BIMp-Chart: A TOOL TO MEASURE BIM IMPLEMENTATION LEVEL IN AN ORGANIZATION

by

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This thesis is dedicated to my mother for making me be who I am, my father for supporting me all the way and respected teachers.

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ABSTRACT

Building Information Modelling (BIM) can be recognized as one of the most significant technological breakthrough in the Architecture, Engineering and Construction (AEC) industry. Pace of implementation of BIM has increased during the last decade as it facilitates different stakeholders to collaborate better during the course of construction projects, improves the quality of design and construction, ultimately increasing the efficiency of projects. However, BIM implementation straggle behind its potential because of variety of factors. In order to evaluate and solve BIM implementation troubles and to achieve maximum benefits from BIM, understanding of current implementation level of BIM in organizations is required. Motivated by this need, the main objective of this study was to propose a BIMp-Chart for the measurement of BIM implementation level within organization comprising set of indexes developed on the bases of critical success factors (CSFs). Detailed literature review followed by a questionnaire survey was conducted and results were analyzed to formulate a BIM-chart. Subsequently, applicability of BIMp-Chart was assessed by comparing and analyzing data sets of four organizations from different regions. The results showed that the proposed chart can assist the practitioners to measure and compare BIM implementation level and to identify the areas that need improvements for successful BIM implementation.

Table of Contents

LIST OF ABBREVIATIONS

AEC	Architectural, Engineering and Construction Industry (UK)
BIM	Building Information Modeling
BIMp-Chart	BIM Implementation Chart
CSFs	Critical Success Factors
ICT	Information and Communication Technology
ISO	International Organization of Standarization

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION

1.1 GENERAL

The trend of construction industry has been changing and moving towards better execution of projects by improving quality, reducing cost and time and increasing productivity, efficiency and sustainability by means of effective collaboration and communication of stakeholders (Arayici et al. 2011). Complexities of construction projects are increasing gradually and they are becoming very difficult to manage. In order to deal with increased complexity of projects, number of information and communication technologies (ICT) are emerging (Latham 2015). It has been recommended that construction projects will be more dynamic and manageable with ICT applications (Bui et al. 2016). One of these ICT applications is BIM. BIM is considered as a key technology for managing construction projects and promises to yield the desired changes necessary for improvement in the construction industry (Jin et al. 2017; Gholizadeh et al. 2018). BIM incorporates all aspects, disciplines, and systems of a facility in a single virtual model and allows all team members to communicate, collaborate, visualize and manage construction work better in order to ensure successful project delivery (Jin et al. 2017; Bhatti 2018).

BIM offers wide range of benefits in which main highlights are collaboration and coordination, faster project processes, easy building lifecycle maintenance, schedule and cost optimization, high flexibility and customization, detection of conflict and mitigation of risk (Yan and Damian 2008; Barlish and Sullivan 2012; Jin et al. 2015;

Ghaffarianhoseini et al. 2017). These benefits of BIM recognized by owners persuade construction firms, construction managers and other design professionals to implement BIM in their projects (Arayici et al. 2011b; Jin et al. 2015).

As interest of practitioners in BIM has gained momentum, BIM implementation rates have been increasing sharply around the developed economies (Smith 2014). A survey conducted between 2007-2012 in North America shows that BIM usage has increased from 28% in 2007 to 71% in 2012 (SMR 2012). In 2011, only 13% of construction players in United Kingdom (UK) implemented BIM in their projects (NBS report 2011). Whereas a survey conducted in 2019 shows that the implementation in UK has escalated to 69% (NBS report 2019). Similarly, BIM implementation in Germany has reached up to 90% (Bhatti et al. 2018). These values implies implementation of BIM to be beneficial for the projects with a potential to enhance construction processes (Arayici et al. 2011b).

Although the BIM implementation is rising at fast pace, its usage within organizations is highly dependent on many factors such as government-led initiatives, support from leadership, unavailability of technological and financial resources and lack of BIM expertise (Jin et al. 2015; Bui et al. 2016; Matarneh and Hamed 2017). These factors can enhance or hinder the successful implementation of BIM, known as CSFs (Enegbuma and Ali 2011). To evaluate and solve challenges of BIM implementation, understanding of current implementation level of BIM in organizations is required (Gomez-sanchez et al. 2016). The idea of identification of CSFs and measuring organization performance has been firstly proposed by Bullen and Rockart in 1981. Since BIM implementation within organization is highly dependent on CSFs, their consideration is essential for proper measurement of BIM within an organization.

Numerous researchers have made efforts to measure the level of organization's engagement with BIM. For the purpose, different models such as bimSCORE, BIM I-CMM, and BIM QuickScan were developed (Berlo et al. 2012; Mccuen et al. 2012). These BIM models provide detailed analysis about BIM maturity level which implies how well an organization uses BIM (Jung and Lee 2015a). Moreover, some indexes were also developed to rapidly measure BIM implementation level which relates to how much an organization uses BIM. These indexes include depth of implementation, the percentage of expert BIM users, years using BIM and BIM adoption rate (SMR, 2007; SMR, 2008). Based on these indexes, SMR (2012) proposed the BIM engagement index to represent the BIM implementation levels. Furthermore, by utilizing these indexes, a study developed BIM charts to visualize and measure the BIM adoption and implementation levels (Jung and Lee 2015a). A worldwide status of BIM adoption and implementation was also reported by (Jung and Lee 2015b) using Technology diffusion model, Hype cycle model, BIM services along with the abovementioned indexes.

It is interesting to note that most of these studies and surveys have been employing similar indexes, for example, level of proficiency, years using BIM and BIM adoption rate (Jung and Lee 2015b). Regardless of the similarities between the indexes used in previously conducted surveys, focus of each survey was primarily on a single country or region at a particular time, concluded specifically for their particular context (Gómez-Sánchez et al. 2016).

This necessitates a need to develop a measurement tool that uses a logical reason for selecting the indexes for measurement of BIM implementation level in an organization by staking a global perspective into account. To overcome this gap, this study opens up with the identification and validation of CSFs for BIM implementation in an organizations by taking the perspective of BIM experts globally. After that set of indexes were developed based on CSFs for the measurement of BIM implementation levels in organizations. On the basis of developed indexes, BIM-Implementation chart (BIMp-Chart) was proposed for measuring overall BIM implementation level of organizations. Finally the applicability of BIMp-Chart was assessed by comparing and analyzing data sets from different organizations. The research outcomes are expected to deliver an improved understanding of BIM implementation fundamentals which will resultantly help construction organizations in defining directions for future development.

1.2 JUSTIFICATION FOR SELECTION OF THE TOPIC

The AEC industry is facing challenges such as time and cost overrun, low quality deliverables and decreased productivity (Matarneh and Hamed 2017). These problems are arising due to the fact that traditional practices are no longer suitable and also due to increased complexity of construction projects (Bryde et al. 2013). Building Information Modeling can be a solution to these problems (Ozorhon and Karahan 2017). Although BIM has proved very beneficial, yet the implementation of BIM in most of the countries is still far from mature (Ghaffarianhoseini et al. 2017). Implementation of BIM is very risky and challenging (Zakaria et al. 2015). Recognition of current implementation level of BIM in organizations is required to solve problems associated with BIM implementation. There is a knowledge gap between practice and theory that lacks systematic analysis on critical success factors of implementing BIM in construction project (Smith 2014). Thus, there is a need to identify critical success factors and to develop a BIMp-Chart that will measure the implementation level of BIM within organizations based on critical success factors and set of indexes. This BIMp-Chart will be helpful for determining the level of implementation of BIM in any organization and also for comparing the growth of BIM within different organizations and improving their level of implementation.

1.3 OBJECTIVES

The research objectives are as follows:

- To identify critical success factors for implementation of BIM within organizations.
- To determine set of indexes against identified critical success factors required for measurement of BIM implementation levels.
- To develop BIMp-Chart based on the set of indexes for measuring overall BIM implementation of organization.
- To access the applicability of BIMp-Chart by comparing and analyzing data sets from different organizations.

1.4 RELEVANCE TO NATIONAL NEEDS

The implementation of BIM is a problem for developed and developing countries, whereas in developed countries their government, technical organizations and institutions are performing great role to implement BIM technology and they have been succeeded to a certain level. The implementation of BIM is a chronic concern for Pakistan. This study will help the Pakistani construction players to better understand the critical success factors for implementation of BIM in order to increase the performance of construction projects. This study will also help to compare the developments of BIM in Pakistan and other countries.

Chapter 2

LITERATURE REVIEW

2.1 CONSTRUCTION INDUSTRY

Owning to the fragmented, uncertain and complicated nature of construction projects, the construction industry is being criticized across the globe mainly due to its inefficiency and disintegrated approach (Arayici et al. 2012). The industry has therefore transform the paradigm to enhance quality, productivity, efficiency and sustainability, and decrease lifecycle cost and delivery time via efficient communication and collaboration between all the stakeholders in construction projects (Azhar 2008; Arayici et al. 2011). Numerous initiatives were undertaken in the industry for the accomplishment of continuous improvement in the way the construction industry operates (Vass and Gustavsson 2017; Ahuja et al. 2018). These range from new contractual/procurement arrangements like partnering, concurrent engineering, and integrated project delivery (Gomez-sanchez et al. 2016), to technological innovations in design and construction processes such as BIM (Han et al. 2008; Azhar 2008; Arayici et al. 2011).

2.2 BIM

BIM has been adopted extensively and promises to yield the desired change for improvement in the construction industry (Jin et al. 2017; Goodrum et al. 2018). The National Institute of Building Sciences defines BIM as “a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward" (National Institute of Building Sciences 2007).

Capabilities of BIM are listed in three stages (Barlish and Sullivan 2012):

i. Object-based modeling
ii. Model-based modeling
iii. Network-based modeling

BIM could be used for many purposes within construction projects including design, modeling, clash detection, cost estimation, scheduling, prefabrication, energy analysis, and facility management. BIM aims at creating more value and enhances collaboration along the supply chain and therefore is closely linked to lean construction, green principles, and integrated project delivery as well (Ghaffarianhoseini et al. 2017). In this respect, BIM goes beyond being just technology but presents a new approach to transform the way the construction industry is doing business. (Ozorhon and Karahan 2017). However, in order to realize the benefits that BIM can offer, there is a need for proper adoption and implementation of BIM at an organizational level (Farzad et al. 2015; Latiffi et al. 2013).

