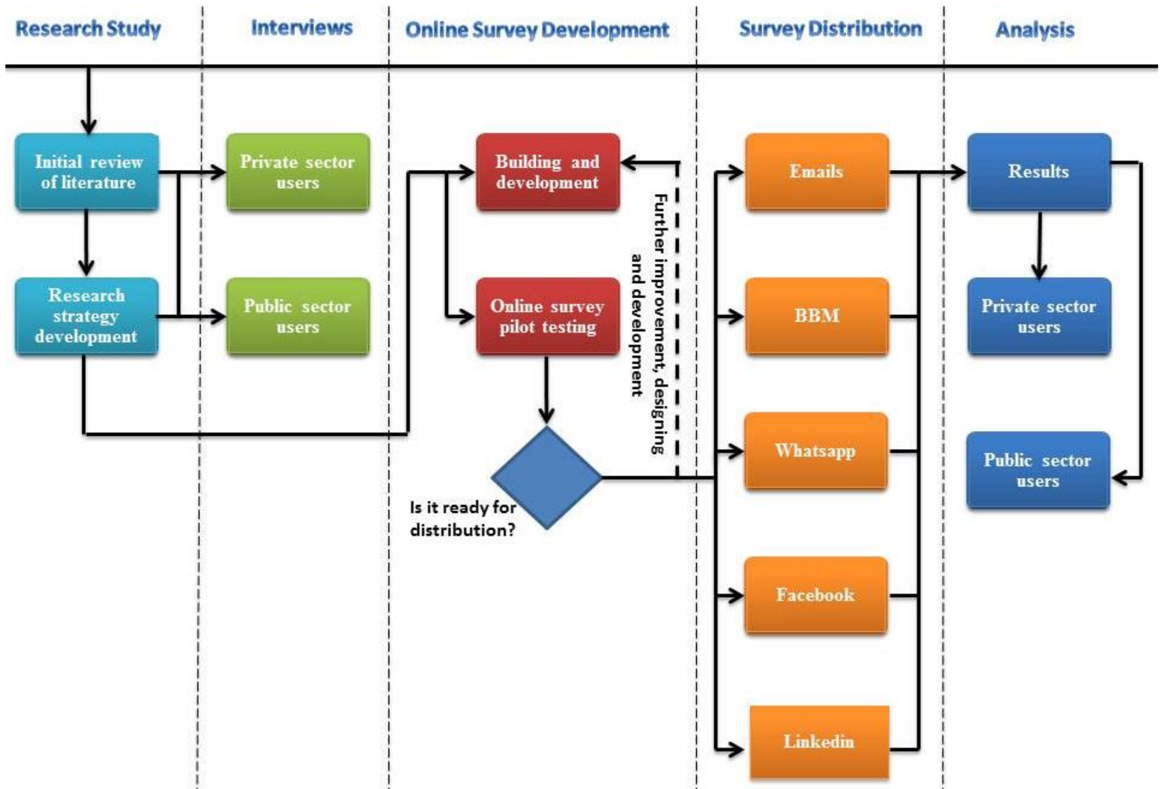



Figure 13: Research Methodology

## 4.3 Research approach

Qualitative and quantitative methods have been used. Various studies also used both Qualitative and quantitative methods to conduct studies related to BIM under engineering, construction and architectural management (Khosrowshahi, & Arayici, 2012; Fai, Filippi, & Paliaga, 2013; Arayici, et. al, 2011). The research approach enables in the introduction of the relevant concepts and gather meaningful data and information and the possibilities to compare data analysis in BIM for precast implementation of structures and CSFs related.

According to Amaratunga et al. (2002) the qualitative approach provides descriptions and explanations with the focus on words. On the other hand, quantitative approach is with the focus on numbers where the researcher undertakes both measurements and control by means of assignation of numbers (Hussey and Hussey 1997).

Both qualitative and quantitative approaches have been chosen to conduct this study so it will help in the achievement of research objectives with deep understanding on precast structure challenges and CSFs for BIM implementation. Table 1 summarizes the quantitative and qualitative methods (Bryman and Bell, 2015; Creswell, 2014; Bryman, 2012; Lichtman, 2010; Neuman, 2011; Teddlie and Tashakkori, 2009).

Table 7: Quantitative and Qualitative Methods Summary

| Items | Quantitative Method | Qualitative Method |
|---|---|---|
| Paradigms | Positivism | Constructivism |
| Research questions | Quantitative research questions | Qualitative research questions |
| Researchers | Quantitative researchers | Qualitative researchers |
| Researcher role | Biases are minimum and the researcher is outside the system | Researcher plays the central role during interpretations based on background and experience |
| Research purpose | Hypotheses testing | Interpretations based on understanding |
| Data forms | Numeric | Narrative |
| Theory role | Deductive (conceptual theory or framework) | Inductive (grounded theory) |
| Data analysis | Statistical analysis | Thematic analysis |
| Data collection emphasis | Numbers | Words |
| Quality and validity | Internal and external validity | Creditability, trustworthiness, and transferability |
| Reality nature | Single reality | Multiple reality |
| Dichotomy | Objectivity | Subjectivity |
| Ways of knowing | Process of science | Learn about something new |
| Advantages | • Economical, quick and easy<br>• Various situations coverage | • Natural way of data collection<br>• Process changes over time<br>• Meanings understanding from participants |

| Table 7: Quantitative and Qualitative Methods Summary | | |
|---|---|---|
| Items | Quantitative Method | Qualitative Method |
| Disadvantages | • Relying on procedures and instruments<br>• Static view creation | • Difficulties in data analysis and interpretation<br>• Difficulties in the research process |

### 4.4 Data collection methods

No research study can be complete without data so data is very important and should be collected. Many data collection methods exist such as questionnaires, observation, secondary data, and sampling (Saunders, Lewis, and Thornhill, 2007). This study is qualitative and quantitative in nature so the questionnaire method has been used. In order to achieve the aim and objectives of this research, survey and interview questions were designed based on literature review and research questions.

Both primary and secondary data collections were used in this study. Primary data collected specifically for this study. Questionnaire is the most popular form of the data collection tool that requires low economic maintenance. Therefore, due to such benefits, the questionnaire tool for quantitative and qualitative data for this study collected through interview questions and survey questions.

Primary data is important to provide new and firsthand information for this study. After interacting with participants, primary data can be gathered with the use of interview and survey questions. After interacting with people based on selected sample size from the population, reports should be prepared. Secondary data collected from current sources that are readily available such as journals, articles, books, etc. The researcher examined secondary sources of data and collated.

### 4.4.1 Research sampling

The sample size specified earlier represents the full set of population (see Figure 14), which a technique of convenience sampling in the research study. The selection of participants is much easier so they can represent full population (Saunders, Lewis, and Thornhill, 2007). The sample selected in this study is from UAE private and public sectors that have experience in precast structures use in the construction industry or implemented BIM BIM system for precast.

In order to carry out this study, the participants chosen were the one involved in the construction project with the use of precast structures and BIM system such as BIM. The participants in this study are mainly from the private and public sectors, and they are also the users of the BIM system for precast structures. Therefore, it includes project managers, and supervisors, site engineers, and contractors (5 participants for pilot study, 44 survey participants, and 8 interviews).

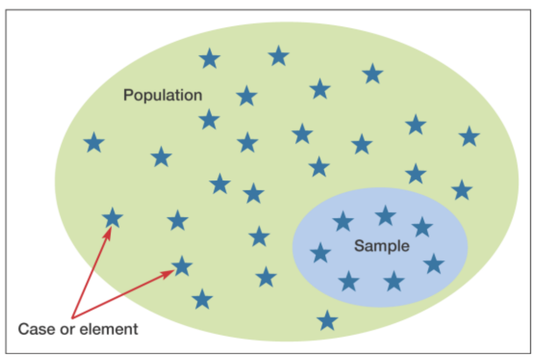



Figure 14: Population, Sample and Case or Element (Saunders, Lewis, and Thornhill, 2007)

### 4.4.2 Pilot study

According to Burns (2000) pre-testing and piloting of the research instrument is vital so the feasibility can be tested to carryout the actual survey. In the case of any potential problems that might arise with the survey, pilot testing helps to identify and deal with such potential problems in survey questions. During pilot testing, it is also checked about the order of the survey questions, which includes to check for any repetitions, missing questions and length of the questions (Punch, 2005).

Pilot testing (see Appendix A) is useful data collection method to determine whether the questionnaire instrument used is free from problems and errors for immediate correction. It helps to identify and determine whether the questionnaire developed is suitable (Carvalho, and White, 1997).

The reliability of the questionnaire is depending on pilot testing for data collection. The accuracy of questionnaires are assured through pilot testing. Accordingly, reliability of the questionnaire is established through pilot testing through data collection (Kasi, 2009). This study conducted pilot testing of the questionnaire to ensure that questions determined and designed are clear and easy to understand by the participants. Five engineers assisted in pilot testing questionnaire for making any changes or improvements for any misunderstanding or inaccuracies and the results of pilot study given in Appendix A. In addition, in this study, the pilot study included participants that is similar to sample population, which will be ultimately surveyed on a full scale basis of 35 participations from engineers.

The pilot study was done smoothly and all participants invited cooperated well to the extent that they sent responses, such as suggestions, and comments. All of the five participants in this pilot study were conducted online to obtain valuable information, which will be helpful to conduct the full survey. All the suggestions and comments were considered and changes were made accordingly.

### 4.4.3 Interviews

Interview is an exchange of views and ideas among two or more people regarding situations related to data research (Kvale, 2006). Interview is conversation between people about inquiry into the study conducted (Snyder, 1996; Edwards, & Holland, 2013; Roulston, 2010). According to Gray (2013), the interview is conducted for reasons of collecting data such as opportunities and personalized data. The type of interview used in this study is structured interviews. Interviews are commonly used for gathering qualitative data. Interview questions are key topics, themes or issues.

David and Sutton (2011) also states that the interviewer asks suitable interview questions to find any clarifications. In this study, structured interview (see Appendix B) have been used to collect data through interview sessions. Interviewees were invited to an interview session through calls and emails.

### 4.4.4 Survey

Survey is the quantitative data collection instrument. The quality of data gathered through the survey is depending on survey questions (Dolnicar, 2013). Emerging and recent technology developments take place in survey research (Couper, 2005). In this study self-administered survey questionnaire has been used such as the web-based online survey (Monsen, and Horn, 2007). Survey instrument for data collection is used for descriptive and exploratory research (Saunders, Lewis, and Thornhill, 2007). In this study, the survey was created in Question Pro with automated coordination with participants. Participants were emailed survey link and invited to take part in this study. According to Hooker, and Monas (2008) Question Pro is a budget online survey and it is cheapest than the web-based survey. Researchers can construct their own online survey. A total of 35 emails were sent to private and public sector organizations with survey link invitation.

## 4.5 Data analysis method

Qualitative and quantitative data analysis methods chosen for this study through interviews and surveys and the data will be analyzed. Saunders, Lewis, and Thornhill, (2007) states there is no standard procedure in the analysis of data. Qualitative and quantitative data analysis involves the specific and clear process to categorize data after creating summary, graphical presentation, statistical analysis for meaningful information and data. Data analysis will use Question Pro so statistical analysis will be conducted to ensure data results achievement through analytical tools. The emphasis is the use of tables, and diagrams to understand data gathered with descriptive statistics, correlation and regression. Qualitative data analysis is through the use of conceptualization by summarizing, categorizing, and structuring data gathered for analysis using narrative forms (Saunders, Lewis, and Thornhill, 2007; Hooker, and Monas, 2008)

### 4.6 Ethical considerations

Many ethical considerations were adhered in this research study during data collection time. The researcher followed ethical rules to ensure the privacy of the participants. Participants were given freedom in terms of questionnaire filling.

The research study was carried out once approval is received from the dissertation supervisor. Furthermore, information such as personal information, nature of participants and other related confidential information were not disclosed in this research. It can be noticed that no direct reference is made to any individuals and also data and information extraction was done anonymously.

The researcher shared personal contact information and details such as a personal email and a mobile phone to tackle any concerns or issues directly during the research study or in the future. Participants received informed consent to participate and they were discussed about the nature of research. Results and findings were reported in a complete and honest manner.

### 4.7 Limitations

The design limitations of research are listed below. This research study is based on case study approach, and interviews and surveys used for private and public sectors. Even though, the researcher gathered only 35 participants in the survey, five participants in pilot testing, and five participants in interviews, it is suitable and enough for this study.

Another limitation that this study faced was shorter time for data collection, such as less than three weeks for better sample size and data gathering more time should have been given. Due to cultural and geographical reasons, this research study was based on organizations in the UAE only so research context is valid and limited to UAE.

## 4.8 Conclusions

This chapter explains research methodology adopted in this study. The qualitative and quantitative approach was chosen in this study and suitable tools and techniques applied. The data collection methods used in this study were interviews and surveys and pilot testing also conducted to ensure the validity and reliability of the instrument.

The researcher conducted 5 pilot testing, 5 interviews and 35 surveys. Qualitative data analysis will be applied, such as the use of summarizing, categorizing, and structuring data gathered for analysis using narrative forms. Quantitative data analysis will be applied and the use Question Pro analytical tools. Finally, various ethical considerations were mentioned during conducting research followed by data analysis in this study.

# Chapter 5.0 Data Analysis and Findings

## 5.1 Background

The purpose of this study is to collect data based on achievement of research objectives and find answers to research questions from the interview and the online survey. In this chapter, there are details on data analysis and findings made from this study. This chapter displays data analysis where the researcher uses statistical format such as tables and figures followed by findings and results elaboration and discussion.

## 5.2 Descriptive Statistics

### 5.2.1 Validity

Figure 15 shows overall participant statistics. It shows that 44 participants completed and participated in this study and the completion rate is 41%. There are zero validation errors in this survey. The survey link was sent out and made available until December 18, 2016 and 44 participants participated in the online survey. Interviewees participants were also contacted and eight interviews were conducted (see Appendix for interview responses or data).

**Overall Participant Statistics**

| | Count |
|---|---|
| Viewed ( Reset ) | 244 |
| Started | 108 |
| Completed | 44 |
| Completion Rate | 40.74% |
| Drop Outs (After Starting) | 64 |
| Validation Errors | 0 |

Last Refreshed : Feb 03, 2017 11:21 PST (Refresh)    Response Rates - Explained

Figure 15: Overall Participant Statistics

### 5.2.2 Demographic Characteristics

Table 8 and Figure 16 shows gender of participants in this study. It shows that the majority of the respondents were females than males such as 24 and 19 out of 43 participations at 55.81% and 44.19%, respectively. The statistics were Mean: 1.558 | Confidence Interval @95%: [1.408-1.708] | Standard Deviation: 0.502.

Table 8: Gender of Participants

| Gender | Frequencies | Percentage |
|---|---|---|
| Male | 19 | 44.19% |
| Female | 24 | 55.81% |

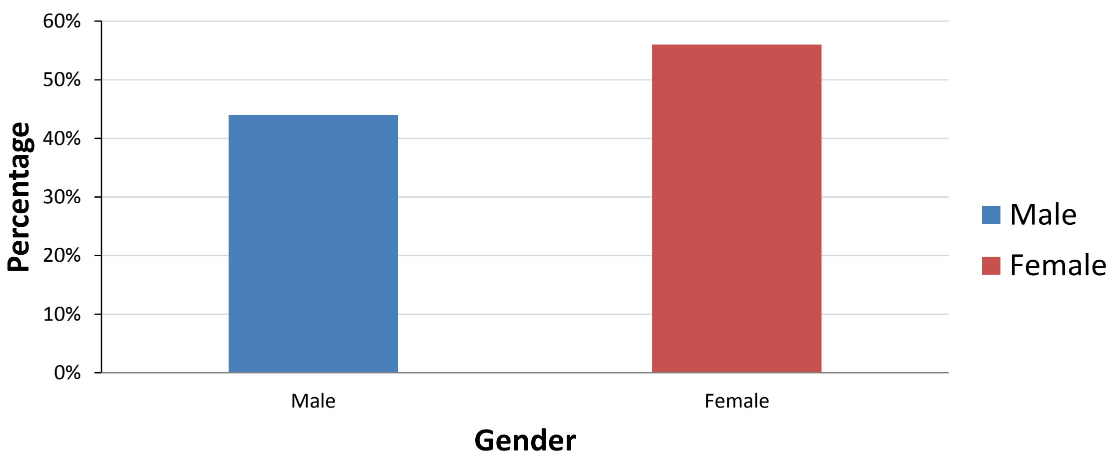



Figure 16: Gender of Participants

Table 9 and Figure 17 show educational level of participants in this study. It shows that the majority of the respondents were graduates 22 out of 44 participations at 50%. Postgraduates were 12 at 27.27%, undergraduate were 3 at 6.82%, others were 3 at 6.82%, some college were 2 at 4.55%, diploma was 1 at 2.27% and higher diploma was 1 at 2.27%. The statistics were Mean: 5.091 | Confidence Interval @ 95%: [4.743 - 5.439] | Standard Deviation: 1.178.

| Table 9: Educational Level of Participants | | |
|---|---|---|
| Educational Level | Frequencies | Percentage |
| Diploma | 1 | 2.27% |
| Higher Diploma | 1 | 2.27% |
| Some college | 2 | 4.55% |
| Undergraduate | 3 | 6.82% |
| Graduate | 22 | 50% |
| Postgraduate | 12 | 27.27% |
| Others | 3 | 6.82% |

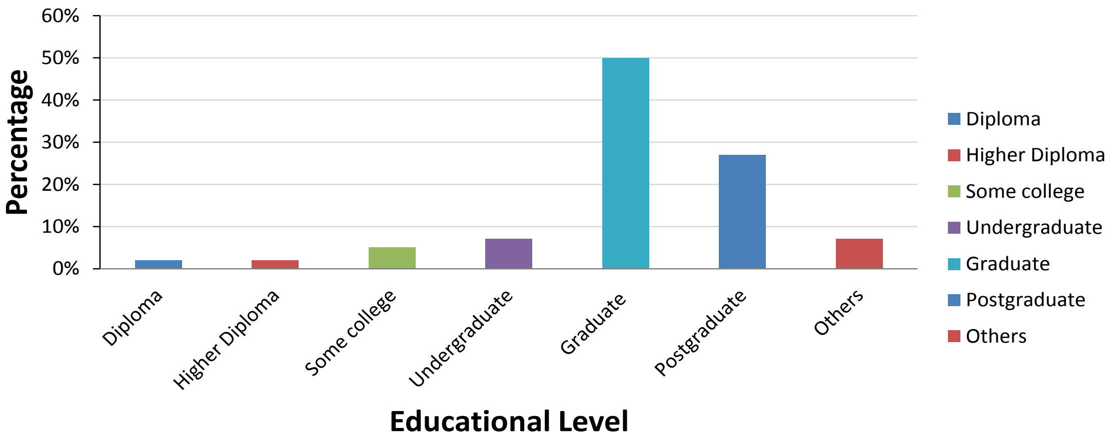



Figure 17: Educational Level of Participants

Table 10 and Figure 18 shows the number of implementation of BIM for precast in this study. It shows that the majority of the respondents 21 out of 44 participations at 47.73% implemented BIM for precast, while 18 at 40.91% did not implement and 5 at 11.36% confirms not applicable. The statistics were Mean: 1.636 | Confidence Interval @ 95%: [1.434 - 1.839] | Standard Deviation: 0.685.

| Table 10: Implementation of BIM for Precast | | |
|---|---|---|
| Implementation of BIM for Precast | Frequencies | Percentage |
| Yes, please answer the following questions. | 21 | 47.73% |
| No | 18 | 40.91% |
| Not applicable | 5 | 11.36% |

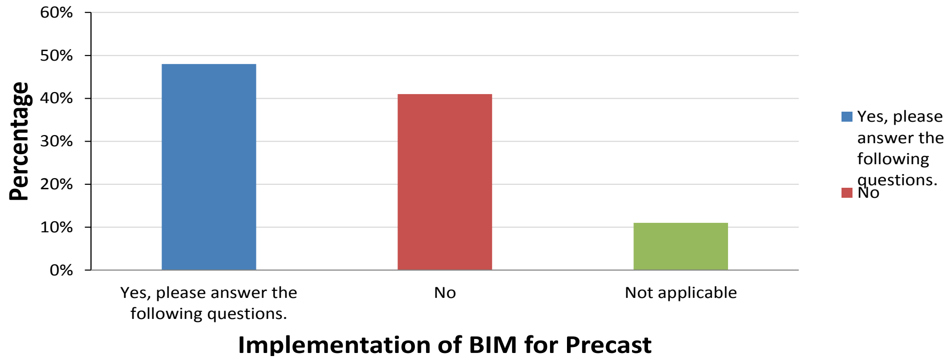



Figure 18: Implementation of BIM for Precast

Table 11 and Figure 19 shows the years worked in the precast industry of participants. It shows that the majority of the respondents were 5-10 years in the precast industry showing 16 participants at 38.10%. The rest of the data showed the experience of participants and they are 1-5 years were 13 participants at 30.95%, less than 1 year were 5 participants at 11.90%, 10-15 years were 3 participants at 7.14%, more than 20 years were 3 participants at 7.14%, and 15-20 years were 2 participants at 4.76%. The statistics were Mean: 2.833 | Confidence Interval @ 95%: [2.439 - 3.228] | Standard Deviation: 1.305.