2.3 BIM ADOPTION AND IMPLEMENTATION

Various studies have been performed to investigate the barriers faced by BIM in the AECO sector. Adoption means installing and configuring a new solution, and training staff on how it works so they're able to use it effectively (Wan et al. 2018). Adoption is the decision made to use the innovation by professionals in that organization. Adoption occurs between decision and implementation process (Hosseini et al. 2016).

Implementation means having your entire company embrace that new solution, wrap it into their workflow, and become more effective as the result (Hosseini et al. 2016).

Firms adopt BIM and accordingly implement it on their projects. Figure 2-1 depicts the difference between adoption and implementation.

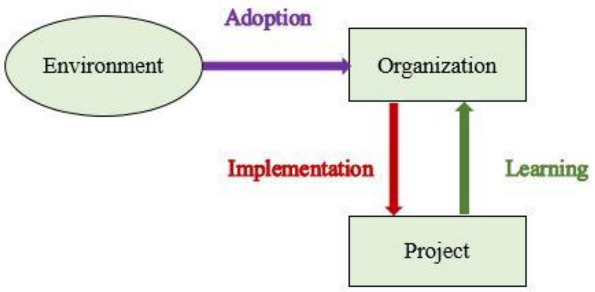


Figure 2-1: BIM adoption and implementation

2.4 CURRENT STATE OF BIM IMPLEMENTATION IN AEC INDUSTRY

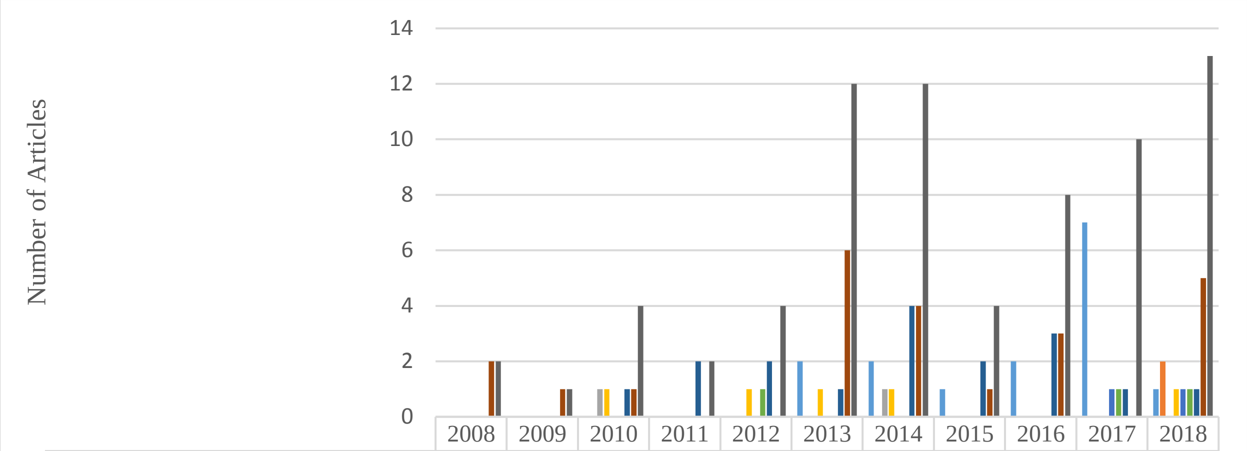
The benefits offered by BIM to the AEC industry are extensively recognized by owners as they are starting to enforce construction companies, construction managers and other design professionals to implement BIM in their projects (Arayici et al. 2011; Jin et al. 2015). As interest in BIM has gained momentum by practitioners, BIM implementation rates have been increasing sharply around the globe (Bernstein et al. 2013). In 2009, BIM has been implemented by almost half of the construction players of North America in their construction projects whereas about 20% of non- BIM user envisioned to implement BIM in their construction projects within two years (Matarneh and Hamed 2017). These digits shows that implementation of BIM has proved beneficial for their projects and BIM can enhance the construction process (Arayici et al. 2011). Despite the fact that BIM in the construction industry is very beneficial for majority of stakeholders, implementation of BIM in projects is still far from mature (Latiffi et al., 2013) because of variety of factors enhance or hinder the implementation of BIM (Ozorhon and Karahan 2017). According to Wan et al. (2018), many firms across the world implement BIM. However, they do not have a clear direction of path they are moving to. Moreover, during the implementation, some firms failed in the successful implementation of BIM and the rest succeeded.

2.5 CSFs FOR BIM IMPLEMENTATION

CSF is defined as "The limited number of areas in which results if they are satisfactory, will ensure successful competitive performance for the organization. They are the few key areas where things must go right for the business to flourish. If results in these areas are not adequate, the organization's efforts for the period will be less than desired" (Jin et al., 2015).

Many researchers attempted to determine the CSFs to BIM implementation. These studies concluded that there are various factors that could affect the successful implementation of BIM. For example, Barlish & Sullivan (2012) mentioned that the largest obstacle in the way of BIM implementation is acknowledgment and enforcement by owners and lack of balanced framework for implementation. Onungwa (2017) highlighted that major challenges of BIM were inadequate infrastructure, lack of skilled workers and insufficient awareness of BIM technology. Ahmad et al (2016) observed that a change in the current practices is required in terms of process and technology to implement BIM effectively. Another study found that BIM implementation is obstructed by inadequate human resources, high initial investment costs, technology resistance and small demand (Kasim et al., 2018). One of the important driver to BIM implementation is government-led initiatives. In USA, the General Services Administration‘s (GSA) standards continue to lead the BIM usage that keeps evolving rapidly (Gomez-sanchez et al., 2016b). Another study suggested that different organizational cultures and company procedures have to be aligned together in a collaborative manner (Ozorhon & Karahan, 2017). Yan & Damian (2008) observed that very few within the AEC industry have an understanding of BIM and its potentials. Training has also been stated as an essential success factor in this context (Zakaria et al., 2013). However, these studies are subjected to particular economies and do not take into account the global perspective of BIM specific personnel.

Based on the previous research regarding BIM implementation, critical success factors have been recognized. For searching the literature, sources like “ASCE”, “Science Direct”, “Google Scholar”, “ICE Virtual library” and “Emerald Insight” etc. were used. Keywords used in the searching process include *BIM, BIM implementation, BIM CSFs, BIM barriers* and *BIM challenges.* As a result, a total of 112 articles published between years 2008-2019 were extracted. This specific period is selected to focus on recent trends in this research domain. For the evaluation, articles were reviewed to make sure that they contain information about critical success factors of BIM implementation. This exercise resulted in the selection of 72 articles for further analysis. The yearly distribution of these articles is shown in Figure 2-2. It can be seen that the number of articles summarily become prominent in the year 2018 representing that the trend has been shifted towards BIM implementation research. It can be observed that American Society of Civil Engineers has the largest number of articles among all the journals.



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
American Society of Civil Engineers	0	0	0	0	0	2	2	1	2	7	1
Journal of Construction Business and Management	0	0	0	0	0	0	0	0	0	0	2
Journal of Computing in Civil and Building Engineering	0	0	1	0	0	0	1	0	0	0	0
Automation in Construction	0	0	1	0	1	1	1	0	0	0	1
International Journal of Construction Management	0	0	0	0	0	0	0	0	0	1	1
Journal of Civil Engineeering and management	0	0	0	0	1	0	0	0	0	1	1
Journals with 1 Relevant Article	0	0	1	2	2	1	4	2	3	1	1
Others	2	1	1	0	0	6	4	1	3	0	5
Total	2	1	4	2	4	12	12	4	8	10	13

Figure 2-2 Trend of published articles

After evaluating the related articles, a graph shown in Figure 2-3 was established to demonstrate the contribution of countries in the field of BIM implementation. This graph was created to identify where BIM implementation research and development is centered. US is found to have the most significant role in the development of research in the body of literature. While countries like India, Spain, Georgia, Finland, Turkey, New Zealand and Israel are deficient in terms of contribution to the body of knowledge.

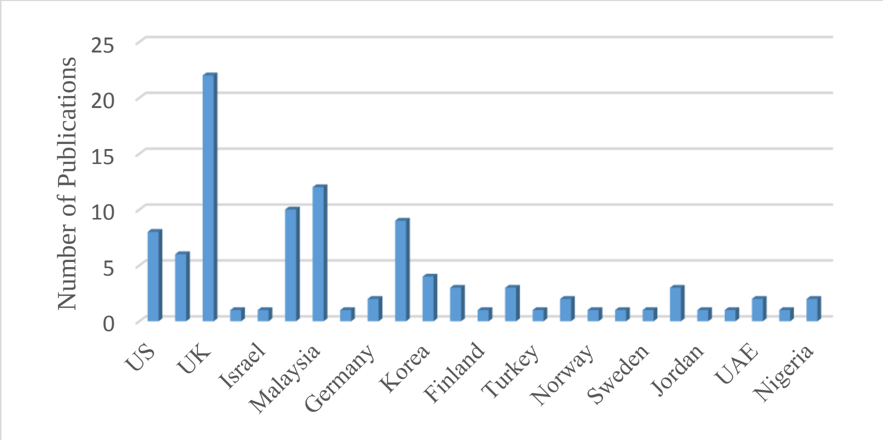


Figure 2-3 Contribution of countries

A total of 63 factors were identified from the literature which were then reduced to 33 factors by merging and renaming some factors that seem to have a similar meaning to avoid repetition. The identified CSFs along with their description are listed in Table 2-1.

To determine the literature score (LR), a two-step content analysis was performed using quantitative and qualitative analysis of identified factors. For quantitative assessment, the relative frequency of appearance in the selected articles was used, whereas the qualitative assessment was done by observing the impact of factors in the views of respective authors and placing them into three impact categories of High, Medium and Low (Bryde et al., 2014). The subjectivity in understanding of results and conclusions of published articles cannot be excluded and consequently, the responsibility is completely assumed by the authors.

Table 2-1: Detail of identified CSFs of BIM implementation

Sr. No.	Factor	Normalized Score	Cumulative Score	Description	Selected Reference
1	Training of employees	0.0845	0.0845	Teaching and learning activities carried out to facilitate the members of an organization on the use of different tools and new processes of BIM.	Abubakar et al. (2014), Chan (2014), Liu et al. (2015), Ozorhon and Karahan (2016), and Mohammad et al. (2018)
2	Financial resources for BIM	0.0445	0.1290	Availability of sufficient budget required for the implementation of BIM within the organization.	Liu et al. (2015), Gomez-sanchez et al. (2016), Jin et al. (2017), Goodrum et al. (2018), and Ahuja et al. (2018)
3	Awareness level about BIM benefits	0.0815	0.2105	Awareness and understanding of the	Latiffi et al. (2013), Zahrizan et al. (2013), Forsythe (2017), Hosseini et al. (2016),

				advantages of BIM at each stage of its process.	Onungwa and Olugu (2017), and Hosseini et al. (2018)
4	BIM expertise	0.0845	0.2950	The availability of skilled and technological experts within the organization implementing BIM.	Latiffi et al. (2014), Chan (2014), Jin et al. (2015), Gomez-sanchez et al. (2016), Bui et al. (2016), and Ozorhon and Karahan (2016)
5	Willingness to change	0.0845	0.3794	Conservativeness of organization to shift from traditional methods and averse comfortable routines.	Gu and London (2010), Gomez-sanchez et al. (2016), Forsythe (2017), Papadonikolaki (2018), and Liao and Teo (2019)
6	BIM vision	0.0519	0.4313	The vision statement of the organization sets the tone for the future of BIM and provides the staff with an outlook of its importance.	Olatunji (2011), Poirier et al. (2015), Vass and Gustavsson (2017), Papadonikolaki (2018), and Liao and Teo (2018)
7	Top management involvement	0.0697	0.5010	Involvement and commitment of	Won et al. (2013), Smith (2014), Ozorhon and Karahan

				organization's top management to expedite the use of BIM.	(2016), Matarneh and Hamed (2017), and Ahuja et al. (2018)
8	Availability of IT resources	0.0282	0.5292	Availability of information and technology necessary for BIM implementation within the organization.	Arayici and Coates (2013), Wang et al. (2013), Ghaffarianhoseini et al. (2017), Xu et al. (2018), and Bhatti et al. (2018)
9	Employer Information Requirement for BIM	0.0282	0.5573	Client's interest and enforcement to use BIM for their projects.	Won et al. (2013), Abubakar et al. (2014), Telaga (2018), and Xu et al. (2018) and Liao and Teo (2019)
10	Government supporting initiatives	0.0726	0.6299	The steps taken by the government to support the implementation of BIM.	Eastman et al. (2010); Latiffi et al. (2013), Zahrizan et al. (2013), and Miettinen and Paavola (2014), and Smith (2014)
11	Legal parameters	0.0237	0.6537	Existence of guidelines on legal issues such as data	Elmualim and Gilder (2014), Smith (2014), Liao and Teo

				sharing, ownership of data, access on BIM platforms, transparency and licensing.	(2017), Ma et al. (2018), Liao and Teo (2018), and Xu et al. (2018)
12	Coordination among project parties	0.0193	0.6729	Existence of collaborative environment between project parties.	Eastman et al. (2010), Barlish and Sullivan (2012), Succar et al. (2012), Shang and Shen (2014), and Lee et al. (2015)
13	Technical supports for interoperability issues	0.0163	0.6892	Existence of technical support for interoperability such as IFC, IDM and etc.	Wong et al. (2009), Olatunji (2011), Memon et al. (2014), Liao and Teo (2017), and Liao and Teo (2018)
14	Organizational structure	0.0771	0.7663	Assignment of new roles and responsibilities to examine and improve the application of BIM.	(Ma et al. 2018; Lam et al. 2017; Gu and London 2010; Papadonikolaki 2017; Xu et al. 2018)
15	Incentives programs from client	0.0133	0.7796	Encouragement by client by giving incentives such as tax reduction etc.	Chan (2014), Gomez-sanchez et al. (2016), Cao et al. (2016),

					and Matarneh and Hamed (2017)
16	Project characteristics	0.0133	0.7930	The aspects of project such as size, budget, location etc.	Gu and London (2010), Won et al. (2013), Cao et al. (2016), Lam et al. (2017), and Mohammad el al. (2018)
17	Information management	0.0089	0.8019	Existence of practical and well-developed strategies for the purposeful exchange of information.	Wong et al. (2009), Eastman et al. (2010), Wang et al. (2013), Morlhon et al. (2014), and Liao and Teo (2017)
18	Experience level within the organization	0.0741	0.8760	Existence of previous experience pertinent to BIM implementation within the organization.	Won et al. (2009), Barlish and Sullivan (2012), Bryde et al. (2013), Zahrizan et al. (2013), and Lam et al. (2017)
19	Knowledge sharing within the industry	0.0089	0.8849	Existence of platforms such as conferences, seminars, workshops etc. to facilitate learning among organizations.	Shang and Shen (2014), Lee et al. (2015), Lee and Yu (2016), Papadonikolaki (2017), and Papadonikolaki (2018)

20	Available capacity building support from Academia/ industry	0.0074	0.8923	Availability of consultancy services from other organizations, universities, etc.	Wang et al. (2013), Ozorhon and Karahan (2016), Cao et al. (2016), Jin et al. (2017), and Garcia et al. (2018)
21	SOP for BIM implementation	0.0074	0.8997	Selection of proper BIM procedures sufficiently fulfilling the needs of the organization.	Azhar (2008), Wong et al. (2009), Matarneh and Hamed (2017), and Ahuja et al. (2018)
22	Time required for training	0.0059	0.9056	Learning time required for the training to implement BIM successfully.	Mohd and Latiffi (2013), Aibinu and Venkatesh (2014), Liu et al. (2015), and Gholizadeh et al. (2018)
23	Risk management	0.0044	0.9101	Management of risks arising when implementing BIM.	Zahrizan et al. (2013), Cao et al. (2016), and Papadonikolaki (2018)
24	Trust	0.0059	0.9160	Collaborative sprit and mutual trust between the members of organization.	Wang et al. (2013), Shang and Shen (2014), and Papadonikolaki (2017)

25	Suppliers using BIM tools	0.0044	0.9205	Lack of understanding among suppliers for using BIM tools	Succar et al. (2012), Miettinen and Paavola (2014), and Gomez-sanchez et al. (2016)
26	Abundant BIM content Libraries	0.0044	0.9249	Availability of BIM Object and Parametric library.	Eastman et al. (2010), Arayici et al. (2012), and Memon et al. (2014)
27	Security concerns	0.0044	0.9293	Issues related to the security of model.	Olatunji (2011), Aibinu and Venkatesh (2014), and Bui et al. (2016)
28	External stakeholders involvement	0.0044	0.9338	External stakeholder's engagement in BIM dynamic and facilitating the transition.	Liao and Teo (2017), Morlhon et al. (2014), and Liao and Teo (2018)
29	Model sharing among disciplines	0.0044	0.9382	Different disciplines sharing models in a "Big Room".	Liu et al. (2015), Liao and Teo (2017), and Liao and Teo (2018)
30	Level of information	0.0030	0.9412	Ability to maintain quality information in the BIM models.	Aibinu and Venkatesh (2014) and Gholizadeh et al. (2018)

31	Size of organization	0.0548	0.9960	Size of organization depending on the number of employees.	Gu and London (2010), Barlish and Sullivan (2012), Latiffi et al. (2013), Eadie et al. (2013), and Hosseini et al. (2016)
32	Continuous Learning	0.0025	0.9985	The concept of learning new skills and knowledge on an ongoing bases exists in organization.	Miettinen and Paavola (2014)
33	Task team member's interest to implement BIM	0.0015	1.0000	Field engineer perceiving the value of implementing their own part of BIM.	Won et al. (2013)

2.6 MEASUREMENT OF BIM IMPLEMENTATION

Various indexes have been used to measure and visualize levels of BIM implementation (Jin et al. 2015). By exploring thorough literature, it was noted that level of involvement, level of proficiency, and years of using BIM are constantly used as indexes for measuring BIM implementation status (SMR 2007; SMR 2008; SMR 2009; SMR 2012; SMR 2014a; SMR, 2014b; Jung and Lee 2015a). These indexes were first developed by the SMR (2008) and have been used in subsequent surveys along with BIM adoption rate. In addition, the technology diffusion model and the hype cycle model were also utilized for the purpose of measuring BIM implementation (Jung and Lee 2015b).

McGraw Hill Construction Research & Analytics has been describing several survey results on the adoption and implementation of BIM in the SmartMarket Report since 2007 (Jung and Lee 2015a). They were the first to introduce BIM adoption rate as one of the measures for BIM adoption and implementation. In 2009, SmartMarket report classified the same into two values i.e. BIM adoption rate for specifically measuring the adoption, and level of involvement for the measurement of BIM implementation (SMR 2009). The BIM adoption rate was aimed at the percentage of respondents that are using BIM while depth of involvement referred to the percentage of projects on which BIM is used (SMR 2007). The level of involvement was categorized into four levels; light use (<16% of projects), moderate use (16– 29%), heavy use (30–59%), and very heavy use (>60%) (SMR 2008). Since 2008, this classification has been utilized in several surveys reporting BIM implementation levels (SMR 2014a; SMR 2014b; Jung and Lee 2015a; Jung and Lee 2015b).

Another index used commonly for the measurement of BIM implementation is years of using BIM (SMR 2007; SMR 2008; Jung and Lee 2015a; Jung and Lee 2015b). This index shows the percentage of BIM users within the target group that have used BIM for more than five years (Jin et al. 2015).

Other models are also available for measuring BIM implementation including Hype cycle model developed by Gartner (Fenn and Raskino 2008) and Technology diffusion model by (Rogers 1983). The hype cycle model is used to measure the potential and maturity of the technology. It comprises of 5 phases; phase 1 and 2 are generally regarded as 'early phase', while phase 3,4 and 5 refers to 'moderate', 'mature' and 'very mature' phases respectively (Jung and Lee 2015b). On the other hand, the technology diffusion model determines the major users of new technology. It also consisted of 5 groups; 'innovators' which are from first 2.5% users, 'early adopters' which are from additional 13.5%, 'early majority' which are from additional 34%, late majority which are from next 34% and laggards which are from additional 16% of all the users.

Jung and Lee (2015a) proposed three different types of BIM charts namely diamond, triangle and ball charts to measure BIM adoption and implementation levels using four types of indexes. Indexes used in their study include BIM adoption rate, years of using BIM, level of proficiency and depth of implementation. These charts were then exercised to report the status of BIM adoption and implementation in three regions; North America, South Korea and Westren Europe. According to results, BIM was found to be most widely adopted and implemented in North America.