Table 11: Years Worked in Precast Industry

| Years Worked in Precast Industry | Frequencies | Percentage |
|---|---|---|
| Less than 1 year | 5 | 11.9% |
| 1-5 years | 13 | 30.95% |
| 5-10 years | 16 | 38.1% |
| 10-15 years | 3 | 7.14% |
| 15-20 years | 2 | 4.76% |
| More than 20 years | 3 | 7.14% |

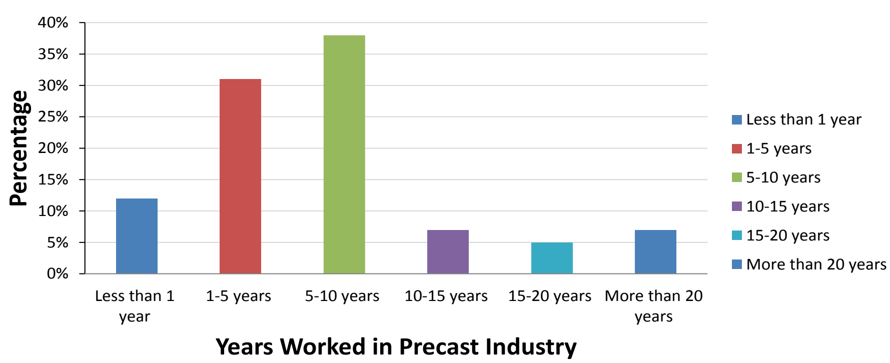


Figure 19: Years Worked in Precast Industry

Table 12 and Figure 20 shows the number of labors/employees in organization/company for 42 participants. The findings shows that the majority of the participant's company/organization includes the number of employees/labors more than 200 were 20 at 47.62%, 20-50 employees/labors were 7 at 16.67%, 50-100 employees/labors were 5 at 11.90%, 150-200 employees/labors were 5 at 11.90%, 100-150 employees/labors were 3 at 7.14%, and less than 20 employees/labors were 2 at 4.76%. The statistics were Mean: 4.476 | Confidence Interval @ 95%: [3.945 - 5.007] | Standard Deviation: 1.

| Table 12: Number of Labors/Employees in your Organization/Company | | |
|---|---|---|
| Number of Labors/Employees in your Organization/Company | Frequencies | Percentage |
| Less than 20 | 2 | 4.76% |
| 20-50 | 7 | 16.67% |
| 50-100 | 5 | 11.9% |
| 100-150 | 3 | 7.14% |
| 150-200 | 5 | 11.9% |
| More than 200 | 20 | 47.62% |

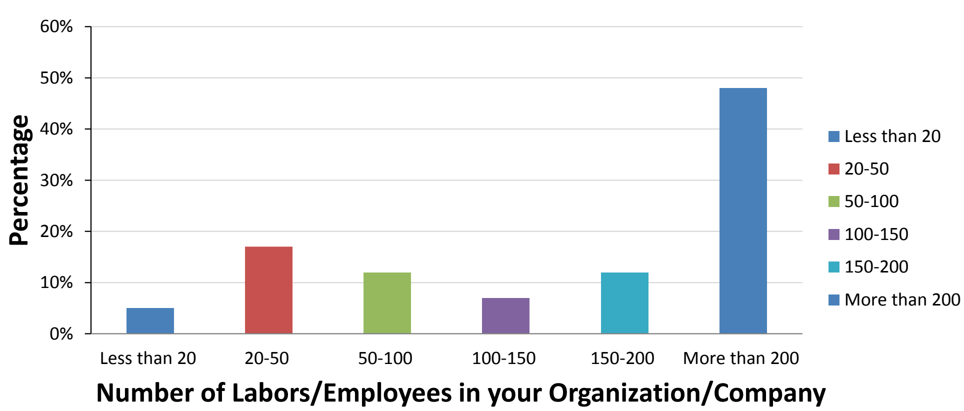



Figure 20: Number of Labors/Employees in your Organization/Company

Table 13 and Figure 21 shows the size of project cost based on input from 43 participants. The majority of the response from participants showed the size of the project cost more than 250 million were 14 at 32.56%, and the rest responded size of the project cost as less than 50 million were 11 at 25.58%, 50-100 million were 10 at 23.26%, 100-150 million were 4 at

9.30%, 200-250 million were 3 at 6.98%, and 150-200 million were 1 at 2.33%. The statistics were Mean: 3.395 | Confidence Interval @ 95%: [2.766 - 4.025] | Standard Deviation: 2.106.

| Table 13: Size of Project Cost | | |
|---|---|---|
| Size of Project Cost | Frequencies | Percentage |
| Less than 50 million | 11 | 25.58% |
| 50-100 million | 10 | 23.26% |
| 100-150 million | 4 | 9.3% |
| 150-200 million | 1 | 2.33% |
| 200-250 million | 3 | 6.98% |
| More than 250 million | 14 | 32.56% |

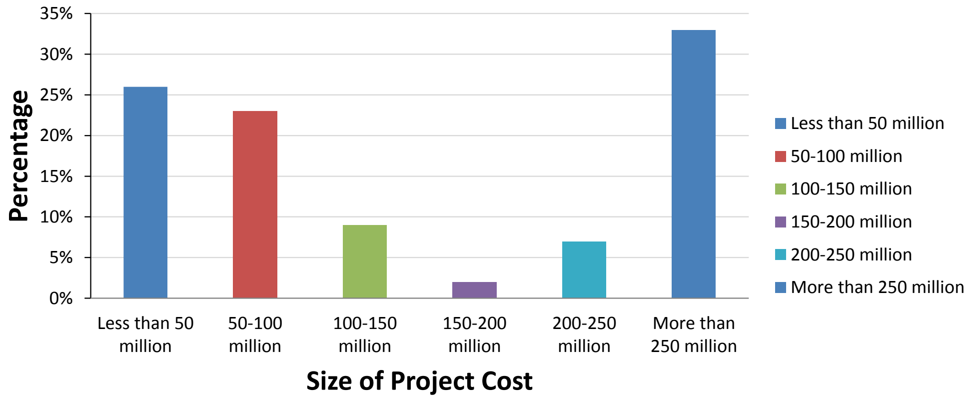



Figure 21: Size of Project Cost

Table 14 and Figure 22 show precast products applicable as per participants. Majority of participants selected structure (beams/columns) were 20 at 18.02% and the rest were walling were 17 at 15.32%, slabs were 15 at 13.51%, stairs were 14 at 12.61%, bridges were 13 at 11.71%, flooring were 12 at 10.81%, others were 9 at 8.11%, MEP elements were 7 at 6.31%, and sculptures were 4 at 3.60%. The statistics were Mean: 4.973 | Confidence Interval @ 95%: [4.497 - 5.449] | Standard Deviation: 2.560.

| Table 14: Precast Products | | |
|---|---|---|
| Precast Products | Frequencies | Percentage |
| Bridges | 13 | 11.71% |
| Flooring | 12 | 10.81% |

| Table 14: Precast Products | | |
|---|---|---|
| MEP Elements | 7 | 6.31% |
| Structure (Beams/Columns) | 20 | 18.02% |
| Slabs | 15 | 13.51% |
| Sculptures | 4 | 3.6% |
| Stairs | 14 | 12.61% |
| Walling | 17 | 15.32% |
| Others: Boundary walls, villas, under ground tanks, manholes, housing, fencing, boundary walls, mosques, labor camp, stadiums, and SLAB. | 9 | 8.11% |

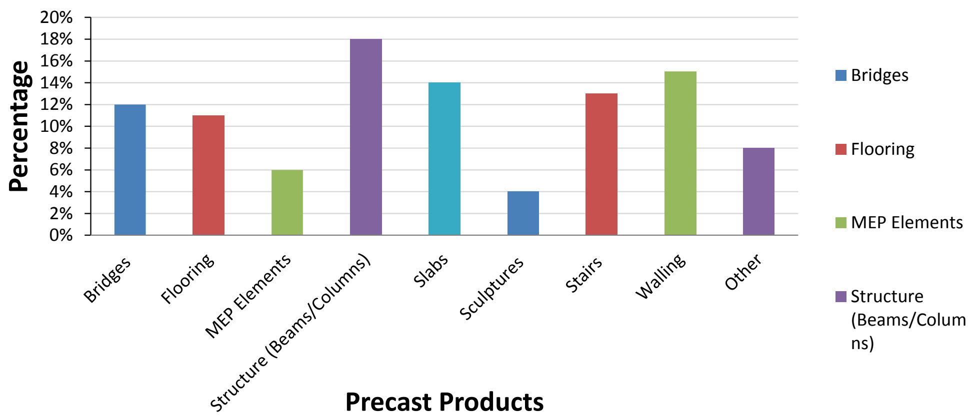



Figure 22: Precast Products

Table 15 and Figure 23 shows the position or the department of participants. Majority of participants holds position or works in the department were management 21 at 48.84%. The other positions/departments design was 10 at 23.26%, others were 7 at 16.28%, production were 4 at 9.30%, and logistics were 1 at 2.33%. The statistics were Mean: 3.930 | Confidence Interval @ 95%: [3.356 - 4.504] | Standard Deviation: 1.920.

| Table 15: Department/Position of Participants | | |
|---|---|---|
| Department/Position | Frequencies | Percentage |
| Design | 10 | 23.26% |
| Production | 4 | 9.3% |
| Procurement | 0 | 0% |
| Logistics | 1 | 2.33% |
| Management | 21 | 48.84% |
| Others: Projects, Head of Erection, Execution, | 7 | 16.28% |

| | | |
|---|---|---|
| Maintenance, Execution, Coordination and Planning. | | |

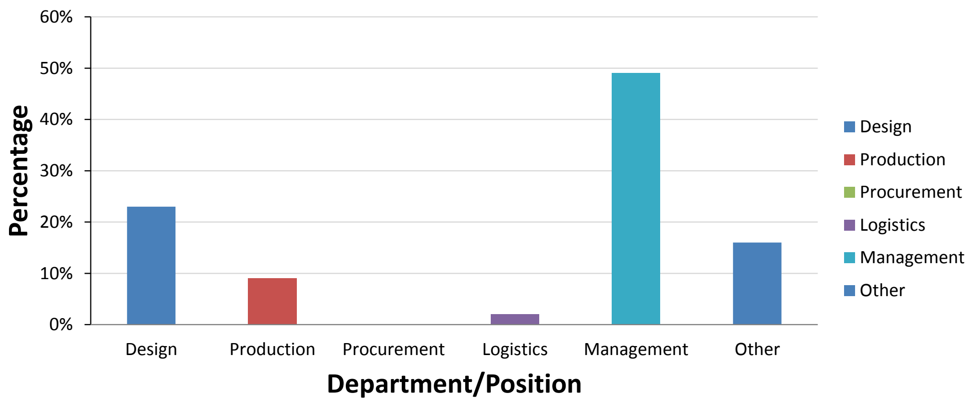



Figure 23: Department/Position of Participants

### 5.2.3 Cost Factors Affecting the Use of Precast Structures

According to results from the interview, the government authority cannot focus on price related strategy and their concern is only high quality so they keep in the mind the Total Quality Management System. They are also not concerned about total costs but specific precast structure type and related costs. Examples are budget planning, cost estimation, cost management, the engineering cost, erection costs, material costs, overhead costs, training costs, transportation, and costs from wastes.

In another interview finding, it shows that cost of quality, service cost and ability to market. The cost of quality is an important decision because precast concrete produced in controlled environment and labor for specialty gain in the work. Service costs include expensive risk such as time or schedule during construction for high-speed delivery & ease of installation makes precast better choice than cast-in-place concrete.

In addition, the most important factors are material costs, erection costs, and cost estimation. As per another interview finding, it shows that budget planning, cost estimation and cost management are important. Furthermore, the results from another interview also shows special construction, project accessibility, project clarity, project size, project type, project difficulty, the level of detail, client difficulty, contractor problems, competition, labor rates and, material costs.

Furthermore, in another interview, the findings were size, type, special construction, project accessibility, project clarity, project difficulty, the level of detail, client difficulty, contractor problems, time of year, competition, labor rates, material costs, general economic pressures and functional life of components.

Table 16 and Figure 25 present the results for the cost factors affecting the use of precast structures based on 43 participants. The results showed budget planning (80.47%), cost estimation (78.60%), cost management (73.81%), engineering cost (72.56%), erection costs (67.91%), inflation (70.23%), material costs (79.52%), overhead costs (77.21%), training costs (64.19%), transportation costs (74.42%), and wastes costs (66.51%). The mean were 4.023, 3.930, 3.690, 3.628, 3.395, 3.512, 3.976, 3.860, 3.209, 3.721, and 3.326, respectively. Therefore, the majority of the respondents agree that budget planning, cost estimation, material costs, and overhead costs affects precast structures use in precast industry.

Table 16: Cost Factors Affecting the Use of Precast Structures

| Cost Factors | Frequencies | Percentage | Mean |
|---|---|---|---|
| Budget planning | 43 | 80.47% | 4.023 |
| Cost estimation | 43 | 78.60% | 3.930 |
| Cost management | 42 | 73.81% | 3.690 |
| Engineering cost | 43 | 72.56% | 3.628 |
| Erection costs | 43 | 67.91% | 3.395 |
| Inflation | 43 | 70.23% | 3.512 |
| Material costs | 42 | 79.52% | 3.976 |
| Overhead costs | 43 | 77.21% | 3.860 |
| Training costs | 43 | 64.19% | 3.209 |
| Transportation costs | 43 | 74.42% | 3.721 |
| Wastes costs | 43 | 66.51% | 3.326 |
| | | | Weighted Mean: 3.661 |

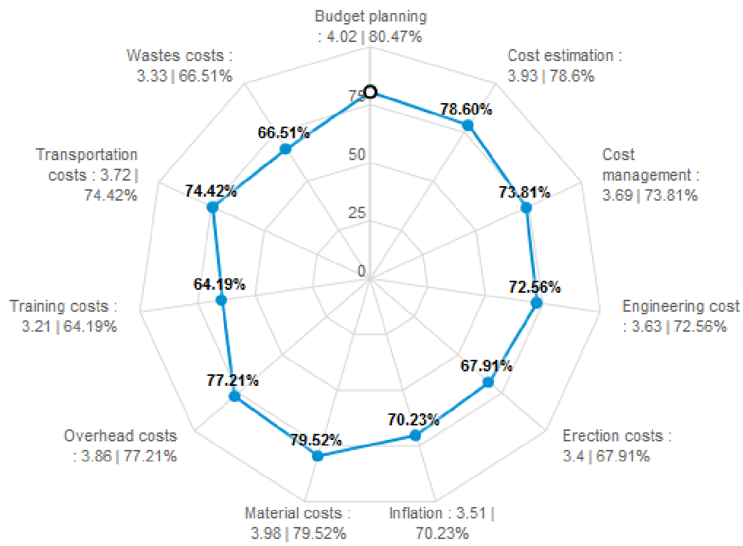



Figure 24: Cost Factors Affecting the Use of Precast Structures

Table 17 and Figure 25 show rank and score from results of cost factors affecting the use of precast structures. The highest scores were budget planning at 4.02, material costs at 3.98, cost estimation at 3.93, overhead costs at 3.86, transportation costs at 3.72, cost management at 3.69, and the engineering cost at 3.63. The findings from literature and this study shows similarities. I also prefer that companies in the construction industry make use of BIM so they can minimize the negative impact of cost factors affecting in the use of precast structures. Glass (2000) describes that the cost in precast structure creates challenges. Due to these challenges, there is lack of consideration for precast concrete consideration where there might be additional costs. Park (2003) also confirms that additional and extra costs of precast structure lead to prevention in implementation. Pheng and Chuan (2001) find that production in feasible prior to delivery. Sacks, Akinci, and Ergen (2003) also states that precast operations involves large costs after production of precast units. This research study finds ranks for factors cost factors ranked in Table 17 and Figure 26 from highest consideration to the lowest consideration and they are budget planning, material costs, cost estimation, overhead costs, transportation costs, cost management, the engineering cost, inflation, erection costs, costs of wastes, and training costs.

| Table 17: Rank and Score of Cost Factors Affecting the Use of Precast Structures | | |
|---|---|---|
| Cost Factors Affecting the Use of Precast Structures | Rank | Score |
| Budget planning | 1st | 4.02 |
| Material costs | 2nd | 3.98 |
| Cost estimation | 3rd | 3.93 |
| Overhead costs | 4th | 3.86 |
| Transportation costs | 5th | 3.72 |
| Cost management | 6th | 3.69 |
| Engineering cost | 7th | 3.63 |
| Inflation | 8th | 3.51 |
| Erection costs | 9th | 3.4 |
| Wastes costs | 10th | 3.33 |
| Training costs | 11th | 3.21 |

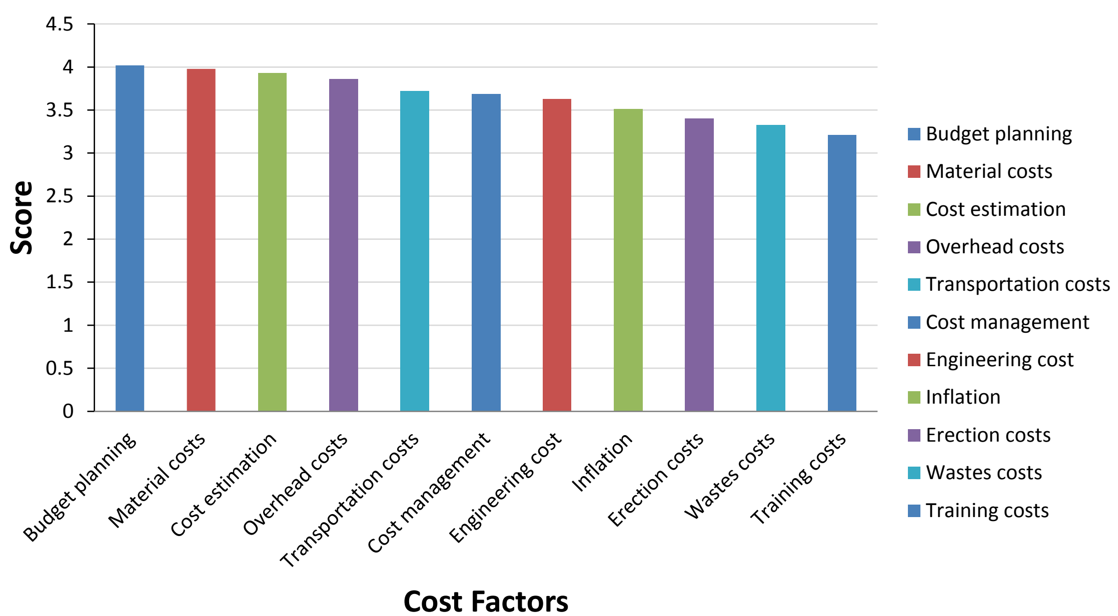



Figure 25: Score of Cost Factors Affecting the Use of Precast Structures

### 5.2.4 Time Factors Affecting the Use of Precast Structures

Time factors affects the use of precast structures and these are found in interview data findings. Time factors are construction speed and project duration, which are necessary when comparing with traditional methods. The government type of customers faces higher reputations and less project durations. In another interview, the findings showed project duration, construction speed, delivery speed, and time for finishing work.

In another interview, the results were similar such as project duration, time for finishing work and time for handling and equipment use. Accordingly, there is need for less procurement time, less finishing time, less supervision time, etc. Precast structures are manufactured in the plant so the contractor can face overlapping activities and they can shorten project duration. The time can be reduced based on the proceeding of foundation works such as wall panels, columns, and beams are being produced at the factory. In addition, in another interview also the results showed construction speed, production planning, time for super and sub precast structure.

There is also a similar result from another interview result such as construction speed, project duration and delivery speed. Furthermore, interview finding also showed other factors that affect use of precast structure such as the shortage of labour, skill shortages, low speed of decision, design errors made by designers and underestimation of time of completion. Moreover, another interview result also listed similar finding such as financial difficulties, the shortage of labour, skill shortages, unforeseen ground, condition**,** unrealistic deadlines for project completion, the poor communication, poor organization of the contractor/consultant, low speed of decision, design errors made by designers and underestimation in the time of completion.

Table 18 and Figure 26 present the results for time factors affecting the use of precast structures based on 42 participants. The results showed construction speed (87.62%), project duration (86.19%), delivery speed (83.33%), production planning and scheduling (83.33%), time for finishing work (83.33%), time for super precast structure (79.05%), time for handling and equipment use (75.24%), time for sub precast structure (73.81%), and communication (69.52%).

The mean were 4.381, 4.31, 4.167, 4.167, 4.167, 3.952, 3.762, 3.69, and 3.476, respectively. Therefore, the majority of the respondents agrees that construction speed, project duration, delivery speed, production planning and scheduling, and time for finishing work affects precast structures use in precast industry.

| Table 18: Time Factors Affecting the Use of Precast Structures | | | |
|---|---|---|---|
| Time Factors | Frequencies | Percentage | Mean |
| Communication | 42 | 69.52% | 3.476 |
| Construction speed | 42 | 87.62% | 4.381 |
| Delivery speed | 42 | 83.33% | 4.167 |
| Production planning and scheduling | 42 | 83.33% | 4.167 |
| Project duration | 42 | 86.19% | 4.310 |
| Time for finishing work | 42 | 83.33% | 4.167 |
| Time for handling and equipment use | 42 | 75.24% | 3.762 |
| Time for sub precast structure | 42 | 73.81% | 3.690 |
| Time for super precast structure | 42 | 79.05% | 3.952 |
| | | | Weighted Mean: 4.008 |

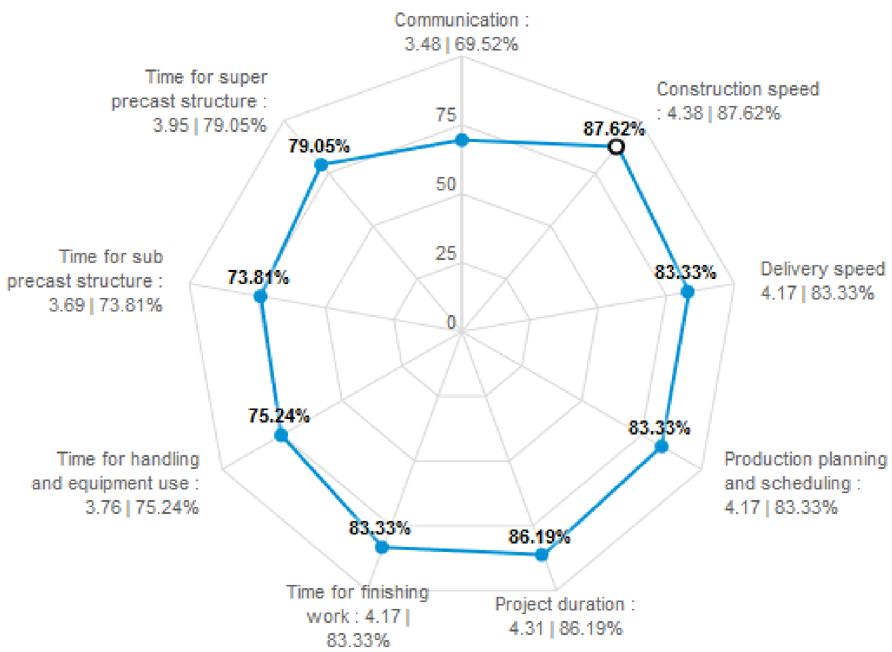



Figure 26: Time Factors Affecting the Use of Precast Structures

Table 19 and Figure 27 show the rank and score from the results of time factors affecting the use of precast structures. The highest scores were construction speed at 4.38, project duration at 4.31, delivery speed at 4.17, production planning and scheduling at 4.17, and time for finishing work at 4.17. The findings from literature and this study shows similarities. I also prefer that companies in the construction industry make use of BIM so they can minimize the negative impact of time factors affecting in the use of precast structures.