Chapter 3

RESEARCH METHODOLOGY

In order to achieve the defined objectives, a comprehensive research methodology comprising three stages was adopted as shown in Figure 3-1. In the first phase, CSFs for BIM implementation were identified from published research followed by two-step content analysis i.e. quantitative and qualitative. 33 factors along with their LS were obtained. These factors were then incorporated into a preliminary survey for obtaining the opinion of BIM experts. After the collection and analysis of data, total score (TS) of each factor was obtained that resulted in the identification of significant CSFs. The next step was the development of indexes on the basis of identified factors for measuring BIM implementation level in organizations through detailed literature review in the subsequent section.

In the second phase, a questionnaire survey was conducted to determine the extent of agreement for the developed indexes from BIM experts. After the collection of responses, data was analyzed and a BIMp-Chart was developed in the third phase followed by its application.

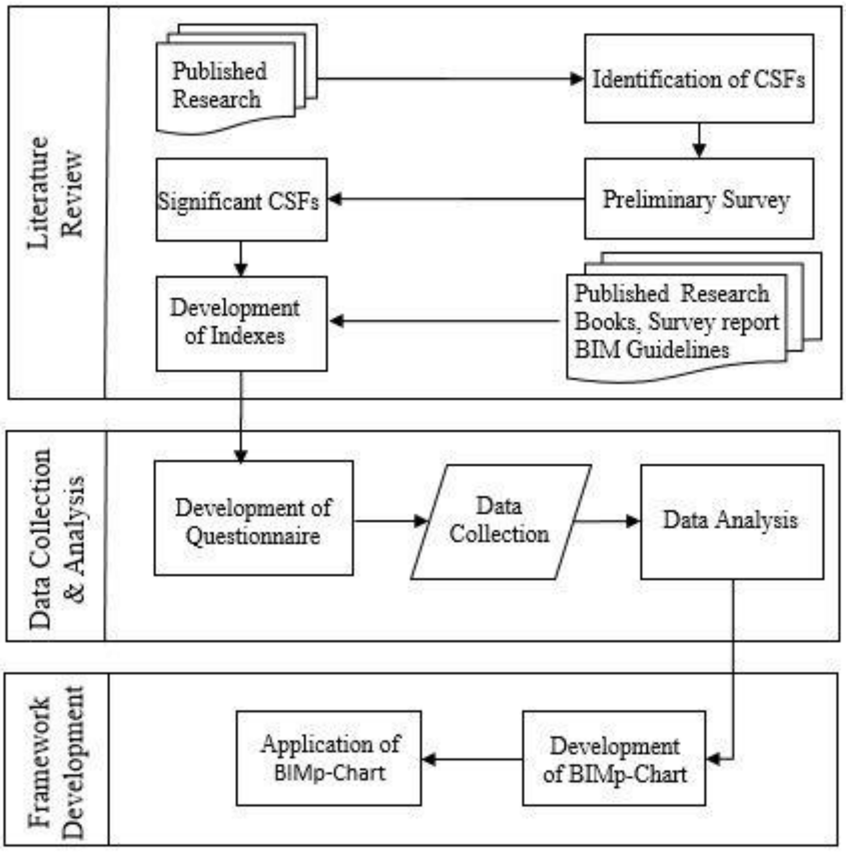


Figure 3-1: Research methodology

3.1 PRELIMINARY SURVEY

An online questionnaire (Appendix B) was used as an instrument to rank the various factors of BIM implementation process. The questionnaire was designed to be simple and direct yet specific. The questionnaire was administered to the BIM experts around the world that are expected to provide input on the practices and views of BIM in the construction industry. Practitioners having more than 3 years of experience in BIM were targeted as it is likely to provide more reliable responses. The questionnaire comprises of two parts: demographics of the respondents; and ranking of CSFs. The respondents were asked to rank the CSFs on the basis of their knowledge and experience on a 1–5 point Likert scale format, where 1 = very low and 5 = very high.

A total of 76 completed questionnaires were received for analysis out of 231 sent out, resulting in 32.9% response rate. The response rate is thought to be satisfactory as it is not lower than 30% (Chan, 2014). BIM experts from 23 countries participated in this survey. The highest number of respondents were from India.

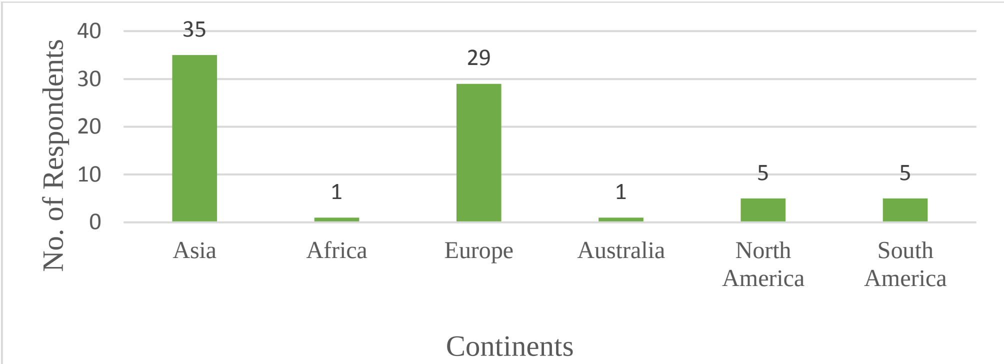


Figure 3-2: Regional distribution of Respondents

The profile of the respondents is presented in Table 3-1. In terms of respondent's role, 38% were BIM managers and 66% of the respondents had over 5 years' BIM experience in the construction industry. In terms of respondent organization, 43% of the respondents belong to consulting firms. In addition, 77% of the respondents work in organizations that had over three years' experience in implementing BIM in their building projects.

Table 3-1: Respondents profile for preliminary survey

Profile	Frequency	Percentage (%)
Role		
BIM Manager	29	38
BIM Specialist	19	25
BIM Coordinator	10	13
Others	18	24
Type of organization		
Consultant	33	43
Designer	17	22
General Contractor	12	16
Sub Contactor	5	7
Supplier	4	5
Client	3	4
Academia	2	3
Years of BIM Experience		
0 to 5	26	34
6 to 10	34	45
11 to 15	11	14
Above 15	5	7
Years of firm BIM experience		
Less than 1	4	5
1 to 3	14	18
4 to 5	21	28
6 to 10	21	28
Above 10	16	21

After collecting data through a questionnaire survey, Cronbach's alpha test was used to check the reliability of the data. The results show the inter-correlation scores was 0.92

which is above the threshold value of 0.7 (Chong et al. 2017). To recognize the current trend of industry on the identified factors, relative importance index (RII) was calculated for each factor. By merging RII with LS, a total score (TS) is calculated for each factor. Giving more value to local experts, weighting split of 60/40 among the survey and literature was used to select major CSFs. Using Pareto analysis, the top 10 factors were obtained on the basis of more than 50% combined significance (Rasul et al. 2019). These factors along with their rank are listed in Table 3-2.

Table 3-2: Ranking of CSFs

Sr #	Factors	60/40	Cumulative
1	Training of employees	0.056183	0.056182526
2	BIM expertise	0.056183	0.112365052
3	Willingness to change	0.056183	0.168547578
4	Awareness level about BIM benefits	0.054997	0.223544334
5	Top management involvement	0.050254	0.273798006
6	Organizational structure	0.04874	0.322538493
7	Experience level within the organization	0.047555	0.37009321
8	Government supporting initiatives	0.046962	0.417055041
9	BIM vision	0.043139	0.460194089
10	Size of organization	0.039847	0.500041295
11	Financial resources for BIM	0.035697	0.535738305
12	Availability of IT resources	0.029175	0.564913574
13	Employer Information Requirement for BIM	0.029175	0.594088844
14	Coordination among project parties	0.025618	0.619706802
15	Model sharing among disciplines	0.024167	0.643873518
16	Level of information	0.023574	0.667447348
17	Project characteristics	0.023246	0.690693764
18	Legal parameters	0.022919	0.713612766
19	Information management	0.021468	0.735080526
20	Knowledge sharing within the industry	0.021468	0.756548286
21	Available capacity building support from Academia/industry	0.020875	0.777423161
22	SOP for BIM implementation	0.020875	0.798298036
23	Time required for training	0.020282	0.818580025
24	Trust	0.020282	0.838862014
25	Technical supports for interoperability issues	0.019955	0.858816589
26	suppliers using BIM tools	0.019689	0.878505693
27	Abundant BIM content Libraries	0.019689	0.898194797

28	External stakeholders involvement	0.019689	0.917883901
29	Continuous learning	0.018899	0.936782491
30	Incentives programs from Client	0.018769	0.955551295
31	Task team member's interest to implement BIM	0.018503	0.974054628
32	Risk management	0.015211	0.98926612
33	Security concerns	0.010734	1

3.2 DEVELOPMENT OF INDEXES

BIM implementation within an organization is highly dependent on CSFs (Bullen and Rockart 1981). Consideration of CSFs is essential for proper measurement of the organization's performance (Bullen and Rockart 1981). Thus, to achieve the objective of developing a BIMp-Chart that measures the BIM implementation level of organizations, indexes were developed for the measurement of shortlisted CSFs. For the purpose, research articles, books and BIM guides were identified. Sources used for searching the research articles include Science Direct, Google Scholar, Emerald Insight etc. with the keywords *BIM, BIM implementation, BIM measurement, BIM training, BIM roles* etc. Initially, a total of 179 articles were retrieved. Abstracts and conclusions of those articles were studies to check if they contain any information regarding shortlisted CSFs. This exercise resulted in the selection of 132 articles. Selected articles were then analyzed in detail to check if they contain any information relevant to the measurement of those CSFs. As a result, irrelevant papers were eliminated resulting in the extraction of 82 papers for further study. On the other hand, 15 survey reports, 7 BIM guides and 5 books sources were also identified for study. Collected data was then studied and analyzed thoroughly to develop the levels of measurement regarding BIM implementation. These developed indexes are discussed in the following section followed by the description of their respective defined levels in Table 3-3.

3.2.1 Training of employees

Due to the unavailability of an index that can measure the training of employees in BIM context, literature was explored wherein discussions of researchers were observed regarding the type of training necessary for successful BIM implementation within organizations. For example, Latiffi et al. (2013) and Smith (2014) mentioned that critical part of education beyond the teaching of concepts and applications of BIM within an organization is concerned with technical training for particular BIM tools. This necessitates both technical education of BIM concepts and features for transitioning from CAD to 3D parametric modeling as well as software training to take advantage of the multiple integration and interoperability benefits that BIM offers (Eastman et al. 2011; Chan, 2014). Vass and Gustavsson (2017) concluded that training on proper model creation, sharing, and integration is critical to enhance BIM implementation in the project. Keeping in view the aforementioned discussion and relevant literature pertaining to the index, the proposed training index is suggested to have *entry*, *foundational*, *intermediate* and *advanced* levels.