Sacks, Akinci, and Ergen (2003) finds that the range of timing affects precast concrete manufacturing during construction projects. Therefore, depending on the design whether custom or standard, there is need for time. According to Polat (2008) and Ergin, Arditi, & Günhan (2000), scheduling is challenging so time factor affects use of precast structures. This research study finds ranks for factors cost factors ranked in Table 18 and Figure 30 from the highest consideration to the lowest consideration and they are construction speed, project duration, delivery speed, production planning and scheduling, time for finishing work, super precast structure, handling and equipment use, sub precast structure and communication.

| Table 18: Rank and Score of Time Factors Affecting the Use of Precast Structures | | |
|---|---|---|
| Time Factors Affecting the Use of Precast Structures | Rank | Score |
| Construction speed | 1st | 4.38 |
| Project duration | 2nd | 4.31 |
| Delivery speed | 3rd | 4.17 |
| Production planning and scheduling | 4th | 4.17 |
| Time for finishing work | 5th | 4.17 |
| Time for super precast structure | 6th | 3.95 |
| Time for handling and equipment use | 7th | 3.76 |
| Time for sub precast structure | 8th | 3.69 |
| Communication | 9th | 3.48 |

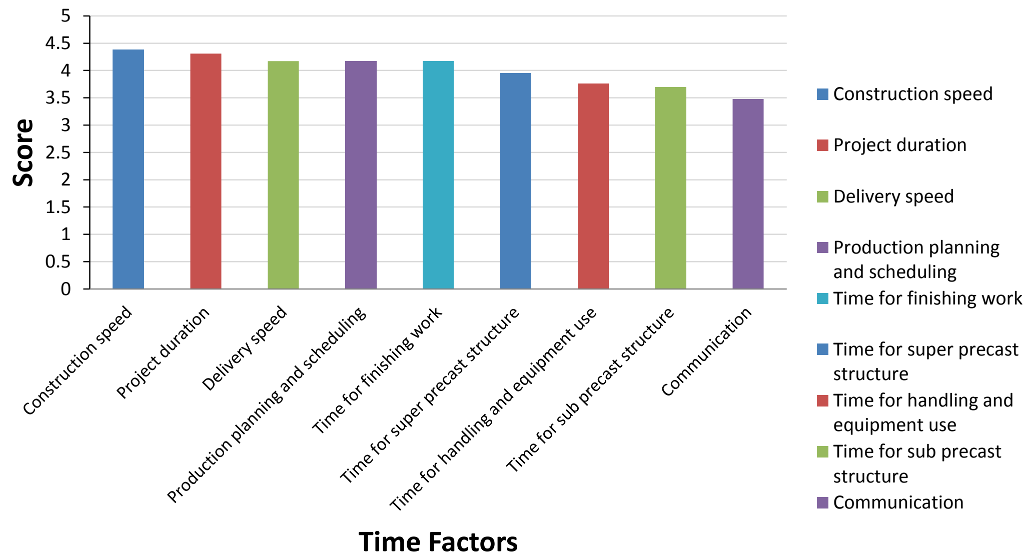



Figure 27: Score of Time Factors Affecting the Use of Precast Structures

### 5.2.5 Quality Factors Affecting the Use of Precast Structures

Quality factors include errors and omissions, quality controlling and monitoring and quantity of labor and related costs based on project size. Errors and omissions will affect also and delay the project and lack of quality. Client or customer expectations are affected because of quality of labor and it is considered as the biggest risk as per interview data. Based on project size, there is a relationship between quality controlling and monitoring, and the quantity of labor and related costs.

In another interview, the findings for quality factors were concrete batch consistency, smooth/rigid molds/forms, labor specialist, uniformity, and the need for well-controlled environment. The other factors by another interview results showed defects detection, quality controlling and monitoring and production automation. Some of the quality factors that government agency should achieve are meeting client or customer expectations, eliminating errors and omissions, assuring quality controlling and monitoring and maintaining the quantity of labor and related costs based on project size.

Table 19 and Figure 28 present results for quality factors affecting the use of precast structures based on 43 participants. The results showed quality controlling and monitoring (85.58%), production automation (83.72%), the quantity of labor and related costs based on project size (81.40%), client or customer expectations (80.93%), errors and omissions (80.93%), design and drafting (79.07%), engineering productivity (79.07%), detection of defects (71.63%), decision-making (71.16%), construction documentation (70.70%), and customer service (69.77%). The mean were 4.279, 4.186, 4.07, 4.047, 4.047, 3.953, 3.953, 3.581, 3.558, 3.535, and 3.488, respectively. Therefore, the majority of the respondents agree that quality controlling and monitoring, production automation, the quantity of labor and related costs based on project size, client or customer expectations, and errors and omissions are factors of the quality that affects precast structures use in precast industry.

Table 19: Quality Factors Affecting the Use of Precast Structures

| Quality Factors | Frequencies | Percentage | Mean |
|---|---|---|---|
| Client or customer expectations | 43 | 80.93% | 4.047 |
| Construction documentation | 43 | 70.70% | 3.535 |
| Customer service | 43 | 69.77% | 3.488 |
| Decision-making | 43 | 71.16% | 3.558 |
| Defects detection | 43 | 71.63% | 3.581 |
| Design and drafting | 43 | 79.07% | 3.953 |
| Engineering productivity | 43 | 79.07% | 3.953 |
| Errors and omissions | 43 | 80.93% | 4.047 |
| Production automation | 43 | 83.72% | 4.186 |
| Quality controlling and monitoring | 43 | 85.58% | 4.279 |
| Quantity of labor and related costs based on project size | 43 | 81.40% | 4.070 |
| | | | Weighted Mean: 3.882 |

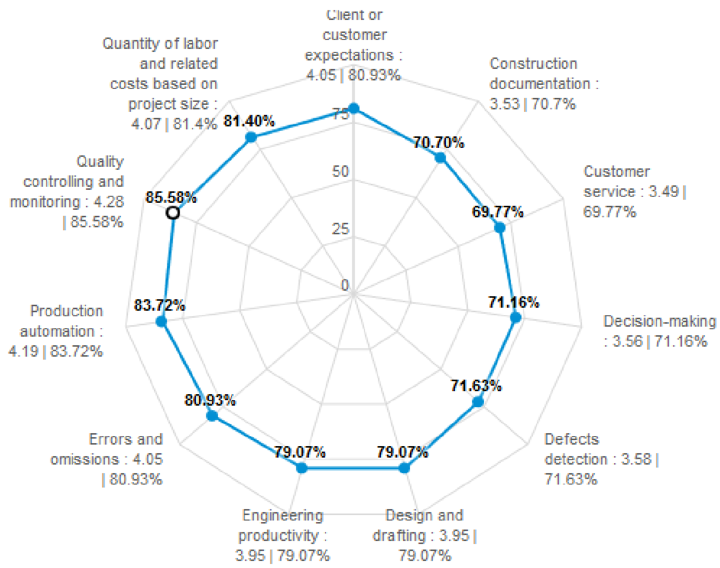



Figure 28: Quality Factors Affecting the Use of Precast Structures

Table 20 and Figure 29 show rank and score from results of quality factors affecting the use of precast structures. The highest scores were quality controlling and monitoring at 4.28, production automation at 4.19, the quantity of labor and related costs based on the project size at 4.07, client or customer expectations at 4.05, and errors and omissions at 4.05. The findings from literature and this study shows similarities. I also prefer that companies in the construction industry make use of BIM so they can minimize the negative impact of quality factors affecting in the use of precast structures. According to Glass (2000), quality is a challenge, especially when trying to make customers or clients happy.

There is need for various quality measures to ensure meeting needs of clients. At the same time, construction techniques are affected by quality when joining elements of precast structure (Park, 2003; Glass, 2000; Polat, 2008; Ergin, Arditi, & Günhan, 2000). This research study finds ranks for factors cost factors ranked in Table 21 and Figure 32 from the highest consideration to the lowest consideration and they are quality controlling and monitoring, production automation, the quantity of labor and related costs based on project size, client or customer expectations, errors and omissions, design and drafting, engineering productivity, detection of defects, decision-making, construction documentation, and customer service.

| Table 20: Rank and Score of Quality Factors Affecting the Use of Precast Structures | | |
|---|---|---|
| Quality Factors Affecting the Use of Precast Structures | Rank | Score |
| Quality controlling and monitoring | 1st | 4.28 |
| Production automation | 2nd | 4.19 |
| Quantity of labor and related costs based on project size | 3rd | 4.07 |
| Client or customer expectations | 4th | 4.05 |
| Errors and omissions | 5th | 4.05 |
| Design and drafting | 6th | 3.95 |
| Engineering productivity | 7th | 3.95 |
| Defects detection | 8th | 3.58 |
| Decision-making | 9th | 3.56 |
| Construction documentation | 10th | 3.53 |
| Customer service | 11th | 3.49 |

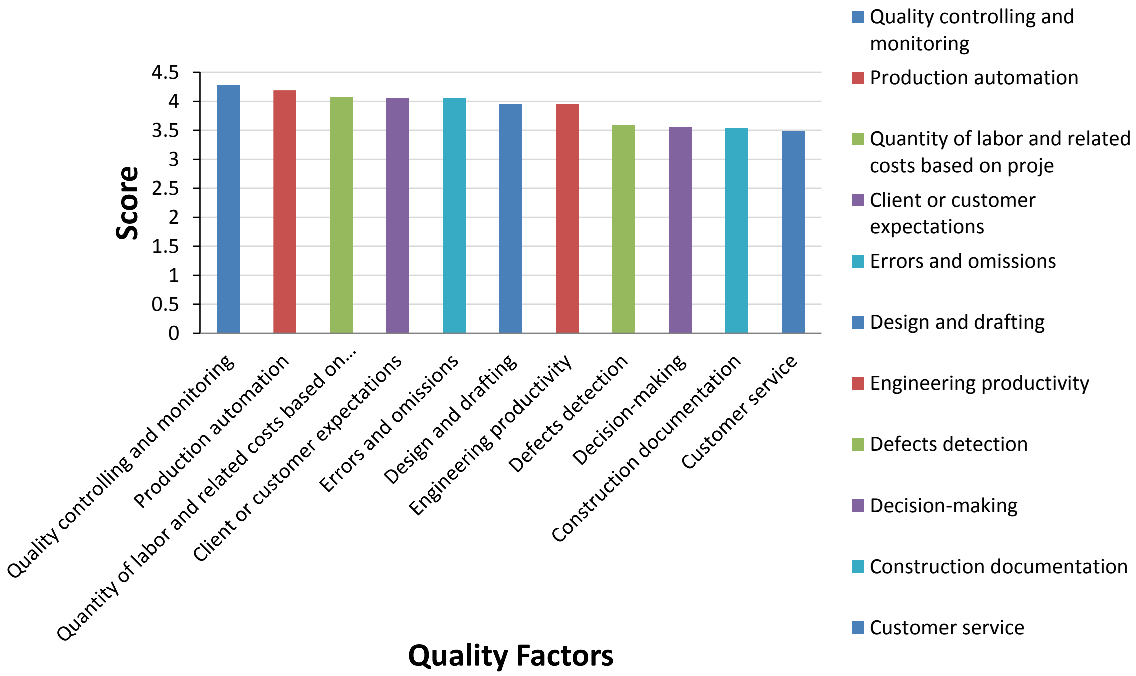



Figure 29: Score of Quality Factors Affecting the Use of Precast Structures

### 5.2.6 Critical Success Factors (CSFs) to Adopt BIM for Precast

CSFs as per interview results are quality management, safety, environmental, culture of sharing, communicating, project management, ease of visualization, accuracy, adapting to current technology, departmental commonness of project outlook, an overview of what will really happen, earlier quantifying and qualifying of risk, low costs and expenses, top management support, training and education, theory refinement and integration, organizational culture, communication, it support, resource availability, stage control, manageable size, skills and abilities, strategies alignment, and tools and techniques, empowered inter-principle lean team, top management support, training and education, refinement and integration of theory, organizational culture, communication, IT support, resource availability, stage control, manageable size, skills and abilities, alignment of strategies, standardization and tools and techniques.

For all CSFs, all participants in this study agree that these factors are important to adopt BIM for precast usage (see Figure 30). They agree percentages are project manager and team at 66.67%, project management at 61.90%, low costs and expenses at 60.47%, functions and features at 60.47%, management commitment, participation, and support at 58.14%, effort and timeliness at 54.76%, quality management at 54.76%, interest and the willingness for BIM at 54.76%, clear business strategy and goals at 53.49%, clients' request for BIM at 53.49%, training and development at 50.00%, web-based at 50.00%, performance metrics at 50.00%, IT capabilities technical support at 50.00%, long-term strategy of the BIM provider at 48.84%, investment in BIM costs at 48.84%, learning the curve at 46.51%, employees' expertise in BIM at 46.51%, safety, and environmental at 40.48%, the pilot project at 40.48%, economic impact at 39.53%, adoption strategy at 37.21%, construction location site at 37.21%, culture of sharing and communicating at 37.21%, and mitigate resistance to change at 32.56%.

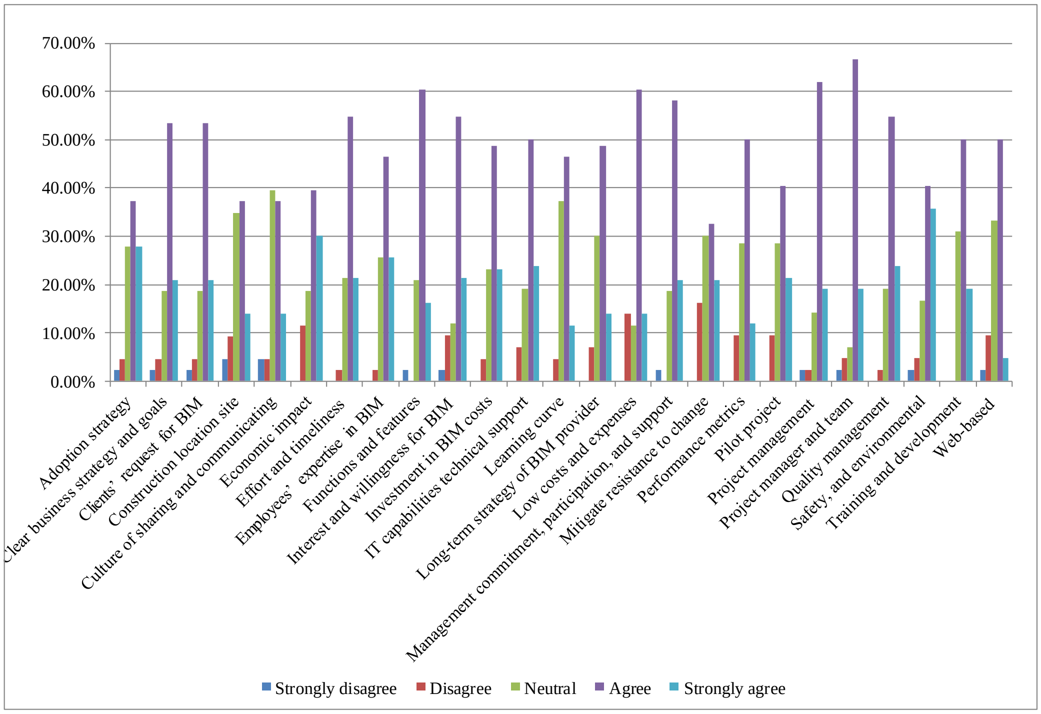



Figure 30: Critical Success Factors to Adopt BIM for Precast

Table 21 and Figure 31 shows ranking score from results of critical success factors to adopt BIM for precast. The highest scores were safety, and environmental at 4.02, quality management at 4.00, effort and timeliness at 3.95, employees' expertise in BIM at 3.95, management commitment, participation, and support at 3.95, project manager and team at 3.95, project management at 3.93, investment in BIM costs at 3.91, IT capabilities technical support at 3.90, economic impact at 3.88, functions and features at 3.88, training and development at 3.88, clear business strategy and goals at 3.86, clients' request for BIM at 3.86, adoption strategy at 3.84, and interest and the willingness for BIM at 3.83.

Table 21: Score of Critical Success Factors to Adopt BIM for Precast

| Critical Success Factors to Adopt BIM for Precast | Score |
|---|---|
| Safety, and environmental | 4.02 |
| Quality management | 4.00 |
| Effort and timeliness | 3.95 |
| Employees' expertise in BIM | 3.95 |
| Management commitment, participation, and support | 3.95 |
| Project manager and team | 3.95 |

| Table 21: Score of Critical Success Factors to Adopt BIM for Precast | |
|---|---|
| Critical Success Factors to Adopt BIM for Precast | Score |
| Project management | 3.93 |
| Investment in BIM costs | 3.91 |
| IT capabilities technical support | 3.90 |
| Economic impact | 3.88 |
| Functions and features | 3.88 |
| Training and development | 3.88 |
| Clear business strategy and goals | 3.86 |
| Clients’ request for BIM | 3.86 |
| Adoption strategy | 3.84 |
| Interest and willingness for BIM | 3.83 |
| Low costs and expenses | 3.74 |
| Pilot project | 3.74 |
| Long-term strategy of BIM provider | 3.70 |
| Learning curve | 3.65 |
| Performance metrics | 3.64 |
| Mitigate resistance to change | 3.58 |
| Culture of sharing and communicating | 3.51 |
| Construction location site | 3.47 |
| Web-based | 3.45 |

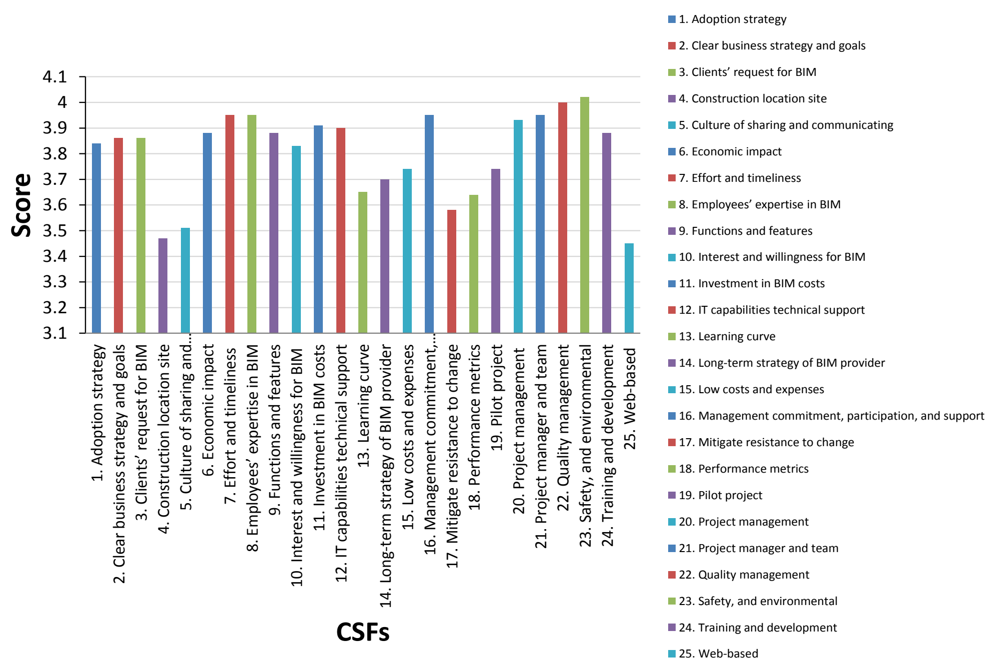



Figure 31: Score of Critical Success Factors to Adopt BIM for Precast

CSFs ensures success with the elimination of impact from challenges and difficulties in precast structures. According to Sacks et al. (2005), it is possible to eliminate challenges through factors such as cost, time and quality. The concept and characteristic of BIM reshapes precast structures in construction projects so BIM software in the market improves cost, quality and time with various features and functions (Omar, Nawi, & Nursal, 2014).

BIM adoption offers various benefits during use of precast structures in terms of cost savings, proper scheduling and better quality (Sanchez, Hampson, and Vaux, 2016). Various CSFs are considered to ensure success of BIM installation and use of precast structures so the better the integration of BIM, then the improved outcome and results (Bender, 2010; CURT, 2010; Won, & Lee, 2010; Gu, & London, 2010; Khosrowshahi, & Arayici, 2012; Arayici, et al. 2011). CSFs criteria are quality, cost and time (Albert, 2004; Harris, 2013; Datta, & Koehn, 2003; Bosché, 2010). With BIM, it is possible for quality improvement and live detection of any problems and helps Quality Managers to make use of data from various times and locations for comparison (Wangm 2015).

The application of BIM comes with rapidity in quality enhancement, time reduction and cost reduction. Therefore, the construction industry embraces BIM where new tools and processes are applied. (Ku, & Taiebat, 2011) Nowadays, BIM observed as common practice within industries such as architectural, engineering, construction, and facilities. Some of the benefits experienced by these industries are costs and schedule during design and construction phases. (Luth, Schorer, & Turkan, 2014) According to Omar, Nawi, & Nursal (2014) finds that BIM comes as solution provider for various problems in the construction industry. With BIM, there are better quality and less time and cost as per Hamdan, Barkokebas, Manrique, & Al-Hussein (2015).

## 5.3 Correlation Analysis (Spearman rho)

Table 22 shows correlation coefficient analysis with numerical value that is close to a positive agreement for more than 0 in black, negative agreement for less than 0 in red and equal to 0 as no agreement in green between CSFs and cost factors relationship.

Table 22: CSF and Cost Factors Relationship

| CSF | Budget planning | Cost estimation | Cost management | Engineering cost | Erection costs | Inflation | Material costs | Overhead costs | Training costs | Transportation costs | Wastes costs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Adoption strategy | 0.47 | 0.48 | 0.28 | 0.32 | 0.16 | 0.30 | 0.29 | 0.14 | -0.05 | 0.16 | 0.18 |
| Clear business strategy… | 0.52 | 0.4 | 0.37 | 0.21 | 0.08 | 0.24 | 0.16 | 0.07 | 0.03 | 0.34 | 0.23 |
| Clients' request for BIM | 0.48 | 0.17 | 0.2 | 0.19 | 0.18 | 0.38 | 0.11 | 0.25 | 0.02 | 0.25 | 0.03 |
| Construction location site | 0.28 | 0.15 | 0.22 | 0.45 | 0.05 | 0.25 | 0.27 | 0.41 | 0.30 | 0.52 | 0.22 |
| Culture of sharing and communi ... | 0.20 | 0.14 | 0.24 | 0.45 | 0.49 | 0.40 | 0.21 | 0.15 | 0.28 | 0.17 | 0.38 |
| Economic impact | 0.34 | 0.09 | 0.24 | 0.33 | 0.23 | 0.04 | 0.23 | 0.04 | 0.25 | 0.38 | 0.32 |
| Effort and timeliness | 0.27 | 0.23 | 0.36 | 0.25 | 0.25 | 0.06 | 0.41 | 0.19 | 0.22 | 0.44 | 0.27 |
| Employees' expertise in BIM | 0.50 | 0.16 | 0.06 | 0.22 | 0.07 | 0.11 | -0.01 | -0.11 | 0.1 | 0.22 | 0.20 |
| Functions and features | 0.13 | -0.08 | -0.04 | 0.18 | 0.10 | 0.24 | 0.04 | 0.23 | 0.14 | 0.03 | 0.16 |
| Interest and willingness for B ... | 0.32 | 0.16 | 0 | 0.07 | 0.17 | 0.15 | 0.08 | 0.02 | -0.14 | 0.15 | 0.30 |
| Investment in BIM costs | 0.44 | 0.11 | 0.15 | -0.09 | -0.01 | 0.07 | -0.14 | -0.09 | 0.04 | 0.26 | 0.14 |

Table 22: CSF and Cost Factors Relationship

| CSF | Budget planning | Cost estimation | Cost management | Engineering cost | Erection costs | Inflation | Material costs | Overhead costs | Training costs | Transportation costs | Wastes costs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IT capabilities technical supp ... | 0.57 | 0.08 | 0.30 | 0.28 | 0.14 | 0.29 | 0.06 | 0.08 | 0.26 | 0.53 | 0.17 |
| Learning curve | 0.26 | 0.42 | 0.08 | 0.32 | 0.36 | 0.41 | 0.31 | 0.20 | 0.17 | 0.15 | 0.41 |
| Long-term strategy of BIM prov ... | 0.53 | 0.14 | 0.38 | 0.39 | 0.21 | 0.40 | 0.12 | 0.28 | 0.25 | 0.26 | 0.24 |
| Low costs and expenses | -0.02 | 0.25 | 0.28 | 0.18 | 0.05 | 0.11 | 0.08 | 0.26 | 0.22 | 0.21 | 0.28 |
| Management commitment, partici ... | 0.32 | 0.48 | 0.26 | 0.08 | -0.11 | 0.10 | 0.19 | 0.10 | 0.02 | 0.38 | 0.13 |
| Mitigate resistance to change | 0.42 | 0.20 | 0.36 | 0.17 | 0.16 | 0.24 | -0.03 | 0.01 | 0.20 | 0.47 | 0.16 |
| Performance metrics | 0.25 | 0.36 | 0.20 | 0.34 | 0.18 | 0.26 | 0.42 | 0.44 | 0.21 | 0.37 | 0.40 |
| Pilot project | 0.30 | 0.28 | 0.13 | 0.22 | 0.19 | 0.50 | 0.11 | 0.20 | 0.14 | 0.25 | 0.24 |
| Project management | 0.24 | 0.25 | 0.14 | 0.11 | 0.34 | 0.41 | 0.53 | 0.27 | 0.15 | 0.23 | 0.41 |
| Project manager and team | 0.51 | 0.16 | 0.35 | 0.30 | 0.32 | 0.34 | 0.42 | 0.41 | 0.08 | 0.22 | 0.31 |
| Quality management | 0.36 | 0.25 | 0.52 | 0.17 | 0.18 | 0.07 | 0.35 | 0.29 | 0.34 | 0.48 | 0.28 |

Table 22: CSF and Cost Factors Relationship

| CSF | Budget planning | Cost estimation | Cost management | Engineering cost | Erection costs | Inflation | Material costs | Overhead costs | Training costs | Transportation costs | Wastes costs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Safety, and environmental | 0.05 | 0.22 | 0.22 | 0.25 | 0.34 | 0.01 | 0.29 | 0.19 | 0.27 | 0.35 | 0.35 |
| Training and development | 0.31 | 0.11 | 0.22 | 0.23 | 0.23 | 0.09 | 0.01 | -0.01 | 0.23 | 0.32 | 0.24 |
| Web-based | 0.22 | 0.15 | 0.10 | 0.25 | 0.22 | 0.46 | 0.07 | 0.09 | 0.26 | 0.23 | 0.21 |

Table 23 shows correlation coefficient analysis with numerical value that is close to a positive agreement for more than 0, a negative agreement for less than 0 in red and equal to 0 as no agreement in green between CSFs and time factors relationship.

Table 23: CSF and Time Factors Relationship

| CSF | Communication | Construction speed | Delivery speed | Production planning and schedule | Project duration | Time for finishing work | Time for handling and equipment | Time for sub precast structure | Time for super precast structure |
|---|---|---|---|---|---|---|---|---|---|
| Adoption strategy | 0.16 | 0.26 | 0.11 | 0.25 | 0.44 | 0.36 | 0.34 | 0.15 | 0.09 |
| Clear business strategy and go ... | 0.22 | 0.20 | 0.27 | 0.31 | 0.48 | 0.36 | 0.24 | 0.14 | 0.07 |
| Clients' request for BIM | 0.13 | 0.36 | 0.19 | 0.34 | 0.26 | 0.29 | 0.24 | 0.11 | 0.07 |
| Construction location site | 0.22 | 0.14 | 0.15 | -0.01 | 0.02 | -0.02 | 0.18 | 0.31 | 0.18 |
| Culture of sharing and | 0.29 | 0.16 | -0.04 | 0.07 | 0.25 | 0.30 | 0.33 | 0.25 | 0.29 |

Table 23: CSF and Time Factors Relationship

| CSF | Communication | Construction speed | Delivery speed | Production planning and schedule | Project duration | Time for finishing work | Time for handling and equipment | Time for sub precast structure | Time for super precast structure |
|---|---|---|---|---|---|---|---|---|---|
| communi ... | | | | | | | | | |
| Economic impact | 0.41 | 0.35 | 0.16 | 0.09 | 0.41 | 0.23 | 0.17 | 0.15 | 0.14 |
| Effort and timeliness | 0.38 | 0.30 | 0.40 | 0.26 | 0.44 | 0.24 | 0.32 | 0.46 | 0.32 |
| Employees' expertise in BIM | 0.27 | 0.34 | 0.09 | 0.12 | 0.48 | 0.36 | 0.28 | 0.17 | 0.08 |
| Functions and features | 0.10 | 0.21 | 0.09 | 0.16 | 0.07 | -0.02 | -0.07 | 0.06 | 0.04 |
| Interest and willingness for B ... | 0.19 | 0.48 | 0.22 | 0.18 | 0.30 | 0.16 | 0.18 | 0 | 0.10 |
| Investment in BIM costs | -0.09 | 0.35 | 0.25 | 0.16 | 0.32 | 0.19 | 0.30 | 0.17 | -0.04 |
| IT capabilities technical supp ... | 0.42 | 0.26 | 0.38 | 0.34 | 0.47 | 0.28 | 0.17 | 0.30 | 0.08 |
| Learning curve | 0.38 | 0.18 | 0.02 | 0.11 | 0.28 | 0.21 | 0.40 | 0.39 | 0.37 |
| Long-term strategy of BIM prov ... | 0.16 | 0.15 | 0.19 | 0.14 | 0.18 | 0.03 | 0.17 | 0.39 | 0.17 |
| Low costs and expenses | 0.26 | 0.24 | 0.39 | 0.28 | 0.42 | 0.30 | 0.21 | 0.23 | 0.24 |
| Management commitment, partici ... | 0.15 | 0.25 | 0.15 | 0.23 | 0.47 | 0.48 | 0.39 | 0.41 | 0.37 |

Table 23: CSF and Time Factors Relationship

| CSF | Communication | Construction speed | Delivery speed | Production planning and schedule | Project duration | Time for finishing work | Time for handling and equipment | Time for sub precast structure | Time for super precast structure |
|---|---|---|---|---|---|---|---|---|---|
| Mitigate resistance to change | 0.02 | 0.20 | 0.25 | 0.38 | 0.60 | 0.51 | 0.44 | 0.48 | 0.33 |
| Performance metrics | 0.23 | 0.10 | 0.06 | 0.29 | 0.25 | 0.28 | 0.26 | 0.44 | 0.39 |
| Pilot project | 0.06 | 0.12 | 0.12 | 0.20 | 0.39 | 0.34 | 0.31 | 0.31 | 0.28 |
| Project management | 0.19 | 0.18 | 0.42 | 0.29 | 0.42 | 0.37 | 0.49 | 0.43 | 0.33 |
| Project manager and team | 0.29 | 0.36 | 0.34 | 0.27 | 0.41 | 0.28 | 0.33 | 0.31 | 0.36 |
| Quality management | 0.26 | 0.50 | 0.48 | 0.46 | 0.42 | 0.27 | 0.39 | 0.36 | 0.32 |
| Safety, and environmental | 0.47 | 0.24 | 0.14 | 0.20 | 0.29 | 0.17 | 0.26 | 0.30 | 0.39 |
| Training and development | 0.31 | -0.08 | 0.14 | 0.22 | 0.29 | 0.03 | 0.09 | 0.32 | 0.22 |
| Web-based | 0.20 | -0.15 | 0.05 | 0 | 0.14 | -0.06 | -0.03 | 0.15 | 0.01 |

Table 24 shows correlation coefficient analysis with numerical value that is close to a positive agreement for more than 0, a negative agreement for less than 0 in red and equal to 0 as no agreement in green between CSFs and quality factors relationship.

Table 24: CSF and Quality Factors Relationship

| CSF | Client or customer expectation | Construction documentation | Customer service | Decision-making | Defects detection | Design and drafting | Engineering productivity | Errors and omissions | Production automation | Quality controlling and monitoring | Quantity of labor and related ... |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Adoption strategy | 0.23 | 0.02 | 0 | 0.20 | 0.31 | 0.12 | 0.30 | 0.18 | 0.07 | 0.31 | 0.06 |
| Clear business strategy and go ... | 0.25 | -0.03 | 0.07 | 0.18 | 0.29 | 0.32 | 0.34 | 0.24 | 0.36 | 0.26 | -0.03 |
| Clients' request for BIM | 0.04 | 0.13 | 0.12 | 0.23 | 0.27 | 0.43 | 0.32 | 0.22 | 0.30 | 0.14 | 0.20 |
| Construction location site | 0.12 | 0.29 | 0.34 | 0.29 | 0.10 | 0.17 | 0.13 | 0.06 | -0.04 | 0.02 | 0.37 |
| Culture of sharing and communi ... | 0.07 | 0.46 | 0.21 | 0.34 | 0.16 | -0.01 | 0.02 | 0.05 | 0 | 0.09 | 0.28 |
| Economic impact | 0.20 | 0.06 | 0.24 | 0.07 | 0.27 | 0.12 | 0.31 | 0.21 | 0.11 | 0.27 | 0.35 |
| Effort and timeliness | 0.22 | -0.01 | 0.44 | 0.02 | 0.39 | 0.41 | 0.37 | 0.32 | 0.27 | 0.41 | 0.12 |
| Employees' expertise in BIM | 0.24 | 0.17 | 0.15 | 0.10 | 0.30 | 0.29 | 0.29 | 0.27 | 0.27 | 0.18 | 0.17 |
| Functions and features | 0.13 | 0.24 | -0.17 | 0.27 | -0.02 | 0.11 | 0.11 | 0.01 | 0.20 | 0.15 | -0.01 |
| Interest and willingness for B ... | -0.01 | 0.10 | -0.11 | 0.07 | 0.24 | 0.19 | 0.15 | 0.16 | 0.11 | 0.29 | 0.35 |

Table 24: CSF and Quality Factors Relationship

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Investment in BIM costs | 0.17 | 0.03 | 0.12 | -0.06 | 0.40 | 0.28 | 0.25 | 0.42 | 0.17 | 0.14 | 0.22 |
| IT capabilities technical supp ... | 0.31 | 0.14 | 0.45 | 0.31 | 0.51 | 0.32 | 0.42 | 0.40 | 0.36 | 0.27 | 0.29 |
| Learning curve | 0 | 0.42 | 0.36 | 0.48 | 0.28 | 0.24 | 0.28 | 0.15 | -0.04 | 0.16 | 0.07 |
| Long-term strategy of BIM prov ... | 0.08 | 0.29 | 0.29 | 0.44 | 0.13 | 0.28 | 0.30 | 0.09 | 0.08 | 0.15 | 0.11 |
| Low costs and expenses | 0.31 | -0.03 | 0.47 | 0.28 | 0.42 | 0.46 | 0.19 | 0.28 | 0.32 | 0.35 | 0.30 |
| Management commitment, partici ... | 0.21 | 0.16 | 0.45 | 0.17 | 0.47 | 0.3 | 0.23 | 0.34 | 0.13 | 0.19 | 0.23 |
| Mitigate resistance to change | 0.24 | 0.07 | 0.52 | 0.14 | 0.6 | 0.52 | 0.26 | 0.44 | 0.26 | 0.16 | 0.33 |
| Performance metrics | 0.22 | 0.28 | 0.51 | 0.35 | 0.27 | 0.11 | 0.31 | 0.27 | 0.03 | 0.32 | 0.37 |
| Pilot project | -0.03 | 0.22 | 0.34 | 0.42 | 0.4 | 0.42 | 0.38 | 0.23 | 0.12 | 0.1 | 0.04 |
| Project management | 0.12 | 0.26 | 0.37 | 0.31 | 0.51 | 0.23 | 0.44 | 0.31 | 0.27 | 0.39 | 0.10 |
| Project manager and team | 0.26 | 0.39 | 0.39 | 0.34 | 0.36 | 0.31 | 0.41 | 0.15 | 0.24 | 0.36 | 0.18 |
| Quality management | 0.24 | 0.13 | 0.51 | 0.29 | 0.48 | 0.42 | 0.56 | 0.41 | 0.51 | 0.40 | 0.11 |
| Safety, and environmental | 0 | 0.18 | 0.28 | 0.22 | 0.21 | 0.10 | 0.20 | 0.27 | 0.25 | 0.21 | 0.14 |

Table 24: CSF and Quality Factors Relationship

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Training and development | -0.01 | 0.14 | 0.01 | 0.04 | 0.12 | 0.23 | 0.20 | 0.24 | 0.35 | -0.08 | -0.13 |
| Web-based | 0.02 | 0.16 | 0.06 | 0.23 | 0.10 | 0.28 | 0.11 | -0.07 | -0.03 | -0.19 | -0.06 |

## 5.4 Conclusions

In this study, research methods to gather data for research questions were 8 interviews and 44 survey participants. Qualitative and quantitative data analyses applied to summarize, categorize, and structure data gathered.

According to respondents, time, quality and cost factors are important for BIM implementation and in the use of precast structures. There is positive impact and CSFs includes various positive relationships. The respondents participated are from public and private sector, and they possess good knowledge about precast structure use and BIM implementation.

In this study, there was a classification of time factors, quality factors and cost factors affecting the usage of precast structures. Survey participants and interview participants stressed on various factors affecting precast structure usage. In addition, CSFs classifications also were conducted which were mentioned in literature review (Chapter 2).

# Chapter 6.0 Recommendation and Conclusion

## 6.1 Background

This chapter consists of recommendations and conclusion through the summary of the findings made. In the first section, I present recommendations for various stakeholders. The second section, it presents conclusions made based on research questions and research objectives. Finally, I also included limitations of this research study and made suggestions for future research.

## 6.2 Recommendations

According to research conducted, I would like to recommend that BIM related courses and development opportunities should be available for major stakeholders such as structural engineers, architects, quantity surveyors, and services engineers so Critical success factors can be achieved with maximum benefits. It is also recommended that the contractor should be involved during BIM implementation such as experienced contractor in the use of BIM with emphasis on precast structures.

Another recommendation is for policy-makers because of challenges available in the construction industry with the use of precast structures. Therefore, this research recommends that policy makers in the construction industry should emphasize widely on challenges faced towards BIM implementation at both project and strategic level.

An additional recommendation is that BIM software selection prior to implementation based on suitable specifications and characteristics. Firms in the construction industry should be careful and check about BIM software related information such as shapes, size, exchange of data methods and possible areas required for implementation. The users of BIM usually depends on market share and own insight of BIM software. In addition, the users should have proper training and knowledge on BIM software and implementation in the integration of current business functions, processes, procedures and activities.

## 6.3 Conclusions

The research explored firms in UAE successfully about their perspective on the challenges, and critical success factors for BIM implementation. This study adopted research methodology both qualitative and quantitative approach. The findings made are from 8 interviews and 44 surveys and firms have an understanding in the alignment of BIM within the construction industry. While using research instruments, it was made sure there is the research validity and reliability of data gathered.

Qualitative data analysis applied to summarize, categorize and structure data based on narrative forms. While, with QuestionPro.com, quantitative data analysis applied and consisted of analytical tools. In addition, this research study considered several ethical considerations during data collection and analysis.

The findings came from both private and public sector. The findings showed that the firms are ready and willing to adopt and implement BIM. According to findings from literature, BIM is one of the best practices within precast use in various nations and regions globally. In order to minimize impact from precast concrete challenges faced by contractors and engineers, there is need for considering benefits and critical success factors of BIM. After consideration, the contractors and engineers in the construction industry will be able to maximize benefits of BIM implementation.

As per responses from participants, the factors showed important for BIM implementation during precast structure usage are time, quality, and cost. The impact showed that there is positive impact showing several positive relationships with critical success factors. Consequently, the factors classified as per time factors, quality factors and cost factors that are affecting precast usage of structures. The findings from interview and survey showed there are various factors compared with findings from literature review as well.

Cases and research conducted in BIM for precast were also examined. Therefore, the results and findings showed that even though there are challenges and limitations, it is possible to implement BIM successfully based on benefits. Critical success factors identified and analyzed were good quality control, lower scheduling time, and control in costs resulting from BIM implementation.

It is possible to apply widely BIM in the UAE precast construction industry without risks and issues when project managers and team are working with good coordination and communication level. Even quality issues will be minimized such as no more reworks, defects or errors in precast structures. The other time issues will be also minimized such as long-lead time and lengthy scheduling and planning in precast structures. In terms of issues related to costs will be also minimized such as costs increase and expenses unexpected in precast structures. The conceptual framework was considered and conducted in this study so the researcher can achieve research objectives and find answers to research questions. The concepts considered were BIM for precast adoption, the best practices, and critical success factors. The examples of best practices were from Malaysia, Hong Kong and Singapore.

Scores of cost related factors affecting in the use of precast structures are budget planning at 4.02, material costs at 3.98, cost estimation at 3.93, overhead costs at 3.86, transportation costs at 3.72, cost management at 3.69, and the engineering cost at 3.63. According to findings by Glass (2000), the cost incurring in precast structures creates challenges for construction firms so firms do not consider the use of precast concrete. According to Park (2003) also extra and additional costs leads to prevention in the implementation and usage of precast structures. Therefore, various other research studies also makes similar findings about costs being challenges such as by Pheng and Chuan (2001), and Sacks, Akinci, and Ergen (2003).

Scores of time related factors affecting in the use of precast structures are construction speed at 4.38, project duration at 4.31, delivery speed at 4.17, production planning and scheduling at 4.17, and time for finishing work at 4.17. Sacks, Akinci, and Ergen (2003), Polat (2008) and Ergin, Arditi, & Günhan (2000) find that time affects manufacturing of precast concrete in either standard or custom designs where scheduling is always a challenge.