3.2.2 BIM expertise

A widely used index, level of proficiency can be used to measure BIM expertise level within an organization. This index has been used by different surveys under different classifications. However, all of them evaluate the level of proficiency by relying on self-evaluation of BIM users about the confidence level of their BIM expertise. This highlights that categorization by users in the given levels was subjective to their own understanding. To overcome this problem, literature related to expertise in BIM was investigated. The research by Arayici and Coates (2013) that defined the levels of staff ability was found helpful in describing the basic levels into which BIM expertise can be classified. To suggest levels according to the requirements of this study into greater detail, four levels were devised namely *beginner, moderate*, *advanced* and *expert*. Two terminologies i.e. primary and secondary BIM services were used in these proposed levels. To avoid any confusion and provide the organizations a clear description of the defined levels, depiction of primary and secondary BIM services as proposed by PSU (unpublished data, 2013) is used. Primary BIM services include existing conditions modeling, cost estimation, phase planning, programming, site analysis, design review, design authoring, energy analysis, 3D coordination, site utilization planning, 3D control and planning, record model, maintenance scheduling, and building system analysis. On the other hand, secondary BIM services relate to structural analysis, lighting analysis, mechanical analysis, other emerging analysis, sustainability analysis, code validation, construction system design, digital fabrication, asset management, space management and disaster planning and management.

3.2.3 Willingness to change

During the literature review, it was observed that the Technology diffusion model can be used for the measurement of willingness to change. For this study, the first two groups (innovator and early adopters) were merged to divide the whole index into 4 uniform levels i.e. *laggards, late majority*, *early majority* and *early adopters*. These levels were based on percentages representing the position of organization's involvement with BIM as compared to other organizations in particular industry.

3.2.4 Awareness level about BIM benefits

Organizations are familiarizing with BIM and evaluating it actively but are primarily focusing on model geometry (Latiffi et al. 2013). Limited organizations recognized the fact that the value of the digital model goes well beyond its geometric representation (Enegbuma and Ali 2011) and has more to do with its information (Wang et al. 2013). Moreover, even a lesser number of them understand the value of good geometric and structured data enriched-models (Khosrowshahi and Arayici 2012). Mark Baldwin (unpublished data, 2019) also provided the basis for defining levels within this index that pertains to perception of an organization about BIM. This resulted in the definition of four levels namely *consideration*, *involvement*, *understanding* and *valuing*, elaborated in Table 3-3.

3.2.5 Top management involvement

The level of involvement developed by SMR (2007) is used by several surveys for measuring the percentage of projects on which BIM is utilized. Literature suggests that top management involvement deals with the approach and commitment of management to expedite BIM within an organization (Ozorhon and Karahan 2016). Hence, level of involvement can be used to measure top management involvement. Four levels namely *light use*, *medium use*, *heavy use* and *very heavy use* were utilized for the subject index as proposed by SMR (2007). The defined levels pertains the application of BIM on a certain percent of projects in an organization.

3.2.6 Organizational structure

The successful implementation of BIM demands the development of new roles (Gómez-Sánchez et al. 2016; ISO 19650-1 2018). Literature in addition to BIM guides such as VA BIM guide (2010), Autodesk (2011), BIM guide (2011), PAS-1192-2 (2013), Singapore BIM guide (2013), QRBG (2015), ISO 19650-1 (2018), and BIM (2019) were consulted to realize the important roles involved in an improved BIM implementation within an organization. Five roles were found to have a vital role in the context. Each role was precisely defined and assigned with its respective responsibility in the referred guidelines and is discussed in the following section.

The model author(s) or the modeler(s) identified as a basic role is a person/team responsible for the creation and maintenance of BIM models (Singapore BIM Guide

2013; Lam et al. 2017). On a leading level, BIM manager is accountable to track and control errors and make responsibilities related decisions. The BIM manager is responsible for the implementation of activities pertaining to security, software, parties' agreement on model access, archiving, information, etc. (Latiffi et al. 2013; Ghaffarianhoseini et al. 2017). BIM implementation also entails a BIM coordinator that reallocates power and decision-making (Zahrizan et al., 2013; Vass and Gustavsson 2017). Moreover, for the organizations doing larger and complex projects on a fast-track basis, the main design technical disciplines (structural, architectural, MEP etc.) have BIM task team managers to synchronize their work with the entire design/construction Team (VA BIM Guide 2010; BIM Guide 2011; PAS-1192-2 2013). Role of information manager is particularly described in the Construction Industry Council BIM protocol (CIC 2013) who is responsible for establishment and management the information procedures, protocols and processes for the project, including other aspects such as the file management, information exchange and common data environment for the project (QRBG 2015). Although this role commonly falls under the category of BIM manager, some guides define it in exclusion (Davies et al. 2017). Considering these roles, organizational hierarchy is developed for each level namely *basic, moderate, mature and very mature.*

3.2.7 Experience level within the organization

Many studies conducted in the domain of BIM evaluate the experience level of respondents on the basis of their years of working with BIM (Khosrowshahi and Arayici 2012; Zahrizan et al. 2013; Jin et al. 2015; Gómez-Sánchez et al. 2016). On this basis, an existing index proposed by SMR (2007) i.e. the percentage of BIM users within the target group who have used BIM for more than five was used to measure the experience level within the organization. For the purpose of the current study, this percentage was divided into 4 levels namely *limited experience, moderate experience, fairly good experience* and *good experience.*

3.2.8 Government supportive initiatives

Recently governments of various countries have started to encourage, specify, or mandate the implementation of BIM in public and private construction projects (Mehran 2016; Liao and Teo 2017; Liao and Teo 2019). However, there are still some economies that lag behind because of no major involvement of their governments (Khosrowshahi and Arayici 2012). Several initiatives were taken by the governments of different countries such as providing BIM training programs, certification, licenses, awareness and motivation programs, giving tax reduction, subsidizing training, software and consultancy (Zahrizan et al. 2014; Yaakob et al. 2016; Liao and Teo 2018). All these initiatives taken by the governments to increase BIM implementation were studied from the published articles. Accordingly, four levels were developed for measuring the government supportive initiatives which include *zero role, basic role, guiding role* and *leading role* with descriptions given in Table 3-3.

3.2.9 BIM vision

For the measurement of 'BIM vision', literature was explored and data was gathered on how organizations define their visions. BIM vision statement is a long term view of the organization (Reddy 2012) that sets the tone for the future of the organizations (Autodesk 2011). Keeping in view, visions of the various organizations using BIM were observed. It was noted that most of the organizations established their vision from the perspective of BIM levels they target. Hence, on the basis of BIM maturity levels, four levels were developed for BIM vision namely *beginner, moderate, advance* and *expert.*

3.2.10 Size of the organization

From the literature, it is observed that construction companies are usually categorized as Micro, Small, Medium and Large (Hosseini et al. 2018). The number of employees in an organization dominates the main criteria used to define businesses (Forsythe 2014). Organizations with 1-4 employees are referred in the studies as micro while those having employees ranging between 5 and 19 are considered as small. Whereas organizations consisting of 20-199 employees are called medium and large are defined to have 200+ employees (Commonwealth 2016; Lam et al. 2017). The literature suggested that larger organizations are in a better position to implement BIM and standardize their business process to optimize it due to larger number of resources and experience available with them (Poirier et al. 2015; Shelton et al. 2016). There is also some evidence suggesting that small and medium-sized organizations are currently lagging behind (Eadie et al. 2013; Liu et al. 2015; Gomez-sanchez et al. 2016; Lam et al. 2017). Considering these facts, four levels for measuring CSF of organizations size were defined as *micro, small, medium* and *large* where micro organizations at the lower level and large organization at the highest level.

Table 3-3: Developed set of indexes

Sr.#	Level Type	Level Description	Reference
		Training of employees	
1	Entry	Introduction to BIM and Technical education on BIM concepts and features.	Eastman et al. (2011), Smith (2014), Masood et al. (2014), and Garcia et al. (2018)
2	Foundational	Hands-on Exercise on basic skills needed for parametric modeling and producing drawings.	Eastman et al. (2011), Arayici et al. (2011b), Arayici et al. (2012) Arayici and Coates (2013), Latiffi et al. (2013), Masood et al. (2014), Chan (2014), Liao and Teo (2017), and Hosseini et al. (2018)
3	Intermediate	Training on how to work in a shared and published information environment (common data environment).	Eastman et al. (2011), Enegbuma and Ali (2011), Arayici et al. (2011b), Arayici et al. (2012) Arayici and Coates (2013), Masood et al. (2014), Chan (2014), Smith (2014), Liao and Teo (2017), and Hosseini et al. (2018)

4	Advanced	Training on the utilization of software tools to apply different dimensions of BIM.	Eastman et al. (2011) and Hosseini et al. (2018)
		BIM expertise	
1	Beginner	Majority of the BIM users in the organization know about primary BIM services but cannot apply them without assistance.	SMR (2012), Arayici and Coates (2013), Masood et al. (2014), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
2	Moderate	Majority of the BIM users in the organization can apply primary BIM services with little supervision but need supervision for the application of secondary BIM services.	SMR (2012), Arayici and Coates (2013), Masood et al. (2014), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
3	Advance	Majority of the BIM users in the organization can apply primary and secondary BIM services without supervision and can apply new on their own.	SMR (2012), Arayici and Coates (2013), Masood et al. (2014), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
4	Expert	Majority of the BIM users in the organization can apply primary and secondary BIM services without	SMR (2012), Arayici and Coates (2013), Masood et al. (2014), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)

		supervision and can create new applications areas with BIM	
		Willingness to change	
1	Laggards	Organization is among the last 16% of the organizations who adopted BIM in a specific country.	Rogers (1983), Rao and Kishore (2010), and Jung and Lee (2015b)
2	Late majority	Organization is among 51 to 84% of the organizations who adopted BIM in a specific country.	Rogers (1983), Rao and Kishore (2010), and Jung and Lee (2015b)
3	Early majority	Organization is among 17 to 50% of the organizations who adopted BIM in a specific country.	Rogers (1983), Rao and Kishore (2010), and Jung and Lee (2015b)
4	Early adopters	Organization is among first 16% of the organizations who adopted BIM in a specific country.	Rogers (1983), Rao and Kishore (2010), and Jung and Lee (2015b)