Scores of quality related factors affecting in the use of precast structures are quality controlling and monitoring at 4.28, production automation at 4.19, quantity of labor and related costs based on the project size at 4.07, client or customer expectations at 4.05, and errors and omissions at 4.05. There is a pattern of similarity with other studies as well such as Glass (2000), Park (2003), Polat (2008), and Ergin, Arditi, & Günhan (2000) describing that the quality is a challenge to meet needs of customers with various quality related issues.

Albert, (2004), Harris, (2013), Datta, & Koehn, (2003), Bosché, (2010), Omar, Nawi, & Nursal (2014), and Sacks et al. (2005) describes that challenges can be eliminated with the help of factors related to quality, time and cost where BIM comes into the role to reshape precast structures usage. According to Sanchez, Hampson, and Vaux, (2016), implementation of BIM comes with benefits such as cost savings, proper scheduling and better quality. Therefore, there is consideration of various critical success factors so BIM implementation success can be for sure while using precast structures (Bender, 2010; CURT, 2010; Won, & Lee, 2010; Gu, & London, 2010; Khosrowshahi, & Arayici, 2012; Arayici, et al. 2011).

It can be concluded that BIM implementation success depends on various factors based on research conducted by this study. Even though, many firms in the construction industry come with limitations of financial, time and manpower resources. Therefore, there will be need for staying focused on specific and important criteria so they can become successful in adoption and implementation of BIM. With the focus on various perspectives, it is possible that challenges and critical success factors considered within BIM implementation.

## 6.4 Future researches

This study contributes mainly in BIM implementation related critical success factors, and challenges with comparison of the best practices. Many books and articles addressed various obstacles and general consideration to BIM implementation in specific nations. However, it is rare to find study on BIM implementation and success factors with emphasis on construction firms in the UAE comparing with elsewhere in the GCC.

The results of this study is possible to put into use for developing such studies and researches for the development of effective and quantifiable management tool so the BIM implementation success level can be compared, analyzed, and evaluated within firms in the construction industry. Therefore, with the follow-up study, it will become possible how BIM critical success factors changes based on different firms in GCC while the construction industry is growing and becoming experienced. Even though, this research study made findings on critical success factors that are usually focused during BIM implementation such as the early stages of project lifecycle, but they can be also used during the maturity stage as well. In addition, there will be need for some and minor changes and adjustments to make critical success factors as a suitable list exhibiting appropriateness as evaluation and measuring model for success.

The focus of BIM implementation is not just precast structure in the construction industry. According to Latiffi, Brahim, & Fathi (2014) BIM is actually introduced for construction management of projects efficiently and effectively. Wang, Huang, & Zheng (2012) also states that BIM is an integrated expression that consists model of projects and information in the construction industry. Therefore, the suggested research required to be conducted is BIM implementation widely even in the construction firm that do not use precast structure. This future research will benefit the construction industry that does not have precast structure possibilities or facilities and firms will be able to make use of how BIM can be implemented and whether it will be beneficial for them in terms saving costs, reducing time and improving quality.

Lee, Tsai, Yang, Juang, & Su (2016) describes that facility management is very important in building lifecycle along with BIM technology. With the use of good BIM tool, it becomes possible to integrate BIM in both design and construction phase so managers gets the platform for browsing information, discussing potential issues and problems, arranging maintenance related activities, tasks and works. Therefore, it is suggested that future study is required on how facility management can be conducted with the use and integration of BIM in the UAE.

## References


Abidin, A. (2007). Simulation Of Industrialised Building System Formation For Housing Construction [online]. Master's. Thesis. Universiti Teknologi Malaysia. [Accessed 30 September 2016]. Available at: http://eprints.utm.my/11242/1/AhmadRazinZainalMFKA2007.pdf

Abubakar, M., Ibrahim, Y., Kado, D., and Bala, K. (2014). Contractors Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry. Computing in Civil and Building Engineering. [online] [Accessed 3 November 2016]. Available at http://itc.scix.net/data/works/att/w78-2014-paper-022.pdf

AEC Online. (2014). Precast Concrete in the GCC. [online]. [Accessed 28 September 2016]. Available at http://www.aeconline.ae/precast-concrete-in-the-gcc-1053669/file-files/precast_concrete_in_the_gcc__aug_2014.pdf

Amaratunga, D., Baldry, D., Sarshar, M., & Newton, R. (2002). Quantitative and qualitative research in the built environment: Application of "mixed" research approach. Work Study, 51(1), 17. [online] [Accessed 14 November 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/218383317?pq-origsite=summon

Ambrose, J. (1993). Building Structures. Viewed 29 September 2016. Available at https://books.google.ae/books?id=5Wjxjpedi4sC&pg=PA447&dq=precast+and+steel+structure+building&hl=en&sa=X&redir_esc=y#v=onepage&q=precast%20and%20steel%20structure%20building&f=false

American Institute of Architects. (2008). The architect's handbook of professional practice, Wiley & Sons. [Online] [Accessed 31 October 2016]. Available at https://books.google.ae/books?id=ISzC_3inw7cC&pg=PA419&dq=a+digital+representations+of+physical+and+functional+characteristics+of+a+facility&hl=en&sa=X&redir_esc=y#v=onepage&q=a%20digital%20representations%20of%20physical%20and%20functional%20characteristics%20of%20a%20facility&f=false

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). BIM adoption and implementation for architectural practices. Structural Survey [online]. Vol. 29(1), 7-25. [Accessed 16 October 2016]. Available at http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/abs/10.1108/02630801111118377

Autodesk, (2012a). “BIM for infrastructure: a vehicle for business transformation.” Autodesk, [online] pp. 1-18. [Accessed 16 October 2016]. Available at http://static-dc.autodesk.net/content/dam/autodesk/www/solutions/building-information-modeling/infrastructure/bim-vehicle-for-business-transformation-whitepaper-en.pdf

Autodesk. (2012b). “The power of BIM for structural engineering.” Autodesk. [online]. [Accessed 16 October 2016]. Available at http://www.ideateinc.com/products/brochures/2013/structural_engineering_brochure.pdf

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering [online]. Vol. 11(3), 241-252 [Accessed 14 October 2016]. Available at http://ascelibrary.org/doi/pdf/10.1061/(ASCE)LM.1943-5630.0000127

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering [online]. Vol. 11(3), 241-252 [Accessed 30 October 2016]. Available at http://ascelibrary.org/doi/pdf/10.1061/(ASCE)LM.1943-5630.0000127

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM -- A case study approach. Automation in Construction, [online] Vol. 24, 149. [Accessed 30 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=How+to+measure+the+benefits+of+BIM+--+A+case+study+approach&rft.jtitle=Automation+in+Construction&rft.au=Barlish%2C+Kristen&rft.au=Sullivan%2C+Kenneth&rft.date=2012-07-01&rft.pub=Elsevier+B.V&rft.issn=0926-5805&rft.eissn=1872-7891&rft.volume=24&rft.spage=149&rft_id=info:doi/10.1016%2Fj.autcon.2012.02.008&rft.externalDBID=BSHEE&rft.externalDocID=288034399&paramdict=en-US

Bender, D. (2010). Implementing Building Information Modeling in the Top 100 Architecture Firms. Journal of Building Information Modeling, 2010, (Spring) 23-24 [online]. [Accessed 16 October 2016]. Available at https://www.brikbase.org/sites/default/files/PPages%20from%20jbim_spring10-5.bender.pdf

Bennett, T. (2012). "Role of BIM in infrastructure seismic retrofit." STRUCTURE Magazine, [online]. Vol. pp. 44-45. [Accessed 16 October 2016]. Available at http://www.structuremag.org/wp-content/uploads/C-Technology-Bennett-Mar121.pdf

Bohlen, T. (2012). Green is the New Black. Al Nisr Publishing LLC [online]. [Accessed 28 September 2016]. Available at http://gulfnews.com/gn-focus/special-reports/big-5/green-is-the-new-black-1.1097876

Bosché, F. (2010). Automated recognition of 3D CAD model objects in laser scans and calculation of as-built dimensions for dimensional compliance control in construction. Advanced Engineering Informatics, 24(1), 107-118. [online] [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Reinforcement+Placement+in+a+Concrete+Slab+Object+Using+Structural+Building+Information+Modeling&rft.jtitle=Computer%E2%80%90Aided+Civil+and+Infrastructure+Engineering&rft.au=Cho%2C+Young+Sang&rft.au=Lee%2C+Seung+Il&rft.au=Bae%2C+Jun+Seo&rft.date=2014-01-01&rft.issn=1093-9687&rft.eissn=1467-8667&rft.volume=29&rft.issue=1&rft.spage=47&rft.epage=59&rft_id=info:doi/10.1111%2Fj.1467-8667.2012.00794.x&rft.externalDocID=MICE794&paramdict=en-US

Brewer, G., and Gajendran, T. (2011). Building Information Modelling And The Culture Of Construction Project Teams: A Case Study. Management and Innovation for a Sustainable Built Environment [online] [Accessed 1 November 2016]. Available at http://misbe2011.fyper.com/proceedings/documents/81.pdf

Bryan, T. (2010). Construction Technology: Analysis and Choice. 2nd edition. Viewed 29 September 2016. Available at https://books.google.ae/books?id=0RiZbrkisZIC&pg=PA307&dq=relationship+between+precast+and+steel+structure+building&hl=en&sa=X&redir_esc=y#v=onepage&q=relationship%20between%20precast%20and%20steel%20structure%20building&f=false

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). International Journal of Project Management, doi:10.1016/j.ijproman.2012.12.001 [online]. Vol. 31(7), 971-980. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=The+project+benefits+of+Building+Information+Modelling+%28BIM%29&rft.jtitle=International+Journal+of+Project+Management&rft.au=David+Bryde&rft.au=Mart%C3%AD+Broquetas&rft.au=J%C3%BCrgen+Marc+Volm&rft.date=2013-10-01&rft.pub=Elsevier+Science+Ltd&rft.issn=0263-7863&rft.eissn=1873-4634&rft.volume=31&rft.issue=7&rft.spage=971&rft.externalDocID=3047667461&paramdict=en-US

Bryman, A., & Bell, E. (2015). Business research methods. Oxford: Oxford University Press. [online] [Accessed 10 November 2016]. Available at https://books.google.ae/books?id=l7u6BwAAQBAJ&printsec=frontcover&dq=Bryman+Business+Research+Methods&hl=en&sa=X&ved=0ahUKEwjVoL6VuLDQAhWIShQKHQDKAAkQ6AEIGzAA#v=onepage&q=Bryman%20Business%20Research%20Methods&f=false

Bryman, A., (2012). Social Research Methods. OUP Oxford. [online] [Accessed 10 November 2016]. Available at https://books.google.ae/books?id=vCq5m2hPkOMC&printsec=frontcover&dq=Bryman+Business+Research+Methods&hl=en&sa=X&ved=0ahUKEwjVoL6VuLDQAhWIShQKHQDKAAkQ6AEIMDAD

buildingSMART Australasia (2012). National Building Information Modelling Initiative. Volume 1: Strategy. buildingSMART Australasia [online]. [Accessed 16 October 2016]. Available at https://bimmi.innovationcast.net/api/files/insight/302/81f4bccd5a3540e499c2762c02e890de-NationalBIMIniativeReport-2012.pdf?_rs=3trWeKjpT1OLYi0UTgaEZcPvDkM1

Carvalho, S., and White, H. (1997). Combining the Quantitative and Qualitative Approaches to Poverty Measurement and Analysis: The Practice and the Potential, Volumes 23-366 [online] [Accessed 11 November 2016]. Available at https://books.google.ae/books?id=yqJZ0R_DXrEC&pg=PA19&dq=what+is+survey+quantitative&hl=en&sa=X&redir_esc=y#v=onepage&q=what%20is%20survey%20quantitative&f=false

Cavieres, A., Gentry, R., & Al-Haddad, T. (2011). Knowledge-based parametric tools for concrete masonry walls: Conceptual design and preliminary structural analysis. Automation in Construction, [online]. Vol. 20(6), pp. 716-728. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580511000045

Cha, H. S., & Lee, D. G. (2015). A case study of time/cost analysis for aged-housing renovation using a pre-made BIM database structure. KSCE Journal of Civil Engineering, [online]. Vol. 19(4), 841-852. [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1672835018?pq-origsite=summon

Chan, A. P. C., & Chan, A. P. L. (2004). Key performance indicators for measuring construction success. Benchmarking: An International Journal, [online]. Vol. 11(2), pp. 203-221. [Accessed 16 October 2016]. Available at http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/abs/10.1108/14635770410532624

Cheong, Y. W., Kwan, H. P., & Hariyanto, A. D. (2005). QUALITY CONTROL IN PRECAST PRODUCTION A case study on tunnel segment manufacture. Dimensi : Journal of Architecture and Built Environment, [online] Vol. 33(2) [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=QUALITY+CONTROL+IN+PRECAST+PRODUCTION+A+case+study+on+Tunnel+Segment+Manufacture&rft.jtitle=Dimensi+%3A+Journal+of+Architecture+and+Built+Environment&rft.au=Yee+Weng+Cheong&rft.au=Hon+Pui+Kwan&rft.au=Agus+Dwi+Hariyanto&rft.date=2005-01-01&rft.pub=Petra+Christian+University&rft.issn=0126-219X&rft.volume=33&rft.issue=2&rft.externalDBID=DOA&rft.externalDocID=oai_doaj_org_article_a7f826546758420ca7508907de3d607f&paramdict=en-US

Clare. (2016). Global Precast Concrete Market Research Report - Industry Analysis, Size, Share, Growth, Trends and Forecast, 2014 – 2021. PR News Wire. [online]. [Accessed 28 September 2016]. Available at http://www.prnewswire.com/news-releases/global-precast-concrete-market-research-report---industry-analysis-size-share-growth-trends-and-forecast-2014---2021-300251174.html

Collins, J. (2016). Incorporating BIM into architectural precast concrete fabrication. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, [online] 33, 1. [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1823082550?pq-origsite=summon

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th International student ed.). Los Angeles: Sage. [online] [Accessed 10 November 2016]. Available at http://buid.summon.serialssolutions.com/#!/search/document?ho=t&l=en&q=Research%20design:%20Qualitative,%20quantitative,%20and%20mixed%20methods&id=FETCHMERGED-buid_catalog_vtls0000081122

Couper, M. P. (2005). Technology trends in survey data collection. Social Science Computer Review, 23(4), 486-501. [online] [Accessed 11 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Technology+Trends+in+Survey+Data+Collection&rft.jtitle=Social+Science+Computer+Review&rft.au=Mick+P+Couper&rft.date=2005-12-01&rft.pub=SAGE+PUBLICATIONS%2C+INC&rft.issn=0894-4393&rft.eissn=1552-8286&rft.volume=23&rft.issue=4&rft.spage=486&rft.externalDocID=912245891&paramdict=en-US

CURT. (2010). BIM Implementation: An Owner's Guide to Getting Started, The Construction Users Roundtable. [online]. [Accessed 16 October 2016]. Available at http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab085571.pdf

Datta, K., & Koehn, E. (2003). Quality, environmental, and health and safety management systems for construction engineering. Journal of Construction Engineering and Management, [online]. Vol. 129(5), pp. 562-569 [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Quality%2C+Environmental%2C+and+Health+and+Safety+Management+Systems+for+Construction+Engineering&rft.jtitle=Journal+of+Construction+Engineering+and+Management&rft.au=Datta%2C+Nirmal+K&rft.au=Koehn%2C+Enno+%22Ed%22&rft.date=2003-10-01&rft.pub=American+Society+of+Civil+Engineers&rft.issn=0733-9364&rft.eissn=1943-7862&rft.volume=129&rft.issue=5&rft.spage=562&rft.epage=569&rft_id=info:doi/10.1061%2F%28ASCE%290733-9364%282003%29129%3A5%28562%29&rft.externalDocID=JCEMD400012900000500056200000110_1061_ASCE_0733_9364_2003_129_5_562&paramdict=en-US

David, M. & Sutton D. (2011). Social Research the Basics. London: SAGE Publications. [online] [Accessed 9 November 2016]. Available at https://books.google.ae/books?id=2CUkA1IuAscC&printsec=frontcover&dq=David,+M.+%26+Sutton+D.+Social+Research+the+Basics.&hl=en&sa=X&redir_esc=y#v=onepage&q&f=false

Ding, Z., Zuo, J., Wu, J., & Wang, J. (2015). Key factors for the BIM adoption by architects: A china study. Engineering, Construction and Architectural Management, [online] Vol. 22(6), pp. 732-748. [Accessed 1 November 2016]. Available at http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/full/10.1108/ECAM-04-2015-0053

Dolnicar, S. (2013). Asking good survey questions. Journal of Travel Research, 52(5), 551-574. [online] [Accessed 11 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Asking+good+survey+questions&rft.jtitle=Journal+of+Travel+Research&rft.au=Dolnicar%2C+Sara&rft.date=2013-09-01&rft.pub=Sage+Publications%2C+Inc&rft.issn=0047-2875&rft.eissn=1552-6763&rft.volume=52&rft.issue=5&rft.spage=551&rft.externalDBID=BSHEE&rft.externalDocID=367711918&paramdict=en-US

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2015). A survey of current status of and perceived changes required for BIM adoption in the UK. Built Environment Project and Asset Management, [online]. Vol. 5(1), pp. 4-21 [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1647083597?pq-origsite=summon

Eastman, C., and Sacks, R. (2002). The Precast Concrete Industry: A proposal for the adoption of advanced Information Technologies. Georgia Institute of Technology College of Engineering [online]. [Accessed 14 October 2016]. Available at http://dcom.arch.gatech.edu/courses/cic/Slides%20and%20Notes/Precast%20Concrete%20Industry%20Sector.ppt

Eastman, C. M. (2008). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors. New Jersey: John Wiley & Sons. [online]. [Accessed 16 October 2016]. Available at https://books.google.ae/books?id=IioygN0nYzMC&printsec=frontcover&dq=BIM+handbook:+A+guide+to+building+information+modeling+for+owners,+managers,+designers,+engineers,+and+contractors&hl=en&sa=X&redir_esc=y

Eastman, C., Lee, J., Lee, J., & Jeong, Y. (2009). Automatic rule-based checking of building designs. Automation in Construction, [online]. Vol. 18(8), 1011-1033. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580509001198

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM handbook: a guide to building information modeling for owners, managers, designers. John Wiley & Sons. [Accessed 16 October 2016]. Available at https://books.google.ae/books?id=aCi7Ozwkoj0C&printsec=frontcover&dq=BIM+handbook:+A+guide+to+building+information+modeling+for+owners,+managers,+designers,+engineers,+and+contractors&hl=en&sa=X&redir_esc=y

Edwards, R., & Holland, J. (2013). What is qualitative interviewing? Bloomsbury Academic. [online] [Accessed 8 November 2016]. Available at https://www.bloomsburycollections.com/book/what-is-qualitative-interviewing/ch1-what-do-the-key-terms-used-about-qualitative-interviews-mean

Epstein, E., & Books24x7, I. (2012). Implementing successful building information modeling (1st ed.). GB: Artech House Inc. [online] [Accessed 2 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Abook&rft.genre=book&rft.title=Implementing+Successful+Building+Information+Modeling&rft.au=Epstein%2C+Erika&rft.date=2012-06-01&rft.pub=Artech+House&rft.isbn=9781608071395&rft.externalDocID=10583832&paramdict=en-UK

Ergin, U., Arditi, D., & Günhan, S. (2000). Factors affecting the use of precast concrete systems. Journal of Architectural Engineering, [online]. Vol. 6(3), pp. 79-86. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Factors+Affecting+the+Use+of+Precast+Concrete+Systems&rft.jtitle=Journal+of+Architectural+Engineering&rft.au=Ergin%2C+Ulu%C3%A7&rft.au=Arditi%2C+David&rft.au=G%C3%BCnhan%2C+Suat&rft.date=2000-09-01&rft.pub=American+Society+of+Civil+Engineers&rft.issn=1076-0431&rft.eissn=1943-5568&rft.volume=6&rft.issue=3&rft.spage=79&rft.epage=86&rft_id=info:doi/10.1061%2F%28ASCE%291076-0431%282000%296%3A3%2879%29&rft.externalDocID=JAEIED000006000003000079000001110_1061_ASCE_1076_0431_2000_6_3_79&paramdict=en-UK

Fai, S., Filippi, M., & Paliaga, S. (2013). parametric modelling (BIM) for the documentation of vernacular construction methods: A BIM model for the commissariat building, Ottawa, Canada. ISPRS Annals of the Photogrammetry, , 115-120. [online] [Accessed 14 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=PARAMETRIC+MODELLING+%28BIM%29+FOR+THE+DOCUMENTATION+OF+VERNACULAR+CONSTRUCTION+METHODS%3A+A+BIM+MODEL+FOR+THE+COMMISSARIAT+BUILDING%2C+OTTAWA%2C+CANADA&rft.jtitle=ISPRS+Annals+of+the+Photogrammetry&rft.au=S.+Fai&rft.au=M.+Filippi&rft.au=S.+Paliaga&rft.date=2013-07-01&rft.pub=Copernicus+Publications&rft.issn=2194-9042&rft.spage=115&rft.epage=120&rft_id=info:doi/10.5194%2Fisprsannals-II-5-W1-115-

2013&rft.externalDBID=DOA&rft.externalDocID=oai_doaj_org_article_bb429283b3b642eb99c4d9279202458a&paramdict=en-US

Froese, T. M. (2010). The impact of emerging information technology on project management for construction. Automation in Construction, [online]. Vol. 19(5), pp. 531-538. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580509001745

Glass, J. (2000). The future for precast concrete in low-rise housing. Leicester, UK: British Precast Concrete Federation. [online] [Accessed 16 October 2016]. Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.466.1801&rep=rep1&type=pdf

Gray, E. (2013). Doing Research in the Real World. London: SAGE Publications. [online] [Accessed 16 November 2016]. Available at https://books.google.com/books?id=uc3yAwAAQBAJ&printsec=frontcover&dq=Gray,+Doing+Research+in+the+Real+World.&hl=en&sa=X&ved=0ahUKEwjMgejpyLDQAhVDGsAKHbAADQoQ6AEIGjAA

Green Precast Systems and Technologies LCC. (2010). Case Studies. [online]. [Accessed 28 September 2016]. Available at http://www.greenprecastsystems.com/case-studies.html

Gruen, A., Behnisch, M., & Kohler, N. (2009). Perspectives in the reality-based generation, nD modelling, and operation of buildings and building stocks. Building Research & Information, [online]. Vol. 37(5-6), 503-519. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Perspectives+in+the+reality-based+generation%2C+nD+modelling%2C+and+operation+of+buildings+and+building+stocks&rft.jtitle=Building+Research+%26+Information&rft.au=Gruen%2C+Armin&rft.au=Behnisch%2C+Martin&rft.au=Kohler%2C+Niklaus&rft.date=2009-11-01&rft.pub=Routledge&rft.issn=0961-3218&rft.eissn=1466-4321&rft.volume=37&rft.issue=5-6&rft.spage=503&rft_id=info:doi/10.1080%2F09613210903189509&rft.externalDocID=419123&paramdict=en-US

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. Automation in Construction, [online]. Vol. 19(8), pp. 988-999. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580510001317

Guo, E. W., Qian, Y. X., & Li, C. G. (2014). The application of building information model in the design of precast concrete structures. Applied Mechanics and Materials, [online] 716-717, 299. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=METHOD+OF+QUALITY+CONTROL+AT+PRODUCTION+PROCESS+OF+PRECAST+CONCRETE+COLUMN&rft.jtitle=Journal+of+Structural+and+Construction+Engineering+%28Transactions+of+AIJ%29&rft.au=SUGIYAMA%2C+Hisashi&rft.au=MITO%2C+Kensuke&rft.date=2014&rft.issn=1340-4202&rft.eissn=1881-8153&rft.volume=79&rft.issue=706&rft.spage=1729&rft.epage=1739&rft_id=info:doi/10.3130%2Faijs.79.1729&rft.externalDBID=n%2Fa&rft.externalDocID=10_3130_aijs_79_1729&paramdict=en-US

Hamdan, S. B., Barkokebas, B., Manrique, J. D., & Al-Hussein, M. (2015). A BIM-based simulation model for inventory management in panelized construction. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 32, 1. [online] [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1712613838?pq-origsite=summon

Han, R., Jin, Q., & An, H. (2013). Exploration on the application of practice teaching based on BIM in the architecture design. Applied Mechanics and Materials, [online] 333-335, 2171. [Accessed 2 November 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1442376110?pq-origsite=summon

Haron, A. (2011). Building Information Modelling: Literature Review on Model to Determine the Level of Uptake by Organisation. University of Salford. [online] [Accessed 2 November 2016]. Available at http://usir.salford.ac.uk/16622/3/CIB_Salford_Building_Information_Modelling_Literature_Review_on_Model_to_Determine_the_Level_of_Uptake_by_Organisation.pdf

Harona, A., Pontingb, A., Zakariac, Z., Nawid, M., Hamide, Z., and Kamarf, K. (2015) Malaysia Construction Research Journal (MCRJ), [online] Vol. 17(2) pp. 21-36. [Accessed 2 November 2016]. Available at https://www.researchgate.net/profile/Mohd_Nasrun_Mohd_Nawi/publication/305191956_An_industrial_report_on_the_Malaysian_building_information_modelling_BIM_taskforce_Issues_and_recommendations/links/57846f3008ae3f355b4a457c.pdf

Harris, F., McCaffer, R., & Edum-Fotwe, F. (2013). Modern construction management (7th ed.). West Sussex: Wiley-Blackwell. [online] [Accessed 16 October 2016]. Available at https://books.google.ae/books?id=LY58xuo0RGwC&printsec=frontcover&dq=Modern+Construction+Management&hl=en&sa=X&redir_esc=y#v=onepage&q=Modern%20Construction%20Management&f=false

Hergunsel, M. (2011). Benefits Of Building Information Modeling For Construction Managers And BIM Based Scheduling. [online] [Accessed 16 October 2016]. Available at https://web.wpi.edu/Pubs/ETD/Available/etd-042011-135239/unrestricted/MHergunsel_Thesis_BIM.pdf

Hong Kong Construction Industry Council (2013). Final Draft Report of the Roadmap for BIM Strategic Implementation in Hong Kong’s Construction Industry, HKCIC [online] [Accessed 16 October 2016]. Available at http://www.hkcic.org/WorkArea/DownloadAsset.aspx?id=11234&langType=1033

Hooker, R., and Monas, S. (2008). Shoestring Venture: The Startup Bible. Steve Monas. [online] [Accessed 8 November 2016]. Available at https://books.google.ae/books?id=uICMLDbOC54C&pg=PA196&dq=question+pro&hl=en&sa=X&redir_esc=y#v=onepage&q=question%20pro&f=false

Howard, R., & Björk, B. (2008). Building information modelling – experts' views on standardisation and industry deployment. Advanced Engineering Informatics, [online]. Vol. 22(2), pp. 271-280 [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S1474034607000201

Hussey, J. and Hussey, R. (1997). Business research: a practical guide for undergraduate and postgraduate students. London: Macmillan. [online] [Accessed 16 November 2016]. Available at https://books.google.com/books?id=UVu1QgAACAAJ&dq=Business+research:+a+practical+guide+for+undergraduate+and+postgraduate+students.&hl=en&sa=X&ved=0ahUKEwjssJ-Ex7DQAhWHD8AKHa4LACwQ6AEIHDAA

IBISWorld. (2016). Precast Concrete Manufacturing in the US: Market Research Report. [online]. [Accessed 28 September 2016]. Available at http://www.ibisworld.com/industry/default.aspx?indid=556

InfoComm International. (2011). Building Information Modeling [online]. [Accessed 14 October 2016]. Available at http://www.infocomm.org/cps/rde/xbcr/infocomm/Brochure_BIM.pdf

Issa, R. R. A., Bynum, P., & Olbina, S. (2013). Building information modeling in support of sustainable design and construction. Journal of Construction Engineering and Management, [online]. Vol. 139(1), 24-34. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Building+information+modeling+in+support+of+sustainable+design+and+construction&rft.jtitle=Journal+of+Construction+Engineering+and+Management&rft.au=Bynum%2C+Patrick&rft.au=Issa%2C+Raja+R.+A&rft.au=Olbina%2C+Svetlana&rft.date=2013-01-01&rft.pub=American+Society+of+Civil+Engineers&rft.issn=0733-9364&rft.eissn=1943-7862&rft.volume=139&rft.issue=1&rft.spage=24&rft.externalDBID=BSHEE&rft.externalDocID=321837836&paramdict=en-US

Kamar, K., Zain, Z., Rahim, A., Ghani, M., Azman, M., Majid, T., and Ahamad, M. (2012), Drivers and Barriers to Industrialised Building System (IBS) Roadmaps in Malaysia, Malaysian Construction Research Journal [online] Vol. 9 (1) [Accessed 2 November 2016]. Available at http://www.vertilite.asia/f/2012/11/2012-MCRJ-Drivers-and-Barriers-of-IBS-Roadmap-in-Malaysia.pdf

Kasi, P. (2009). Research: What, Why and How? AuthorHouse. [online] [Accessed 11 November 2016]. Available at https://books.google.ae/books?id=ozfH7f6qp9AC&pg=PA104&dq=pilot+testing+questionnaire&hl=en&sa=X&redir_esc=y#v=onepage&q=pilot%20testing%20questionnaire&f=false

Kennedy. (2004). An assessment strategy to help forestall plagiarism problems. Studies in Learning ,Evaluation, Innovation and Development [online]. Vol. 1 (1). [Accessed 16 October 2016]. Available at http://www.sleid.cqu.edu.au/viewissue.php?id=5

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. Engineering, Construction and Architectural Management [online]. Vol. 19(6), 610-635. [Accessed 16 October 2016]. Available at http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/abs/10.1108/09699981211277531

Ku, K., & Taiebat, M. (2011). BIM experiences and expectations: The constructors' perspective. International Journal of Construction Education and Research, 7(3), 175-197. [online] [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=BIM+Experiences+and+Expectations%3A+The+Constructors%27+Perspective&rft.jtitle=International+Journal+of+Construction+Education+and+Research&rft.au=Ku%2C+Kihong&rft.au=Taiebat%2C+Mojtaba&rft.date=2011-07-01&rft.issn=1557-8771&rft.eissn=1550-3984&rft.volume=7&rft.issue=3&rft.spage=175&rft.epage=197&rft_id=info:doi/10.1080%2F15578771.2010.544155&rft.externalDBID=n%2Fa&rft.externalDocID=10_1080_15578771_2010_544155&paramdict=en-UK

Kvale, S. (2006). Dominance through interviews and dialogues. Qualitative Inquiry, 12(3), 480-500. [online] [Accessed 16 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Dominance+through+interviews+and+dialogues&rft.jtitle=Qualitative+Inquiry&rft.au=Kvale%2C+Steinar&rft.date=2006-06-01&rft.pub=Sage+Publications%2C+Inc&rft.issn=1077-8004&rft.eissn=1552-7565&rft.volume=12&rft.issue=3&rft.spage=480&rft.externalDBID=BSHEE&rft.externalDocID=148305114&paramdict=en-US

Kymmell, W. (2007), Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations (McGraw-Hill Construction Series): Planning and Managing Construction Projects with 4D CAD and Simulations, McGraw Hill Professional, New York, NY . [online] [Accessed 16 October 2016]. Available at https://books.google.ae/books?id=vV8qgetzBQEC&printsec=frontcover&dq=building+Information+Modelling:+Planning+and+Managing+Construction+Projects+with+4D+CAD+and+Simulations&hl=en&sa=X&redir_esc=y

Latiffi, A.A., Brahim, J. & Fathi, M.S. (2014). "The Development of Building Information Modeling (BIM) Definition", Applied Mechanics and Materials, [online] Vol. 567, pp. 625. [Accessed 19 April 2017]. Available at http://ezproxy.buid.ac.ae/login?url=http://search.proquest.com/docview/1826121219?pq-origsite=summon

Lee, G., Sacks, R., Eastman, C., and Wessman, R. (2004). Development Of An Intelligent 3d Parametric Modeling System For The North American Precast Concrete Industry: Phase II. Taub Computer Center [online]. [Accessed 14 October 2016]. Available at http://tx.technion.ac.il/~cvsacks/publications/ISARC%202004%20-%20Development%20of%20an%20Intelligent%203D%20Modeling%20System%20for%20the%20Precast%20Industry.pdf

Lee, S., & Ha, M. (2013). Customer interactive building information modeling for apartment unit design. Automation in Construction [online]. Vol. 35, 424-430. [Accessed 16 October 2016]. Available at http://buid.summon.serialssolutions.com/#!/search?bookMark=ePnHCXMwNV3BCsIwDB3iwek_SH9gkDXd1p6H4sGjnku7tQdBlLH5_SZddy2hpIHm5UHyciz2xFtDkafUUiuVW2Ymd4Q1mGQyZbsjGqQ7qu20od9UgpFt1WhoDlsS7aA1ZXHvifB_3mESLJ6QxoZ-Qfi8MFpkbVF-gUiLY_iQjgThzJSatMVCH0OMqRniVDyvl0d_q_KWgWogrGqrECVEaGJQXRgkDk5DiMoQzSEwHNBrF2sYAxolwXnkbK5Yo6am2sZ5w3sRzuu9nNIt-zSTpxYVYsd6f2SgVoMN-Ox3VZKwW4vVy64hshwiC42lEOEf_wRecQ

Lee, W., Tsai, M., Yang, C., Juang, J. & Su, J. 2016, "V3DM+: BIM interactive collaboration system for facility management", Visualization in Engineering, [online] Vol. 4, no. 1, pp. 1-15. [Accessed 22 April 2017]. Available at http://ezproxy.buid.ac.ae/login?url=http://search.proquest.com/docview/1815229539?pq-origsite=summon

Lichtman, M. (2010). Qualitative research in education: A user's guide (2nd ed.). Los Angeles: Sage. [online] [Accessed 12 November 2016]. Available at https://books.google.ae/books?id=_5zOUjv7ULkC&pg=PA9&dq=Quantitative+Method%09Qualitative+Method+comparison+table&hl=en&sa=X&ved=0ahUKEwimley-u7DQAhWBPxQKHfO9CQUQ6AEIJTAC#v=onepage&q=Quantitative%20Method%09Qualitative%20Method%20comparison%20table&f=false

Liu, W., Guo, H., Li, H., & Li, Y. (2014). Using BIM to improve the design and construction of bridge projects: A case study of a long-span steel-box arch bridge project. International Journal of Advanced Robotic Systems [online]. Vol. 11, 125 [Accessed 16 October 2016]. Available at http://cdn.intechopen.com/pdfs-wm/47351.pdf

Luth, G. P., Schorer, A., & Turkan, Y. (2014). Lessons from using BIM to increase design-construction integration. Practice Periodical on Structural Design and Construction, 19(1), 103-110. [online] [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ff

mt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Lessons+from+Using+BIM+to+Increase+Design-Construction+Integration&rft.jtitle=Practice+Periodical+on+Structural+Design+and+Construction&rft.au=Luth%2C+Gregory+P&rft.au=Schorer%2C+Alyssa&rft.au=Turkan%2C+Yelda&rft.date=2014-02-01&rft.pub=American+Society+of+Civil+Engineers&rft.issn=1084-0680&rft.eissn=1943-5576&rft.volume=19&rft.issue=1&rft.spage=103&rft.epage=110&rft_id=info:doi/10.1061%2F%28ASCE%29SC.1943-5576.0000200&rft.externalDocID=10_1061_ASCE_SC_1943_5576_0000200&paramdict=en-UK

McArthur, J., & Sun, X. (2015). Best practices for BIM Execution Plan development for a Public–Private Partnership Design-Build-Finance-Operate-Maintain project [online] Vol. 149 [Accessed 4 November 2016]. Available at http://www.witpress.com/Secure/elibrary/papers/BIM15/BIM15011FU1.pdf

McCraven, S. (2010). How Far Has BIM Come in the Precast Concrete Industry? NCPA [online]. [Accessed 14 October 2016]. Available at http://precast.org/2010/07/how-far-has-bim-come-in-the-precast-concrete-industry/

McCuen, L. (2008). Scheduling, estimating, and BIM: A profitable combination. AACE International Transactions, BIM11. [online] [Accessed 2 November 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/208171251?pq-origsite=summon

McGraw Hill Construction, (2012) “The business value of BIM for Infrastructure.” SmartMarket Report, pp. 1-60. [online]. Vol. [Accessed 16 October 2016]. Available at http://images.autodesk.com/adsk/files/business_value_of_bim_for_infrastructure_smartmarket_report__2012.pdf

McGraw Hill Construction. (2014). Business Value Of BIM In Global Markets 2014 Smart Market Report. [online] [Accessed 16 October 2016]. Available at https://synchroltd.com/newsletters/Business%20Value%20Of%20BIM%20In%20Global%20Markets%202014.pdf

Messner, J., Dossick, C., Won, J., & Lee, G. (2013). Where to focus for successful adoption of building information modeling within organization. Journal of Construction Engineering and Management, [online] 139(11), 4013014. [Accessed 3 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Where+to+Focus+for+Successful+Adoption+of+Building+Information+Modeling+within+Organization&rft.jtitle=Journal+of+Construction+Engineering+and+Management&rft.au=Messner%2C+John&rft.au=Dossick%2C+Carrie&rft.au=Won%2C+Jongsung&rft.au=Lee%2C+Ghang&rft.date=2013-11-01&rft.pub=American+Society+of+Civil+Engineers&rft.issn=0733-9364&rft.eissn=1943-7862&rft.volume=139&rft.issue=11&rft_id=info:doi/10.1061%2F%28ASCE%29CO.1943-7862.0000731&rft.externalDocID=10_1061_ASCE_CO_1943_7862_0000731&paramdict=en-UK

Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013). The benefits, obstacles and problems of practical bim implementation. Procedia Engineering, [online]. Vol. 57, 767-774. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=The+Benefits%2C+Obstacles+and+Problems+of+Practical+Bim+Implementation&rft.jtitle=Procedia+Engineering&rft.au=Migilinskas%2C+Darius&rft.au=Popov%2C+Vladimir&rft.au=Juocevicius%2C+Virgaudas&rft.au=Ustinovichius%2C+Leonas&rft.date=2013&rft.issn=1877-7058&rft.eissn=1877-7058&rft.volume=57&rft.spage=767&rft.epage=774&rft_id=info:doi/10.1016%2Fj.proeng.2013.04.097&rft.externalDBID=n%2Fa&rft.externalDocID=10_1016_j_proeng_2013_04_097&paramdict=en-US

Mom, M., Tsai, M., & Hsieh, S. (2014). Developing critical success factors for the assessment of BIM technology adoption: Part II. analysis and results. Journal of the Chinese Institute of Engineers, [online] Vol. 37(7), 859-868. [Accessed 1 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Developing+critical+success+factors+for+the+assessment+of+BIM+technology+adoption%3A+Part+II.+Analysis+and+results&rft.jtitle=Journal+of+the+Chinese+Institute+of+Engineers&rft.au=Mom%2C+Mony&rft.au=Tsai%2C+Meng-Han&rft.au=Hsieh%2C+Shang-Hsien&rft.date=2014-10-03&rft.issn=0253-3839&rft.eissn=2158-7299&rft.volume=37&rft.issue=7&rft.spage=859&rft.epage=868&rft_id=info:doi/10.1080%2F02533839.2014.888798&rft.externalDBID=n%2Fa&rft.externalDocID=10_1080_02533839_2014_888798&paramdict=en-UK

Monsen, E., and Horn, L. (2007). Research: Successful Approaches. American Dietetic Association. [online] [Accessed 11 November 2016]. Available at https://books.google.ae/books?id=0Mq_NH8yJXsC&pg=PA177&dq=what+is+survey+quantitative+data+collection&hl=en&sa=X&redir_esc=y#v=onepage&q=what%20is%20survey%20quantitative%20data%20collection&f=false

Morlhon, R., Pellerin, R., & Bourgault, M. (2015). Defining building information modeling implementation activities based on capability maturity evaluation: A theoretical model. International Journal of Information Systems and Project Management, [online] 3(1), 51-65. [Accessed 3 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Defining+Building+Information+Modeling+implementation+activities+based+on+capability+maturity+evaluation%3A+a+theoretical+model&rft.jtitle=International+Journal+of+Information+Systems+and+Project+Management&rft.au=Romain+Morlhon&rft.au=Robert+Pellerin&rft.au=Mario+Bourgault&rft.date=2015-01-01&rft.pub=SciKA&rft.issn=2182-7788&rft.eissn=2182-

7788&rft.volume=3&rft.issue=1&rft.spage=51&rft.epage=65&rft_id=info:doi/10.12821%2Fijispm030103&rft.externalDBID=DOA&rft.externalDocID=oai_doaj_org_article_98f03ff03f9e4da99408c3206b202efc&paramdict=en-UK

Nawari, N. O. (2012). BIM standard in off-site construction. Journal of Architectural Engineering, [online]. Vol. 18(2), 107-113. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=BIM+Standard+in+Off-Site+Construction&rft.jtitle=Journal+of+Architectural+Engineering&rft.au=Nawari%2C+Nawari+O&rft.date=2012-06-01&rft.issn=1076-0431&rft.eissn=1943-5568&rft.volume=18&rft.issue=2&rft.spage=107&rft.epage=113&rft_id=info:doi/10.1061%2F%28ASCE%29AE.1943-5568.0000056&rft.externalDBID=n%2Fa&rft.externalDocID=10_1061__ASCE_AE_1943_5568_0000056&paramdict=en-US

Neuman, W. (2011). Social Research Methods: Qualitative and Quantitative Approaches [online] [Accessed 10 November 2016]. Available at https://books.google.ae/books?id=iHGncQAACAAJ&dq=Neuman,+Social+Research+Methods:+Qualitative+and+Quantitative+Approaches&hl=en&sa=X&ved=0ahUKEwi7peaht7DQAhVH0xQKHXCIBAcQ6AEIGzAA

Nissilä, J., Heikkilä, R., Romo, I., Malaska, M., & Aho, T. (2014). BIM based schedule control for precast concrete supply chain. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 31, 1. [online] [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1565841622?pq-origsite=summon

Omar, M. F., Mohd Nasrun Mohd Nawi, & Nursal, A. T. (2014). Towards the significance of decision aid in building information modeling (BIM) software selection process. E3S Web of Conferences, 3, 01023. [online] [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1762699576?pq-origsite=summon

Omar, M. F., Nawi, M., & Nursal, A. T. (2014). Towards the significance of decision aid in building information modeling (BIM) software selection process. E3S Web of Conferences, [online]. Vol. 3, 01023. [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1762699576?pq-origsite=summon

Ozorhon, B., Abbott, C., Aouad, G., and Powell, J. (2014). Innovation in Construction A Project Life Cycle Approach. Salford Centre for Research and Innovation in the built and human environment (SCRI) [online]. [Accessed 28 September 2016]. Available at http://s3.amazonaws.com/academia.edu.documents/32160740/SCRIResearchReport4Innovation.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1475685816&Signature=mDtA8vSmXW7yZat6oLbOAfChj1A%3D&response-content-disposition=inline%3B%20filename%3DAcademic_Enterprise_papers.pdf