		Awareness level about BIM benefits	
1	Consideration	Still becoming familiar with the topic, actively evaluating BIM, believing it as useful and are open to explore its potential.	Rogers (1983), Arayici et al. (2011b), SMR (2012), Wang et al. (2013) SMR (2014a), and Lam et al. (2017)
2	Involvement	Focus lies primarily in model geometry. BIM use-cases for people in this group revolve around model creation, visualization, as well as clash detection and other model coordination.	Enegbuma and Ali (2011), Khosrowshahi and Arayici (2012), Latiffi et al. (2013), and Baldwin, unpublished data, (2019)
3	Understanding	Recognized that the value of digital model goes well beyond its geometric representation and has more to do with its information. Understand that well-structured, high quality, data-rich models are the basis of all BIM processes	Enegbuma and Ali (2011), Khosrowshahi and Arayici (2012), Latiffi et al. (2013), Masood et al. (2014), and (Baldwin, unpublished data, (2019)
4	Valuing	Understanding the value of good geometric and structured data enriched-models. However, above all they recognize BIM with process management; that is defining and executing workflows to manage digitally-enabled tasks.	Khosrowshahi and Arayici (2012), Latiffi et al. (2013), and Baldwin, unpublished data, (2019)

		Top management involvement	
1	Light	BIM application on up to 15% of their projects	SMR (2012), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
2	Moderate	BIM application on 15 to 30% of their projects	SMR (2012), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
3	Heavy	BIM application on 31 to 60% of their projects.	SMR (2012), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
4	Very heavy	BIM application on above 60% of their projects.	SMR (2012), SMR (2014a), SMR (2014b), Jung and Lee (2015a), and Jung and Lee (2015b)
		Organizational structure	
1	Basic	BIM manager → Model authors	VA BIM guide (2010), BIM guide (2011), Latiffi et al. (2013), Singapore BIM guide (2013), PAS-1192-2 (2013), Masood et al. (2014), Eadie et al.

			(2015), QRBG (2015), Gómez-Sánchez et al. (2016), Ghaffarianhoseini et al. (2017), Vass and Gustavsson (2017), Davies et al. (2017), Liao and Teo (2019), and BIM (2019)
2	Moderate	BIM manager → BIM coordinator → Model authors	Zahrizan (2013), Singapore BIM guide (2013), PAS-1192-2 (2013), QRBG (2015), Gómez-Sánchez et al. (2016), Vass and Gustavsson (2017), Ghaffarianhoseini et al. (2017), and Davies et al. (2017)
3	Mature	BIM manager → BIM coordinator → Task team managers → Model authors	VA BIM guide (2010), BIM guide (2011), PAS-1192-2 (2013), QRBG (2015), Gómez-Sánchez et al. (2016), Ghaffarianhoseini et al. (2017), and Davies et al. 2017)
4	Very mature	BIM manager → Information manager → BIM coordinator → Task team managers → Model authors	PAS-1192-2 (2013), QRBG (2015), Gómez-Sánchez et al. (2016), and Davies et al. (2017)

	Experience level within the organization		
	Years of using BIM: the percentage of BIM users within the target group who have used BIM for more than five years		SMR (2012), SMR (2014a), SMR 2014b), and Jung and Lee (2015a)
1	Limited	0-25%	
2	Moderate	26-50%	
3	Fairly good	51-75%	
4	Good	76-100%	
	Government supportive initiatives		
1	Zero role	Government does not play any role in supporting the application of BIM.	Liu et al. (2015) and Liao and Teo (2019)
2	General role	Government takes full advantage of their administrative functions and actively participate in BIM promotion process.	Wong et al. (2009), Zahrizan (2013), Latiffi et al. (2013), Smith (2014), Masood et al. (2014), Zahrizan et al. (2014), Liu et al. (2015), Yaakob et al. (2016), Mehran (2016), and Matarneh and Hamed (2017)

3	Guiding role	Government have been supporting the application of BIM through incentive policies.	Zahrizan (2013), Zahrizan et al. (2014), Masood et al. (2014), Liu et al. (2015), Mehran (2016), Liao and Teo (2018); Ahuja et al. 2018, and Liao and Teo (2019)
4	Leading role	Government have been supporting the application of BIM through compulsory policies.	Wong et al. (2009), Khosrowshahi and Arayici (2012), Bryde et al. (2013), Zahrizan (2013), Masood et al. (2014), Mehran (2016), Vass and Gustavsson (2017), Liao and Teo (2017), Matarneh and Hamed (2017), and Liao and Teo (2019)
		BIM vision	
1	Beginner	Basic BIM vision has established.	Autodesk (2011), Ereider et al. (2013), Zahrizan (2013), Masood et al. (2014), Hosseini et al. (2018), Liao and Teo (2018), and Liao and Teo (2019)
2	Moderate	To implement BIM at level 1	Gu and London (2010), Khosrowshahi and Arayici (2012), Zahrizan (2013), Masood et al.

			(2014), Eadie et al. (2015), Hosseini et al. (2018), and Amuda-Yusuf (2018)
3	Advance	To implement BIM at level 2	Gu and London (2010), Khosrowshahi and Arayici (2012), Masood et al. (2014), Eadie et al. (2015), Hosseini et al. (2018), and Amuda-Yusuf (2018)
4	Expert	To implement BIM at level 3	Gu and London (2010), Khosrowshahi and Arayici (2012), Masood et al. (2014), Eadie et al. (2015), Hosseini et al. (2018), and Amuda-Yusuf (2018)
		Company size	
1	Micro	Organization that has 1-4 employees	SMR (2012), Forsythe (2014), Poirier et al. (2015), Liu et al. (2015), Shelton et al. (2016) Commonwealth (2016), and Hosseini et al. (2018)
2	Small	Organization that has 5-19 employees	SMR (2012), Forsythe (2014), Poirier et al. (2015), Liu et al. (2015), Shelton et al. (2016)

			Commonwealth (2016), and Hosseini et al. (2018)
3	Medium	Organization that has 20-199 employees	SMR (2012), Forsythe (2014), Poirier et al. (2015), Liu et al. (2015), Shelton et al. (2016) Commonwealth (2016), and Hosseini et al. (2018)
4	Large	Organization that has more than 200 employees	SMR (2012), Forsythe (2014), Poirier et al. (2015), Liu et al. (2015), Shelton et al. (2016) Commonwealth (2016), and Hosseini et al. (2018)

3.3 DATA COLLECTION

To obtain an expert opinion regarding developed indexes, a global survey was conducted to enhance the representativeness and reliability. The participants of this survey were BIM experts with BIM implementation experience. An online questionnaire (Appendix B) developed in Google Forms® was sent to BIM experts through LinkedIn® and other professional networks. The survey was conducted between the months of August–November 2019. The questionnaire consisted of two major sections; section one comprising the demographic and professional information of participants. Section two consisted of two questions for each index. One was related to the assessment of levels of respective indexes on a 5-point Likert scale. Whereas, second question was related to suggestions for improvement of these indexes.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 DEMOGRAPHIC INFORMATION OF SURVEY RESPONDENTS

Out of 250 questionnaires sent to global target audience, a total of 99 responses were collected from 26 different countries, giving a response rate of 39.6%. This sample size was considered sufficient according to statistics provided by (Dillman et al. 2013). These responses were collected from a range of experienced industry professionals, as presented in Table 4-1. It is apparent from the table that the majority of the respondents were BIM Managers (38%) and BIM Specialists (25%), with 66% of the respondents having more than 5 years of BIM experience. The respondents were mainly working with the consultant (65%), general contractor (16%), subcontractor (7%) and client (4%). Moreover, other respondents (8%) were with academic institutions, suppliers and developers. The majority of the respondents (77%) belong to organizations that have more than 3 years of experience with BIM.

Table 4-1: Respondents profile

Profile	Frequency	Percentage (%)
Role		
BIM manager	29	38
BIM specialist	19	25
BIM coordinator	10	13
Others	18	24
Type of organization		

Consultant	50	65
General contractor	12	16
Sub contactor	5	7
Client	3	4
Other	6	8
Years of BIM experience		
0 to 5	26	34
6 to 10	34	45
11 to 15	11	14
Above 15	5	7
Years of organization BIM experience		
Less than 1	4	5
1 to 3	14	18
4 to 5	21	28
6 to 10	21	28
Above 10	16	21

4.2 DATA ANALYSIS

Cronbach's alpha test was applied to measure the internal consistency of the data. The results show the inter-correlation scores was 0.94. This value implies that the data is highly reliable. For the ease of analysis, results were classified into three categories Agreed, Neutral and Disagree. Table 4-2 shows the results for each level of the defined index. All the levels fall in the category 'Agree' except for the last two levels of Experience level within the organization.

Table 4-2 Analysis of results

Index	Sr.#	Level Type	Agree	Neutral	Disagree	Category
Training of employees	1	Entry	72	17	10	Agree
	2	Foundational	74	13	12	Agree
	3	Intermediate	76	18	5	Agree
	4	Advanced	68	19	12	Agree
BIM expertise	1	Beginner	49	33	17	Agree
	2	Moderate	53	30	16	Agree
	3	Advance	51	26	22	Agree
	4	Expert	47	24	28	Agree
Experience level within the organization	1	Limited	54	22	23	Agree
	2	Moderate	37	39	23	Agree
	3	Fairly Good	37	24	38	Disagree
	4	Good	36	20	43	Disagree

Willingness to change	1	Laggards	42	29	28	Agree
	2	Late Majority	44	26	29	Agree
	3	Early Majority	41	29	29	Agree
	4	Early Adopters	55	26	18	Agree
Awareness level about BIM benefits	1	Consideration	60	27	12	Agree
	2	Involvement	67	21	11	Agree
	3	Understanding	69	25	5	Agree
	4	Valuing	68	24	7	Agree
Top management involvement	1	Light	46	21	32	Agree
	2	Moderate	46	26	27	Agree
	3	Heavy	53	25	21	Agree
	4	Very Heavy	65	14	20	Agree
Company size	1	Micro	43	14	42	Agree
	2	Small	49	18	32	Agree
	3	Medium	61	15	23	Agree
	4	Large	62	12	25	Agree
Government supportive	1	Zero role	44	21	34	Agree
	2	General role	37	27	35	Agree

	3	Guiding role	38	26	35	Agree
	4	Leading role	44	23	32	Agree
BIM vision	1	Beginner	60	25	14	Agree
	2	Moderate	62	25	12	Agree
	3	Advance	69	19	11	Agree
	4	Expert	66	15	18	Agree
Organizational structure	1	Basic	44	27	28	Agree
	2	Moderate	54	29	16	Agree
	3	Mature	57	22	20	Agree
	4	Very mature	52	23	24	Agree

Suggestions given by the respondents were analyzed carefully and 3 BIM Experts having BIM experience of more than 5 years were interviewed regarding modification of experience levels. As explained earlier Experience level within the organization is an existing index that measures the percentage of BIM users within the target group who have used BIM for more than five years. This index has been used in many surveys when measuring BIM implementation in particular countries and regions. Respondents suggested that this index needs to be modified to measure BIM implementation on a smaller scale. In light of suggestions from respondents and interviews from BIM experts, the years of using BIM were reduced from five years to three years in case of measuring BIM implementation at an organizational level.