Park, H. (2009). Whole life performance assessment: Critical success factors. Journal of Construction Engineering and Management, [online] Vol. 135(11), pp. 1146-1161. [Accessed 1 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Whole+Life+Performance+Assessment%3A+Critical+Success+Factors&rft.jtitle=Journal+of+Construction+Engineering+and+Management&rft.au=Park%2C+Sung+Ho&rft.date=2009-11-01&rft.issn=0733-9364&rft.eissn=1943-7862&rft.volume=135&rft.issue=11&rft.spage=1146&rft.epage=1161&rft_id=info:doi/10.1061%2F%28ASCE%29CO.1943-7862.0000090&rft.externalDBID=n%2Fa&rft.externalDocID=10_1061__ASCE_CO_1943_7862_0000090&paramdict=en-UK

Park, R. (2003). Seismic Design of Precast Concrete Building Structures. FIB-Féd. Int. duBéton [online]. Vol. 27 [Accessed 16 October 2016]. Available at http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/2002/DOI_Articles/jl-02-september-october-5.pdf

Penttilä, H. 2006, "Describing the changes in architectural information technology to understand design complexity and free-form architectural expression", ITCON 11 (Special Issue The Effects of CAD on Building Form and Design Quality) [online]. pp. 395-408. [Accessed 16 October 2016]. Available at http://www.itcon.org/data/works/att/2006_29.content.02253.pdf

Pickup, J. (2013). BIM Adoption & Precast Concrete: Design and Implementation of a Strategic Guide [online]. Master's. Thesis. University of Sydney. [Accessed 30 September 2016]. Available at: http://s3.amazonaws.com/academia.edu.documents/34465931/BIM___Precast_Concrete_-_Design_and_Implementation_of_a_Strategic_Guide.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1475686384&Signature=RTrvOXpO4AYlb0tBVLy4WAW44Ow%3D&response-content-disposition=inline%3B%20filename%3DBIM_and_Precast_Concrete_-_Design_and_Im.pdf

Polat, G. (2008). Factors affecting the use of precast concrete systems in the united states. Journal of Construction Engineering and Management, [online]. Vol. 134(3), pp. 169-178. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Factors+Affecting+the+Use+of+Precast+Concrete+Systems+in+the+United+States&rft.jtitle=Journal+of+Construction+Engineering+and+Management&rft.date=2008-03-01&rft.pub=American+Society+of+Civil+Engineers&rft.issn=0733-9364&rft.eissn=1943-7862&rft.volume=134&rft.issue=3&rft.spage=169&rft.epage=178&rft_id=info:doi/10.1061%2F%28ASCE%290733-9364%282008%29134%3A3%28169%29&rft.externalDocID=10_1061_ASCE_0733_9364_2008_134_3_169&paramdict=en-UK

Punch, K. (2013). Introduction to Social Research: Quantitative and Qualitative Approaches. SAGE. [online] [Accessed 8 November 2016]. Available at https://books.google.ae/books?id=G2fOAgAAQBAJ&printsec=frontcover&dq=Introduction+to+Social+Research:+Quantitative+and+Qualitative+Approaches&hl=en&sa=X&ved=0ahUKEwjCnt_n2frQAhVIOxQKHdqVCdEQ6AEIGjAA#v=onepage&q=Introduction%20to%20Social%20Research%3A%20Quantitative%20and%20Qualitative%20Approaches&f=false

Ren, Y., Skibniewski, M. J., & Jiang, S. (2012). Building information modeling integrated with electronic commerce material procurement and supplier performance management system. Journal of Civil Engineering and Management, [online]. Vol. 18(5), 642. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Building+information+modeling+integrated+with+electronic+commerce+material+procurement+and+supplier+performance+management+system&rft.jtitle=Journal+of+Civil+Engineering+and+Management&rft.au=Ren%2C+Yali&rft.au=Skibniewski%2C+Miroslaw+J&rft.au=Jiang%2C+Shaohua&rft.date=2012-10-01&rft.pub=Vilnius+Gediminas+Technical+University&rft.issn=1392-3730&rft.volume=18&rft.issue=5&rft.spage=642&rft_id=info:doi/10.3846%2F13923730.2012.719835&rft.externalDBID=IAO&rft.externalDocID=327236195&paramdict=en-UK

Robert, B. (2000). Introduction to Research Methods. London: Sage Publications. [online] [Accessed 8 November 2016]. Available at https://books.google.ae/books?id=MQqPAAAACAAJ&dq=Introduction+to+Research+Methods%E2%80%99&hl=en&sa=X&redir_esc=y

Rogers, J., Chong, H., & Preece, C. (2015). Adoption of building information modelling technology (BIM): Perspectives from malaysian engineering consulting services firms. Engineering, Construction and Architectural Management, [online]. Vol. 22(4), 424-445. [Accessed 16 October 2016]. Available at http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/full/10.1108/ECAM-05-2014-0067

Roulston, K. (2010). Considering quality in qualitative interviewing. Qualitative Research, 10(2), 199-228. [online] [Accessed 8 November 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Considering+quality+in+qualitative+interviewing&rft.jtitle=Qualitative+Research&rft.au=Roulston%2C+K&rft.date=2010-04-01&rft.issn=1468-7941&rft.eissn=1741-3109&rft.volume=10&rft.issue=2&rft.spage=199&rft.epage=228&rft_id=info:doi/10.1177%2F1468794109356739&rft.externalDBID=n%2Fa&rft.externalDocID=10_1177_1468794109356739&paramdict=en-US

Sacks, R., & Barak, R. (2008). Impact of three-dimensional parametric modeling of buildings on productivity in structural engineering practice. Automation in Construction, [online]. Vol. 17(4), 439-449. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580507001082

Sacks, R., Akinci, B., and Ergen, E. (2003). BIM AND REAL-TIME MONITORING IN SUPPORT OF LEAN PRODUCTION OF ENGINEERED-TO-ORDER PRECAST CONCRETE BUILDINGS, 11th Annual Conference of the International Group for Lean Construction. Virginia, USA [online]. Vol. [Accessed 16 October 2016]. Available at http://leanconstruction.dk/media/18094/3D%20Modeling%20and%20Real-Time%20Monitoring%20in%20Support%20of%20Lean%20Production%20of%20Engineered-to-order%20Precast%20Concrete%20Buildings.pdf

Sacks, R., and Barak, R. (2006). Quantitative Assessment of the Impact Of 3D Modelling Of Building Structures On Engineering Productivity. Joint International Conference on Computing and Decision Making in Civil and Building Engineering [online]. [Accessed 28 September 2016]. Available at http://bim.technion.ac.il/ICCCBE%202006%20-%20QUANTITATIVE%20ASSESSMENT%20OF%20THE%20IMPACT%20OF%203D%20MODELING.pdf

Sacks, R., Eastman, C. M., & Lee, G. (2004). Parametric BIM in building construction with examples from precast concrete. Automation in Construction, [online]. Vol. 13(3), 291-312. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580503000438

Sacks, R., Eastman, C. M., Lee, G., and Orndorff, D. (2005). A Target Benchmark of the Impact of Three-dimensional Parametric Modeling in Precast Construction. Journal of the Precast/Prestressed Concrete Institute [online]. Vol. 50 (4), 126-139. [Accessed 28 September 2016]. Available at http://www.pci.org/uploadedFiles/Siteroot/Publications/PCI_Journal/2005/DOI_Articles/JL-05-JULY-AUGUST-6.pdf

Sacks, R., Kaner, I., Eastman, C. M., & Jeong, Y. (2010). The rosewood experiment — building information modeling and interoperability for architectural precast facades. Automation in Construction [online]. Vol. 19(4), 419-432. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580509001824

Sanchez, A., Hampson, K., and Vaux, S. (2016). Delivering Value with BIM: A whole-of-life approach. [online]. [Accessed 14 October 2016]. Available at https://books.google.ae/books?id=zxPeCwAAQBAJ&pg=PT173&dq=3d+modelling+for+precast&hl=en&sa=X&redir_esc=y#v=onepage&q=3d%20modelling%20for%20precast&f=false

Saunders, M., Lewis, P. and Thornhill, A. (2007). Research methods for business students. Harlow: Prentice Hall. [online] [Accessed 9 November 2016]. Available at https://is.vsfs.cz/el/6410/leto2014/BA_BSeBM/um/Research_Methods_for_Business_Students__5th_Edition.pdf

Schinler, D. & Nelson, E. (December, 2008). "BIM and the structural engineering community." STRUCTURE Magazine, [online]. pp. 10-12. [Accessed 16 October 2016]. Available at http://www.structuresworkshop.com/files/C-Tech-BIM-Schinler_Nelson-Dec-08.pdf

Seo, J., Kim, H., and Kim, I. (2012). Open BIM-based quality control for enhancing the design quality in the architectural design phase. Korea Journal of Construction Engineering and Management [online]. Vol. 13(4), 3-15. [Accessed 16 October 2016]. Available at https://www.researchgate.net/publication/264168566_Open_BIM-

Based_Quality_Control_for_Enhancing_the_Design_Quality_in_the_Architectural_Design_Phase

Sheth, Z. and Malsane, M. (2014). Building information modelling, a tool for green built environment. All India Seminar on Innovation in Green Building Technology, Green Build 2014, The Institute of Engineers (India), Nagpur, India, [online] [Accessed 31 October 2016]. Available at https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/15120/1/Building%20information%20modelling.pdf

Smith, D. K. & Tardif, M. (2012). Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers, John Wiley & Sons. [online] [Accessed 30 October 2016]. Available at https://books.google.ae/books?id=gQ-6gcoU6J4C&printsec=frontcover&dq=Building+information+modeling:+a+strategic+implementation+guide+for+architects,+engineers,+constructors,+and+real+estate+asset+managers&hl=en&sa=X&redir_esc=y#v=onepage&q=Building%20information%20modeling%3A%20a%20strategic%20implementation%20guide%20for%20architects%2C%20engineers%2C%20constructors%2C%20and%20real%20estate%20asset%20managers&f=false

Snyder, H. (1996). Qualitative interviewing: The art of hearing data. Library and Information Science Research, 18(2), 194-195. [online] [Accessed 9 November 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0740818896900249

Steel, J., Drogemuller, R., & Toth, B. (2012). Model interoperability in building information modelling. Software & Systems Modeling, [online]. Vol. 11(1), pp. 99-109. [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/917882133?pq-origsite=summon

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, [online] Vol. 18(3), 357-375. [Accessed 31 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580508001568

Succar, B. (2009;2008). "Building information modelling framework: A research and delivery foundation for industry stakeholders", Automation in Construction. [online] vol. 18, no. 3, pp. 357-375. [Accessed 16 October 2016]. Available at http://www.sciencedirect.com.ezproxy.buid.ac.ae/science/article/pii/S0926580508001568

Sugiyama, H., & Mito, K. (2014). method of quality control at production process of precast concrete column. Journal of Structural and Construction Engineering (Transactions of AIJ), [online] Vol. 79(706), 1729-1739. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=METHOD+OF+QUALITY+CONTROL+AT+PRODUCTION+PROCESS+OF+PRECAST+CONCRETE+COLUMN&rft.jtitle=Journal+of+Structural+and+Construction+Engineering+%28Transactions+of+AIJ%29&rft.au=SUGIYAMA%2C+Hisashi&rft.au=MITO%2C+Kensuke&rft.date=2014&rft.issn=1340-4202&rft.eissn=1881-8153&rft.volume=79&rft.issue=706&rft.spage=1729&rft.epage=1739&rft_id=info:doi/10.3130%2Faijs.79.1729&rft.externalDBID=n%2Fa&rft.externalDocID=10_3130_aijs_79_1729&paramdict=en-US

Taihairan, R., & Ismail, Z. (2015). BIM: Integrating cost estimates at Initial/Design stage. International Journal of Sustainable Construction Engineering and Technology, [online]. Vol. 6(1), 62-74. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=BIM%3A+Integrating+Cost+Estimates+at+Initial%2FDesign+Stage&rft.jtitle=International+Journal+of+Sustainable+Construction+Engineering+and+Technology&rft.au=Raja+Bukhary+Raja+Taihairan&rft.au=Zulhabri+Ismail&rft.date=2015-10-01&rft.pub=Penerbit+UTHM&rft.issn=2180-3242&rft.volume=6&rft.issue=1&rft.spage=62&rft.epage=74&rft.externalDBID=DOA&rft.externalDocID=oai_doaj_org_article_7c43cd70d05e4ab897c1bce67754a513&paramdict=en-UK

Teddlie, C. & Tashakkori, A. 2009, Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences, SAGE Publication, Inc. [online] [Accessed 10 November 2016]. Available at https://books.google.ae/books?id=XvMAYYvS1rEC&printsec=frontcover&dq=Foundations+of+Mixed+Methods+Research&hl=en&sa=X&ved=0ahUKEwj5xbeWurDQAhUKPxQKHRkyDwcQ6AEIGTAA#v=onepage&q=Foundations%20of%20Mixed%20Methods%20Research&f=false

Volk, R., Stengel, J., & Schultmann, F. (2014). Building information modeling (BIM) for existing buildings — literature review and future needs. Automation in Construction, [online] Vol. 38, 109-127. [Accessed 30 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Building+Information+Modeling+for+existing+buildings+--+Literature+review+and+future+needs&rft.jtitle=Automation+in+Construction&rft.au=Volk%2C+Rebekka&rft.au=Stengel%2C+Julian&rft.au=Schultmann%2C+Frank&rft.date=2014-03-01&rft.pub=Elsevier+B.V&rft.issn=0926-5805&rft.eissn=1872-7891&rft.volume=38&rft.spage=109&rft_id=info:doi/10.1016%2Fj.autcon.2013.10.023&rft.externalDBID=BSHEE&rft.externalDocID=354773370&paramdict=en-US

Wang, J., Sun, W., Shou, W., Wang, X., Wu, C., Chong, H., Sun, C. (2015). Integrating BIM and LiDAR for real-time construction quality control. Journal of Intelligent & Robotic Systems, 79(3), 417-432. [online] [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1774956981?pq-origsite=summon

Wang, L.J., Huang, X. & Zheng, R.Y. (2012), "The Application of BIM in Intelligent Construction", Applied Mechanics and Materials, [online] Vol. 188, pp. 236. [Accessed 22 April 2017]. Available at http://ezproxy.buid.ac.ae/login?url=http://search.proquest.com/docview/1442937465?pq-origsite=summon

Wang, Q., J C P Cheng, & Sohn, H. (2016). Automatic reconstruction of as-built BIM from laser scanned data of precast concrete elements for dimensional quality assessment. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 33, 1. [online]  [Accessed 16 October 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1823081685?pq-origsite=summon

Waugh, N. (2013). Concrete Solutions for Green Buildings. Gulf Construction [online]. [Accessed 30 September 2016]. Available at http://www.gulfconstructiononline.com/news/15875_Concrete-solutions-for-green-buildings.html

Whitmore, B. (2016). Precast Forecast 2016. National Precast Concrete Association [online]. [Accessed 28 September 2016]. Available at http://precast.org/2016/01/precast-forecast-2016/

Won, J., & Lee, G. (2010). Identifying the consideration factors for successful BIM projects. In Proceedings International Conference. [online]. [Accessed 16 October 2016]. Available at http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/pf72.pdf

Won, J., and Lee, G. (2010). Identifying the consideration factors for successful BIM project. Nottingham University Press. Proceedings of the International Conference on. Computing in Civil and Building Engineering. [online] [Accessed 4 November 2016]. Available at http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/pf72.pdf

Yanagida, J., Ohnuma, N., Yamaguchi, M., & Yamada, M. (2012). A study on quality control of precast concrete and examination of cover depth of precast concrete. Concrete Journal, [online] Vol. 50(2), pp. 163-170. [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=A+Study+on+Quality+Control+of+Precast+Concrete+and+Examination+of+Cover+Depth+of+Precast+Concrete&rft.jtitle=Concrete+Journal&rft.au=Yanagida%2C+J&rft.au=Ohnuma%2C+N&rft.au=Yamaguchi%2C+M&rft.au=Yamada%2C+M&rft.date=2012&rft.issn=0387-1061&rft.eissn=2186-

2753&rft.volume=50&rft.issue=2&rft.spage=163&rft.epage=170&rft_id=info:doi/10.3151%2Fcoj.50.163&rft.externalDBID=n%2Fa&rft.externalDocID=10_3151_coj_50_163&paramdict=en-US

Zahrizan, Z., Ali, N., Haron, A., Ponting, A., and Hamid, Z. (2012). An Exploratory Study on the Potential of Implementing Building Information Modelling (BIM) in Malaysian Construction Industry: Lesson Learnt from Singapore and Hong Kong Construction Industry. International Journal of Civil Engineering & Geo-Environmental [online] [Accessed 2 November 2016]. Available at https://community.ump.edu.my/ecommstaff/sites/default/library/subfolders/11953/1/icege3.pdf#page=11

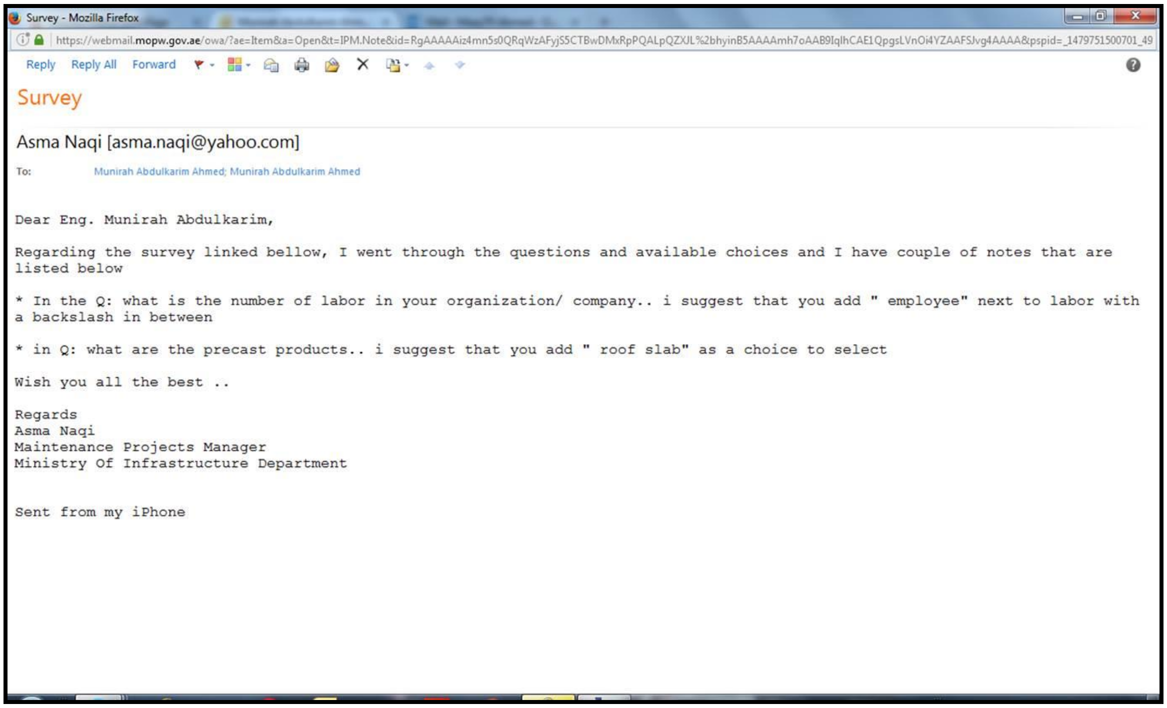
Zahrizan, Z., Ali, N., Haron, A., Ponting, A., and Hamid, Z. (2013). Exploring The Adoption Of Building Information Modelling (BIM) In The Malaysian Construction Industry: A Qualitative Approach. International Journal of Research in Engineering and Technology, Vol. 2(8). [online] [Accessed 2 November 2016]. Available at http://esatjournals.net/ijret/2013v02/i08/IJRET20130208060.pdf

Zhang, D. (2012). Project time and cost control using building information modeling [online] [Accessed 2 November 2016]. Available at http://search.proquest.com.ezproxy.buid.ac.ae/docview/1493848769?pq-origsite=summon

Zhang, S., Teizer, J., Lee, J., Eastman, C. M., & Venugopal, M. (2013). Building information modeling and safety: Automatic safety checking of construction models and schedules. Automation in Construction, [online]. Vol. 29, 183 [Accessed 16 October 2016]. Available at http://ke9dn2ja4z.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info%3Asid%2Fsummon.serialssolutions.com&rft_val_fmt=info%3Aofi%2Ffmt%3Akev%3Amtx%3Ajournal&rft.genre=article&rft.atitle=Building+Information+Modeling+and+Safety%3A+Automatic+Safety+Checking+of+Construction+Models+and+Schedules&rft.jtitle=Automation+in+Construction&rft.au=Zhang%2C+Sijie&rft.au=Teizer%2C+Jochen&rft.au=Lee%2C+Jin-Kook&rft.au=Eastman%2C+Charles+M&rft.date=2013-01-01&rft.pub=Elsevier+B.V&rft.issn=0926-5805&rft.eissn=1872-

7891&rft.volume=29&rft.spage=183&rft_id=info:doi/10.1016%2Fj.autcon.2012.05.006
&rft.externalDBID=BSHEE&rft.externalDocID=308044086&paramdict=en-UK

# Appendix A Pilot Study



Survey - Mozilla Firefox

Reply Reply All Forward

Survey

Asma Naqi [asma.naqi@yahoo.com]

To: Munirah Abdulkarim Ahmed; Munirah Abdulkarim Ahmed

Dear Eng. Munirah Abdulkarim,

Regarding the survey linked bellow, I went through the questions and available choices and I have couple of notes that are listed below

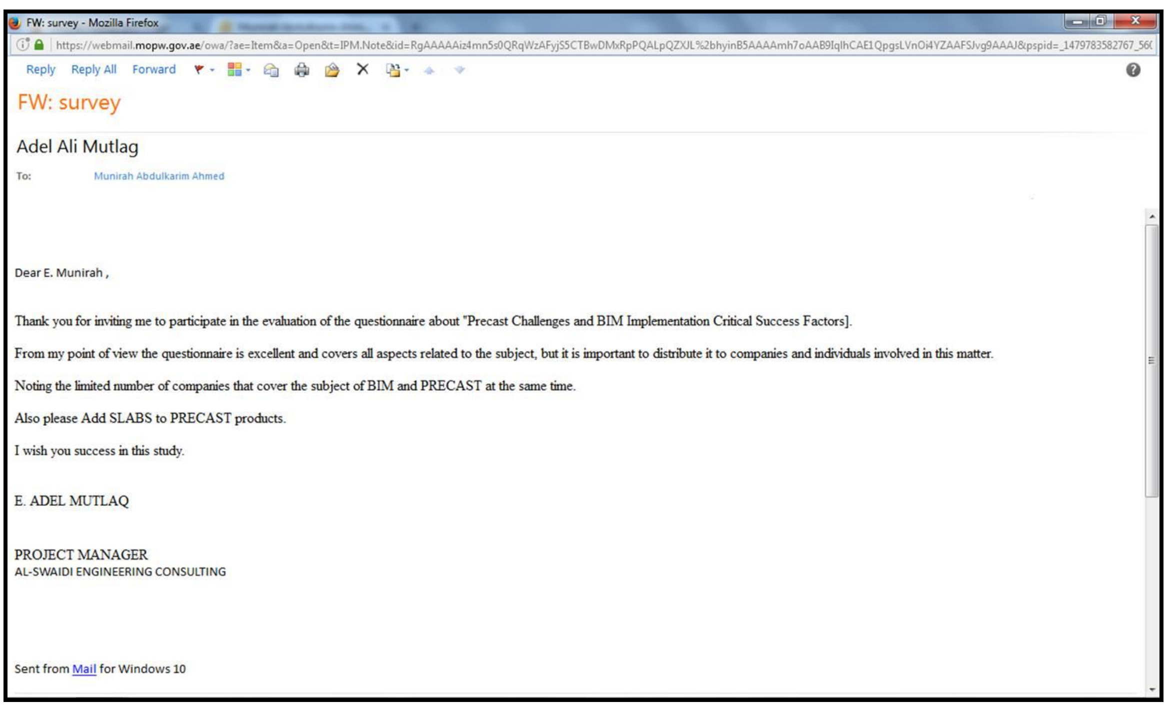
* In the Q: what is the number of labor in your organization/ company.. i suggest that you add " employee" next to labor with a backslash in between

* in Q: what are the precast products.. i suggest that you add " roof slab" as a choice to select

Wish you all the best ..