4.3 DEVELOPMENT OF BIMp-Chart

The concept of BIM chart was first proposed by the research team at Yonsei University in 2012 (Jung and Lee 2015a). Based on the defined indexes, a decagon was developed to measure the overall BIM implementation level as illustrated in Figure 4-1. All 10 indexes were placed at each corner of decagon. The decagon consists of 4 levels with center denotes 0% and each corner designates 100%. The overall BIM implementation level can be signified by calculating the area of the decagon shape against the same standard referred to as the BI-value. The maximum BI-value is 294. Depending on the BIM implementation status, different shapes and values can be obtained. The obtained shapes can help to highlight the areas that need improvements and obtained values can compare overall results. A large decagon represents high BIM implementation levels and a small decagon low levels.

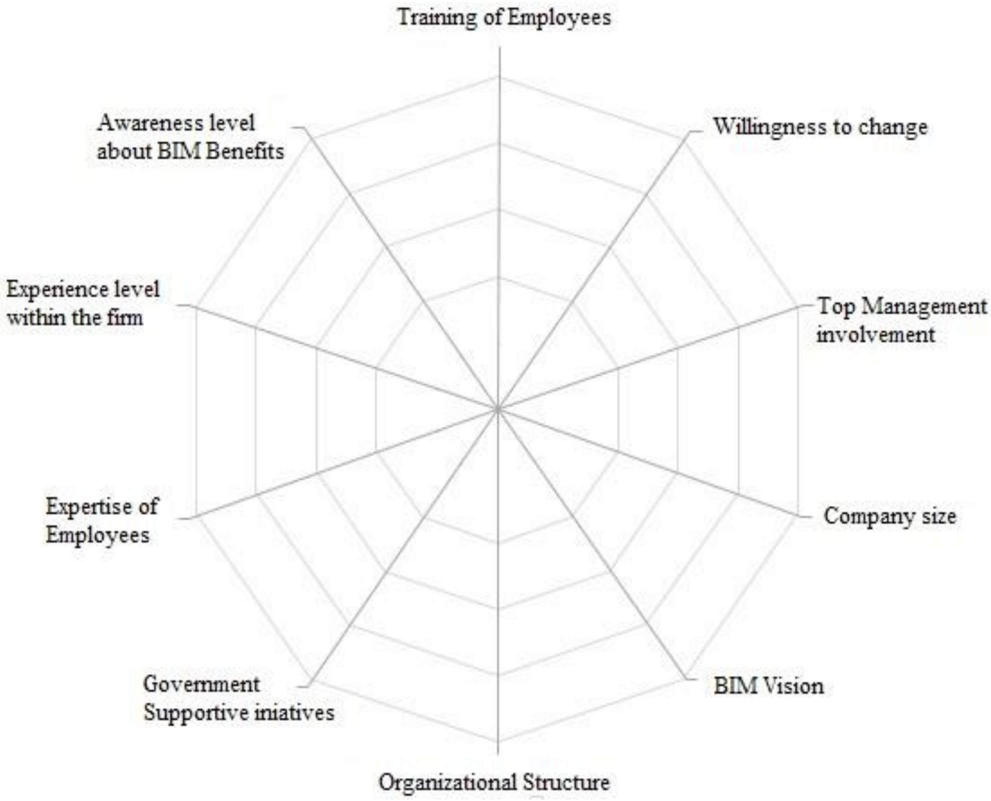


Figure 4-1: Development of BIMp-Chart

4.4 APPLICATION OF BIMp-Chart

To assess the applicability of the developed chart, four organizations from four different regions were interviewed. The demographics details of organizations are shown in Table 4-3.

Table 4-3 Demographics of organizations

Demographics	Organization A	Organization B	Organization C	Organization D
Designation of representative	BIM Manager	BIM Specialist	BIM Coordinator	BIM Manager
BIM experience of interviewee (in years)	6	5	5	8
Country of organization	Qatar	Portugal	Multinational	Egypt
Type of organization	Contractor	Consultant	Consultant	Contractor
Organizations' BIM experience (in years)	6 to 10	1 to 3	4 to 5	4 to 5

All the indexes were discussed in detail with the representatives of organizations and they were asked to select one level from each index according to their organization. Table 4-4 shows the data sets provided by all the four representatives. Four particular shapes were obtained after incorporating the values into the proposed BIMp-Chart. Areas of these shapes were then calculated on AutoCAD and results were analyzed and compared.

Table 4-4: Application of BIMp-Chart

Index	Organization A	Organization B	Organization C	Organization D
Training of employees	Advance	Advance	Advance	Intermediate
Willingness to change	Early majority	Early adopters	Early adopters	Laggards
Top management involvement	Heavy	Very heavy	Very heavy	Moderate
Company size	Large	Small	Medium	Large
BIM vision	Advance	Advance	Advance	Moderate
Organizational structure	Moderate	Basic	Very mature	Mature
Government supportive initiatives	Guiding role	Zero role	Leading role	General role
Expertise of employees	Moderate	Moderate	Expert	Moderate
Experience level within the organization	Fairly good	Limited	Moderate	Moderate
Awareness level about BIM benefits	Understanding	Understanding	Valuing	Involvement

Figure 4-2 represent the shape obtained for organization A. It can be seen that organization A needs more improvement in BIM expertise level and organizational structure. Area obtained for organization A was 160.

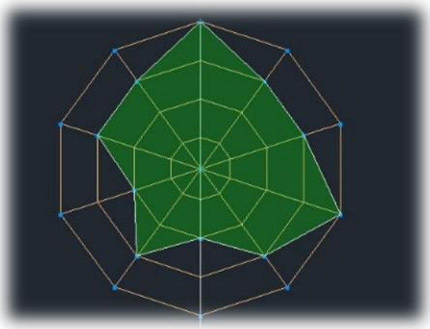


Figure 4-2: BIMp-Chart for Organization A

While for Figure 4-3 which is for organization B, BI- value of 121 was obtained. Few areas in organization B are extremely good but needs to improve number of areas for high BIM implementation.

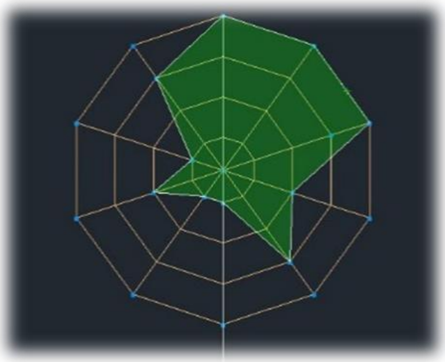


Figure 4-3: BIMp-Chart for Organization B

Similarly, for organization C shape in Figure 4-4 was formed and calculated area was 234. Organization C lacks in terms of experience level within the organization.

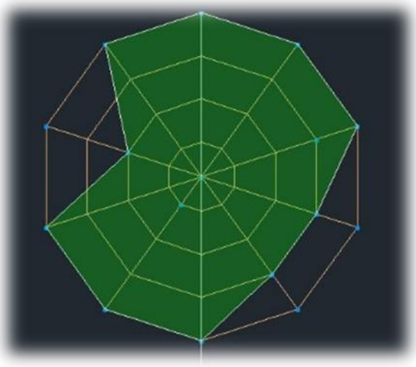


Figure 4-4: BIMp-Chart for Organization C

Finally, Figure 4-5 represents the BIM implementation level of organization D. Although organization D is a large organization but it needs to work on almost all the areas for better BIM implementation within an organization. The area calculated for organization D was 81. After observing all the four shapes and by comparing the calculated areas, it is clear that organization C has the highest BIM implementation level and organization D has the lowest BIM implementation level.

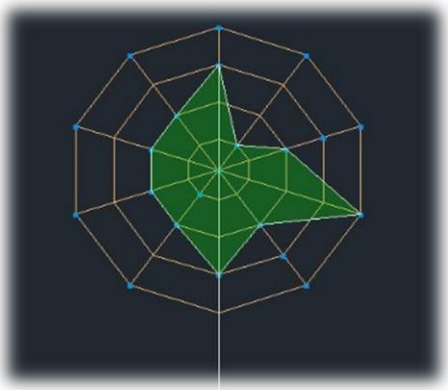


Figure 4-5: BIMp-Chart for Organization D

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

There has been an increasing interest in implementing BIM in construction industry as it saves time of project teams, cost and enhances the quality of the projects through improved coordination, planning and lifecycle management of facilities references. However, BIM implementation is not free of risks and challenges because of many factors. This study highlights the factors that are critical for the successful implementation of BIM through a global perspective which will help to better understand the fundamental elements of the implementation of BIM. After that, literature related to each significant factor was studied thoroughly to develop indexes for the measurement of individual factors. The developed indexes were then validated by taking the perception of industry BIM experts globally. Based on the developed indexes, BIMp-Chart was proposed for the measurement of BIM implementation level within organizations. BIMp-Chart will help the organizations to rapidly visualize BIM implementation levels as simple figures and to compare their current BIM performance with the previous one and with other organizations. The proposed chart can also enable organizations to highlight the areas that need improvements so that they could work out on strategies for successfully implementing BIM. Finally, the test cases were presented to show that BIMp-Chart can provide BIM managers and researchers with a mean to visually and quantitatively compare the different levels of BIM implementation in an organization.

5.2 LIMITATION AND FURTHER RESEARCH

This study discussed literature along with field data gathered from the survey. Further researchers can incorporate detail interviews from field practitioners to get even more realistic results. Future researchers can use BIMp-Chart as basic point to develop more advance tool by also incorporating the interdependencies of factors on each other.