Regards
Asma Naqi
Maintenance Projects Manager
Ministry Of Infrastructure Department

Sent from my iPhone



FW: survey - Mozilla Firefox

Reply Reply All Forward

FW: survey

Adel Ali Mutlag

To: Munirah Abdulkarim Ahmed

Dear E. Munirah ,

Thank you for inviting me to participate in the evaluation of the questionnaire about "Precast Challenges and BIM Implementation Critical Success Factors].

From my point of view the questionnaire is excellent and covers all aspects related to the subject, but it is important to distribute it to companies and individuals involved in this matter.

Noting the limited number of companies that cover the subject of BIM and PRECAST at the same time.

Also please Add SLABS to PRECAST products.

I wish you success in this study.

E. ADEL MUTLAQ

PROJECT MANAGER
AL-SWAIDI ENGINEERING CONSULTING

Sent from Mail for Windows 10

**From:** mariam.abdulkarim@moid.gov.ae <mariam.abdulkarim@moid.gov.ae>
**Sent:** Tuesday, December 13, 2016 3:14 PM
**To:** maay75@outlook.com
**Subject:** Comment on survay

Dear student
Regarding to the survey, I am done with it and my comment is: the first two factors in question 12 are similar to each other (adoption strategy and clear business strategy and goals) .. so one is enough in my opinion.

Wish you all the best

Eng. Mariam Moh. Abdulkarim
Manager of Shaam Hospital

**From:** Ali Shaaer <al_shaaer2020@yahoo.com>
**Date:** December 13, 2016 at 3:37:38 PM GMT+4
**To:** Muneera <maay75@outlook.com>
**Subject: Survey comments**

Dear Eng. Muneera,
First of all thank you for giving me the appotunity to participate in the survey. I found it very useful actually I think using precast is very useful in saving time. Moreover, using BIM minimizing mistakes and conflicts that may occur due to human errors between MEP and civil works. In general survey is clear.
Wish you all the best
Eng. Sheikha Alshaaer
Dewa

From: Marwa Mahmoud Abdelazim Faramawy <Marwa.Faramawy@moid.gov.ae>
Date: 12/13/16 11:32 AM (GMT+04:00)
To: maay75@outlook.com
Subject:

Dear survey collector,

I just wanted to inform you that I did the survey, and it is good and covering all needed areas of your topic

Good luck
Eng. Marwa Alfaramawy
Civil & Environmental Engineer

Sent from my Samsung Galaxy smartphone.

## Appendix B Interview Questions

| | |
|---|---|
| Employee Name: | |
| Job Title: | |
| Organization Name: | |

**1. Which are the factors affecting the use of precast structures in terms of cost?**
Examples: Budget planning, Cost estimation, Cost management, Engineering cost, Erection costs, Inflation, Material costs, Overhead costs, Training costs, Transportation costs, and Wastes costs.

**2. Which are the factors affecting the use of precast structures in terms of time?**
Examples: Communication, Construction speed, Delivery speed, Production planning and scheduling, Project duration, Time for finishing work, Time for handling and equipment use, Time for sub precast structure, and Time for super precast structure.

**3. Which are the factors affecting the use of precast structures in terms of quality?**
Examples: Client or customer expectations, Construction documentation, Customer service, Decision-making, Defects detection, Design and drafting, Engineering productivity, Errors and omissions, Production automation, Quality controlling and monitoring, and Quantity of labor and related costs based on project size.

4. **What are the critical success factors to adopt BIM for precast?**

Examples: Adoption strategy, Clear business strategy and goals, Clients' request for BIM, Construction location site, Culture of sharing and communicating, Economic impact, Effort and timeliness, Employees' expertise in BIM, Functions and features, Interest and willingness for BIM, Investment in BIM costs, IT capabilities technical support, Learning curve, Long-term strategy of BIM provider, Low costs and expenses, Management commitment, participation, and support, Mitigate resistance to change, Performance metrics, Pilot project, Project management, Project manager and team, Quality management, Safety, and environmental, Training and development, and Web-based.

**Comments / Recommendations / Suggestions:**

## Appendix C Survey Questions

Hello:

You are invited to participate in my survey [Critical Success Factors for Using Precast Structures in the Construction Industry in the UAE]. In this survey, approximately [35] people will be asked to complete a survey that asks questions about [Precast Challenges and BIM Implementation CSFs]. It will take approximately [5] minutes to complete the questionnaire.

It is very important for me to learn your opinions. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential.

Thank you very much for your time and support. Please start with the survey now by clicking on the **Continue** button below.

| Section A: Participant Profile |
|---|

What is your gender?

❍Male

❍Female

What is your educational level?

❍Diploma

❍Higher Diploma

❍Some college

❍Undergraduate

❍Graduate

❍Postgraduate

❍Other: ______________________

Did your company, firm or organization implement Building Information Modeling (BIM) 3D for precast?

❍Yes, please answer the following questions.

❍No

❍Not Sure

How long have you worked in precast industry?

❍Less than 1 year

❍1-5 years

❍5-10 years

❍10-15 years

❍15-20 years

❍More than 20 years

What is the number of labors in your organization/company?

❍Less than 20 labors

❍20-50 labors

❍50-100 labors

❍100-150 labors

❍150-200 labors

❍More than 200 labors

What is the size of project cost?

❍Less than 50 million

❍50-100 million

❍100-150 million

❍150-200 million

❍200-250 million

❍More than 250 million

What are the precast products?

❍Bridges

❍Flooring

❍MEP Elements

❍Structure (Beams/Columns)

❍Slabs

❍Sculptures

❍Stairs

❍Walling

❍Other: ______________________

Which is your department/position?

❍Design

❍Production

❍Procurement

❍Logistics

❍Management

❍Other: ______________________

| Section B: Precast Structure Challenges |
|---|

Which are the factors affecting the use of precast structures in terms of cost?

Please input the extent of your agreement or your disagreement to answer the following areas by choosing. The Likert rating scale and number are following:

1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, or 5 = Strongly agree.

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Budget planning | ○ | ○ | ○ | ○ | ○ |
| Cost estimation | ○ | ○ | ○ | ○ | ○ |
| Cost management | ○ | ○ | ○ | ○ | ○ |
| Engineering cost | ○ | ○ | ○ | ○ | ○ |
| Erection costs | ○ | ○ | ○ | ○ | ○ |
| Inflation | ○ | ○ | ○ | ○ | ○ |
| Material costs | ○ | ○ | ○ | ○ | ○ |
| Overhead costs | ○ | ○ | ○ | ○ | ○ |
| Training costs | ○ | ○ | ○ | ○ | ○ |
| Transportation costs | ○ | ○ | ○ | ○ | ○ |
| Wastes costs | ○ | ○ | ○ | ○ | ○ |

Which are the factors affecting the use of precast structures in terms of time?

Please input the extent of your agreement or your disagreement to answer the following areas by choosing. The Likert rating scale and number are following:

1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, or 5 = Strongly agree.

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Communication | ○ | ○ | ○ | ○ | ○ |
| Construction speed | ○ | ○ | ○ | ○ | ○ |
| Delivery speed | ○ | ○ | ○ | ○ | ○ |
| Production planning and scheduling | ○ | ○ | ○ | ○ | ○ |
| Project duration | ○ | ○ | ○ | ○ | ○ |
| Time for finishing work | ○ | ○ | ○ | ○ | ○ |
| Time for handling and equipment use | ○ | ○ | ○ | ○ | ○ |
| Time for sub precast structure | ○ | ○ | ○ | ○ | ○ |
| Time for super precast structure | ○ | ○ | ○ | ○ | ○ |

Which are the factors affecting the use of precast structures in terms of quality?

Please input the extent of your agreement or your disagreement to answer the following areas by choosing. The Likert rating scale and number are following:

1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, or 5 = Strongly agree.

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Client or customer expectations | ○ | ○ | ○ | ○ | ○ |
| Construction documentation | ○ | ○ | ○ | ○ | ○ |
| Customer service | ○ | ○ | ○ | ○ | ○ |
| Decision-making | ○ | ○ | ○ | ○ | ○ |
| Defects detection | ○ | ○ | ○ | ○ | ○ |
| Design and drafting | ○ | ○ | ○ | ○ | ○ |
| Engineering productivity | ○ | ○ | ○ | ○ | ○ |
| Errors and omissions | ○ | ○ | ○ | ○ | ○ |
| Production automation | ○ | ○ | ○ | ○ | ○ |
| Quality controlling and monitoring | ○ | ○ | ○ | ○ | ○ |
| Quantity of labor and related costs based on project size | ○ | ○ | ○ | ○ | ○ |

## Section C: Critical Success Factors for Building Information Modeling Implementation

What are the critical success factors to adopt BIM for precast?

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Adoption strategy | ○ | ○ | ○ | ○ | ○ |
| Clear business strategy and goals | ○ | ○ | ○ | ○ | ○ |
| Clients' request for 3D system | ○ | ○ | ○ | ○ | ○ |
| Construction location site | ○ | ○ | ○ | ○ | ○ |
| Culture of sharing and communicating | ○ | ○ | ○ | ○ | ○ |
| Economic impact | ○ | ○ | ○ | ○ | ○ |
| Effort and timeliness | ○ | ○ | ○ | ○ | ○ |
| Employees' expertise in 3D system | ○ | ○ | ○ | ○ | ○ |
| Functions and features | ○ | ○ | ○ | ○ | ○ |
| Interest and willingness for 3D system | ○ | ○ | ○ | ○ | ○ |
| Safety, and environmental | ○ | ○ | ○ | ○ | ○ |
| Training and development | ○ | ○ | ○ | ○ | ○ |
| Web-based | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| Investment in 3D system costs | ○ | ○ | ○ | ○ | ○ |
| IT capabilities technical support | ○ | ○ | ○ | ○ | ○ |
| Learning curve | ○ | ○ | ○ | ○ | ○ |
| Long-term strategy of 3D system provider | ○ | ○ | ○ | ○ | ○ |
| Low costs and expenses | ○ | ○ | ○ | ○ | ○ |
| Management commitment, participation, and support | ○ | ○ | ○ | ○ | ○ |
| Mitigate resistance to change | ○ | ○ | ○ | ○ | ○ |
| Performance metrics | ○ | ○ | ○ | ○ | ○ |
| Pilot project | ○ | ○ | ○ | ○ | ○ |
| Project management | ○ | ○ | ○ | ○ | ○ |
| Project manager and team | ○ | ○ | ○ | ○ | ○ |
| Quality management | ○ | ○ | ○ | ○ | ○ |

Comments/Recommendations/Suggestions:

## Appendix D Interview Response 1

| | |
|---|---|
| Employee Name: | Mohamed Ibrahim Al Mansoori |
| Job Title: | CEO of Engineering Affairs |
| Organization Name: | Sheikh Zayed Housing Program |

**5. Which are the factors affecting the use of precast structures in terms of cost?**

As a governmental authority, focusing on price is not a chosen strategy, especially where high-quality is concerned, keeping in mind the TQM system. In the case of precast structures, the focus should be on the total cost not a specific type.

**6. Which are the factors affecting the use of precast structures in terms of time?**

Of course there is a huge difference in construction speed and project duration while using the precast system in compare with the traditional methods. And as a government having a governmental type of costumers (G2G), ending up with a less project durations will be more significant and make higher reputations.

**7. Which are the factors affecting the use of precast structures in terms of quality?**

The biggest risk is in quality of labor, it may affect the client or customer expectations
Errors and omissions will affect also and delay the project  and lack of quality

**8. What are the critical success factors to adopt BIM for precast?**

Quality management, Safety, and environmental I think they are the most important factors.

## Appendix E Interview Response 2

| | |
|---|---|
| Employee Name: | Mariam Abdulkarim Mohammed |
| Job Title: | Manager of Execution Department / Project Manager of : Shaam Hospital / Sheikh Khalifa Specialty Hospital in RaK |
| Organization Name: | Ministry of Infrastructure Development |

1. **Which are the factors affecting the use of precast structures in terms of cost?**

I'm going to order them as follows, more importantly, the least important:

| |
|---|
| Erection costs |
| Budget planning |
| Cost estimation |
| Cost management |
| Transportation |
| Engineering cost |
| Material costs |
| Material costs |
| Overhead costs |
| Training costs |
| Wastes costs |

2. **Which are the factors affecting the use of precast structures in terms of time?**

| |
|---|
| Project duration |
| Construction speed |
| Delivery speed |
| Time for finishing work |

3. **Which are the factors affecting the use of precast structures in terms of quality?**

| |
|---|
| Errors and omissions |
| Quality controlling and monitoring |

| |
|---|
| Quantity of labor and related costs based on project size |

**4. What are the critical success factors to adopt BIM for precast?**

| |
|---|
| Safety, and environmental<br>Culture of sharing and communicating |

**Comments / Recommendations / Suggestions:**

| |
|---|
| BIM is an important requirement must be taken into account but the high cost may be a barrier. |

## Appendix F Interview Response 3

| | |
|---|---|
| Employee Name: | Dr. Abdullah Fikry |
| Job Title: | Engineering Construction Expert |
| Organization Name: | Ministry of infrastructure Development |

**1. Which are the factors affecting the use of precast structures in terms of cost?**

Erection costs

**2. Which are the factors affecting the use of precast structures in terms of time?**

Project duration, Time for finishing work and Time for handling and equipment use

**3. Which are the factors affecting the use of precast structures in terms of quality?**

Quality controlling and monitoring, and Quantity of labor and related costs based on project size

**4. What are the critical success factors to adopt BIM for precast?**

Project management, Safety, and environmental

## Appendix G Interview Response 4

| | |
|---|---|
| Employee Name: | Nassib Shahin |
| Job Title: | Sales Engineer |
| Organization Name: | Abu Dhabi Precast LLC |

**1. Which are the factors affecting the use of precast structures in terms of cost?**

Cost of quality. Precast concrete is being produced in a controlled environment and labor had gain the specialty to their work.

Service cost. In construction, schedule/time is an expensive risk hence speedy delivery & ease of installation makes precast better choice than cast-in-place concrete. A contractor saves money for every minute he or she is ahead of schedule.

Marketability. Make the above advantage of precast as part of sale strategy and make it as better mousetrap at a lower cost.

**2. Which are the factors affecting the use of precast structures in terms of time?**

Project Fast-tracking. Since precast is being manufactured in the plant, contractor can overlap activities to shorten the overall duration of the project. Activities such as foundation works can proceed while the wall panels, columns, beams are being produced at the factory.

Less procurement time, less finishing time, less supervision time, etc.

**3. Which are the factors affecting the use of precast structures in terms of quality?**

Concrete batch consistency. Smooth/Rigid molds/forms. Specialist labor. Uniformity. Well controlled environment.

**4. What are the critical success factors to adopt BIM for precast?**

Ease of visualization. Accuracy. Adapting to current technology. Departmental commonness of project outlook. Overview of what will really happen. Earlier quantifying and qualifying of risk.

**Comments / Recommendations / Suggestions:**

In precast, you definitely save the TCO (total cost of ownership) of a project especially if it is in repetitive construction.

## Appendix H Interview Response 5

| | |
|---|---|
| Employee Name: | SALAH BAHY |
| Job Title: | BIM Consultant / Revit Instructor/ BIM Manager |
| Organization Name: | Gensler Abu Dhabi |

**1. Which are the factors affecting the use of precast structures in terms of cost?**

The most effective factors in terms of cost are:

A- Cost estimation.

B- Erection costs.

C- Material costs.

**2. Which are the factors affecting the use of precast structures in terms of time?**

The most effective factors in terms of time are:

A- Construction speed including delivery speed.

B- Production planning and scheduling.

C- Time for sub precast structure.

D- Time for super precast structure.

**3. Which are the factors affecting the use of precast structures in terms of quality?**

The most effective factors in terms of quality are:

A- Production automation.

B- Quality controlling and monitoring.

C- Defects detection.

**4. What are the critical success factors to adopt BIM for precast?**

The most effective factors in terms of quality are:

A- Production automation.

B- Quality controlling and monitoring.

C- Defects detection.

## Appendix I Interview Response 6

| | |
|---|---|
| Employee Name: | Eng. Hassan Juma Al Mansoori |
| Job Title: | Minister Deputy |
| Organization Name: | Ministry of Infrastructure development |

**1. Which are the factors affecting the use of precast structures in terms of cost?**

Cost management

Cost estimation

Budget planning

**2. Which are the factors affecting the use of precast structures in terms of time?**

Construction speed

Delivery speed

Project duration

**3. Which are the factors affecting the use of precast structures in terms of quality?**

Quality by precast concrete is important to government agency to achieve the following:

Client or customer expectations

Errors and omissions

Quality controlling and monitoring

Quantity of labor and related costs based on project size

**4. What are the critical success factors to adopt BIM for precast?**

The use of BIM is important in the government agency to achieve the following:

Quality management

Environmental

| |
|---|
| Low costs and expenses |
| Safety |

**Comments / Recommendations / Suggestions:**

The most important factors to adopt precast method in construction is as follows:

1- Reducing cost and achieving efficiency by finishing with less time, and time means money.

2- Precast concrete reduces pollution and it is environmentally friendly,

3- It reduces health risk of pouring concrete.

4- Precast concrete reduces wastes which means reducing footprint.

5- It is also sustainable can result in high quality product by using less unskilled workers

## Appendix J Interview Response 7

Employee Name: Husam Jawhar

Job Title: Projects Manager

Organization Name: Yousif GeneraL Contracting Est.

**1. Which are the factors affecting the use of precast structures in terms of cost?**

Special Construction, Project accessibility, Project clarity, Project Size, Project Type, Project Difficulty, Level of detail, Client difficulty, Contractor problems, Competition, Labor Rates and, Material Costs.

**2. Which are the factors affecting the use of precast structures in terms of time?**

Shortage of labour, Skill shortages, Low speed of decision, Design errors made by designers and Underestimation of time of completion.

**3. Which are the factors affecting the use of precast structures in terms of quality?**

Methodology

Results and Discussion

**4. What are the critical success factors to adopt BIM for precast?**

Top management support, training and education, theory refinement and integration, organizational culture, communication, it support, resource availability, stage control, manageable size, skills and abilities, strategies alignment, and tools and techniques.

## Appendix K Interview Response 8

Employee Name: Mohammad Mahmoud AlMegdade

Job Title: Estimation and Planning g Engineer

Organization Name: Yousif GeneraL Contracting Est.

**1. Which are the factors affecting the use of precast structures in terms of cost?**

Size, Type, Special Construction, Project accessibility, Project clarity, Project Difficulty, Level of detail, Client difficulty, Contractor problems, Time of Year**,** Competition, Labor Rates, Material Costs, General Economic Pressures and Functional Life of Components.

**2. Which are the factors affecting the use of precast structures in terms of time?**

Financial difficulties, Shortage of labour, Skill shortages, Unforeseen ground, Condition**,** Unrealistic deadlines for project completion, Poor communication, Poor organization of the contractor/consultant, Low speed of decision, Design errors made by designers and Underestimation of time of completion.

**3. Which are the factors affecting the use of precast structures in terms of quality?**

**Methodology:** Profile of the study area, Data Collection, Sampling and Sample Size, Determination and Relative Importance Index.

**Results and Discussion:** Contractor Related Factors and Consultant Related Factors.

**4. What are the critical success factors to adopt BIM for precast?**

Empowered inter-principle lean team, top management support, training and education, theory refinement and integration, organizational culture, communication, IT support, resource availability, stage control, manageable size, skills and abilities, strategies alignment, standardization and tools and techniques.