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Appendix A – Questionnaire for CSFs

BIM Implementation Model for organization based on critical success factors and set of indexes.

Dear Respondent,

The aim of this survey is to identify critical success factors (CSFs) for implementation of BIM within organization. This will help understand the current implementation level of BIM in an organization which will ultimately be useful in defining directions for future development.

You are requested to contribute to the survey by selecting the significance of the factors.

In case you have any queries, please feel free to contact.

Regards,
Qurratulain Malik
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School of Civil and Environmental Engineering,
National University of Science & Technology (NUST), Islamabad, Pakistan
Email: malikanna825@gmail.com

*Required

1. **Email address** *

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Personal Information

2. **Your Name:** *

____

3. **Name of your Organization:**

____

4. **Your role/designation in your Organization:** *

____

5. **Country of your Organization:** *

____

6. **Please indicate the type of your Organization:** *
Mark only one oval.

- Designer
- Client
- Consultant
- General Contractor
- Sub Contractor
- Supplier
- Other: ____________________

7. **Please indicate the experience (in years) you have with BIM technology** *
Mark only one oval.

- 0-5
- 6-10
- 11-15
- 16-20
- Above 20

8. **Please indicate the years of BIM implementation in your organization:** *
Mark only one oval.

- 0
- 1-3
- 4-5
- 6-10
- Above 10

Critical Success factors for BIM implementation within organization

9. **The literature identifies critical factors for the implementation of BIM in an organization. Rank the below mentioned factors according to their degree of importance based on your experience and knowledge.** *

Numbers	Equivalent to
1	Very Low
2	Low
3	Medium
4	High
5	Very High

Mark only one oval per row.

	1	2	3	4	5
Training of employees					
Financial resources for BIM					
Awareness level about BIM benefits					
BIM expertise of employees					
Willingness to change					
BIM vision & mission					
Available National BIM standards					
Top management support/ commitment					
Availability of IT resources					
Employer Information Requirement for BIM					
Government supporting initiatives					
Legal parameters					
Supportive organizational culture					
Coordination among project parties					
Technical supports for Interoperability issues					
Organizational structure					
Incentives programs from Client					
Project characteristics					
Information management					
Experience level within the firm					
Knowledge sharing within the industry					
Available capacity building support from Academia/industry					
SOP for BIM implementation					
Time required for training					
Risk management					
Trust					
Suppliers using BIM tools					
Abundant BIM content Libraries					
Security concerns					
External stakeholders involvement					
Model sharing among disciplines					
Level of information					

	1	2	3	4	5
Size of firm					
Continuous learning					
Task team member's interest to implement BIM					

Appendix B – Questionnaire for Indexes

Indexes Questionnaire

Dear Respondent,

The aim of this study is to develop a model that contains set of indexes for the measurement of BIM implementation level within organization. This will help understand the current implementation level of BIM in an organization which will ultimately be useful in defining directions for future development.

Significant Critical success factors (CSFs) for the implementation of BIM were identified with the help of literature score and field score. Indexes are developed for each CSF through detailed literature review. Each section has 2 questions regarding individual index. These indexes contain 4 levels from beginner level to advance level. Description of the levels are given in their respective sections. You are requested to contribute to the survey by giving ranking to each level and providing suggestions for the whole set of index.

In case you have any queries, please feel free to contact.

Regards,
Qurratulain Malik
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School of Civil and Environmental Engineering,
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*Required

Training of Employees

Fours levels (Entry, Foundational, Intermediate, Advance) are given to measure the Training level within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

1. **Entry: Introduction to BIM and Technical education on BIM concepts and features.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

2. **Foundational: Hands-on Exercise on basic skills needed for parametric modeling and producing drawings.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

3. **Intermediate: Training on how to work in a shared and published information environment (common data environment).** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

4. **Advance: Training on the utilization of software tools to apply different dimensions of BIM.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

5. **Any suggestions for the improvement of above mentioned Training levels and their respective descriptions?**

BIM Expertise

Fours levels (Beginner, Moderate, Advance, Expert) are given to measure the BIM Expertise level within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

6. **Beginner: Majority of the BIM users in the organization know about primary BIM services(Existing Conditions Modeling, Cost Estimation, Phase Planning, Programming, Site Analysis, Design Review, Design Authoring, Energy Analysis, 3D Coordination, Site Utilization Planning, 3D Control and Planning, Record Model, Maintenance Scheduling, and Building System Analysis) but cannot apply them without assistance.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

7. **Moderate: Majority of the BIM users in the organization can apply primary BIM services with little supervision but need supervision for the application of secondary BIM services(Structural Analysis, Lightening Analysis, Mechanical Analysis, Other Emerging analysis, Sustainability Analysis, Code Validation, Construction System Design, Digital Fabrication, Asset Management, Space Management and Disaster Planning and management).** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

8. **Advance: Majority of the BIM users in the organization can apply primary and secondary BIM services without supervision and can apply new on their own.** *
Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

9. **Expert: Majority of the BIM users in the organization can apply primary and secondary BIM services without supervision and can create new applications areas with BIM.** *
Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

10. **Any suggestions for the improvement of above mentioned BIM Expertise levels and their respective descriptions?**

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Experience level within the firm

Fours levels (Limited, Moderate, Fairly Good, Good) are given to measure the BIM Experience level within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

11. **Limited: 0-25% of BIM users within the company have used BIM for more than five years** *
Mark only one oval.

	1	2	3	4	5	
Very low	⬭	⬭	⬭	⬭	⬭	Very High

12. **Moderate: 26-50% of BIM users within the company have used BIM for more than five years** *
Mark only one oval.

	1	2	3	4	5	
Very low	⬭	⬭	⬭	⬭	⬭	Very High

13. **Fairly Good: 51-75% of BIM users within the company have used BIM for more than five years** *
Mark only one oval.

	1	2	3	4	5	
Very low	⬭	⬭	⬭	⬭	⬭	Very High

14. **Good: 76-100% of BIM users within the company have used BIM for more than five years** *

Mark only one oval.

	1	2	3	4	5	
Very low	◯	◯	◯	◯	◯	Very High

15. **Any suggestions for the improvement of above mentioned BIM Experience levels and their respective descriptions?**

Willingness to change

Fours levels (Laggards, Late Majority, Early Majority, Early Adopters) are given to measure the Willingness level to change within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

16. **Laggards: Organization is among the last 16% of the organizations who adopted BIM in a specific country.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

17. **Late Majority: Organization is among 51 to 84% of the organizations who adopted BIM in a specific country.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

18. **Early Majority: Organization is among 17 to 50% of the organizations who adopted BIM in a specific country.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

19. **Early Adopters: Organization is among first 16% of the organizations who adopted BIM in a specific country.** *
Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

20. **Any suggestions for the improvement of above mentioned Willingness levels to change and their respective descriptions?**

Awareness level about BIM benefits

Fours levels (Consideration, Involvement, Understanding, Valuing) are given to measure the Awareness level about BIM benefits within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

21. **Consideration: Still becoming familiar with the topic, actively evaluating BIM, believing it as useful and are open to explore its potential.** *
Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

22. **Involvement: Focus lies primarily in model geometry. BIM use-cases for people in this group revolve around model creation, visualization, as well as clash detection and other model coordination.** *
Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

23. **Understanding: Recognized that the value of digital model goes well beyond its geometric representation and has more to do with its information. Understand that well-structured, high quality, data-rich models are the basis of all BIM processes.** *
Mark only one oval.

	1	2	3	4	5	
Very Low	⬭	⬭	⬭	⬭	⬭	Very High

24. **Valuing: Understanding the value of good geometric and structured data enriched-models. However, above all they recognize BIM with process management; that is defining and executing workflows to manage digitally-enabled tasks.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

25. **Any suggestions for the improvement of above mentioned Awareness level about BIM benefits and their respective descriptions?**

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Top Management Involvement

Fours levels (Light, Moderate, Heavy, Very Heavy) are given to measure the Top Management Involvement within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

26. **Light: BIM application on up to 15% of their projects** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

27. **Moderate: BIM application on 15 to 30% of their projects** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

28. **Heavy: BIM application on 31 to 60% of their projects.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

29. **Very Heavy: BIM application on above 60% of their projects.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

30. **Any suggestions for the improvement of above mentioned Top Management Involvement levels and their respective descriptions?**

Company Size

Fours levels (Micro, Small, Medium, Large) are given to measure the Company Size within organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

31. **Micro: Organization that has 1-4 employees.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

32. **Small: Organization that has 5-19 employees.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

33. **Medium: Organization that has 20-199 employees.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

34. **Large: Organization that has more than 200 employees.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

35. **Any suggestions for the improvement of above mentioned Company Size levels and their respective descriptions?**

Government Supportive initiatives

Fours levels (Not Involved, General Role, Guiding Role, Leading Role) are given to measure the Government Support. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

36. **Not Involved: Government does not play any role in supporting the application of BIM.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

37. **General Role: Government takes full advantage of their administrative functions and actively participate in BIM promotion process.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

38. **Guiding Role: Government have been supporting the application of BIM through incentive policies.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

39. **Leading Role: Government have been supporting the application of BIM through compulsory policies.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

40. **Any suggestions for the improvement of above mentioned Government Support levels and their respective descriptions?**

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BIM vision

Fours levels (Entry, Basic, Moderate, Advance) are given to measure the level of BIM vision established by an organization. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

41. **Beginner: Basic BIM vision has established.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

42. **Basic: To work in 2D or three-dimensional (3D) formats to present design through a collaborative tool and a common data environment (CDE).** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

43. **Moderate: To work in fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic).** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

44. **Advance: To work in fully integrated and collaborative real-time project model facilitated by web services.** *

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

45. **Any suggestions for the improvement of above mentioned BIM Vision levels and their respective descriptions?**

46. *Mark only one oval.*

- Option 1

Organizational Structure

Fours levels (Beginner, Moderate, Advance, Expert) are given to measure the Structure of an organization. Each level contains the organizational tree. Rank the below mentioned description of each level according to their degree of accuracy based on your experience and knowledge.

47. **Beginner: BIM Manager → Model Authors** *

Mark only one oval.

	1	2	3	4	5	
Very Low						Very High

48. **Moderate: BIM Manager → BIM Coordinator → Model Authors** *

Mark only one oval.

	1	2	3	4	5	
Very Low						Very High

49. **Advance: BIM Manager → BIM Coordinator → Task Team Managers → Model Authors** *

Mark only one oval.

	1	2	3	4	5	
Very Low						Very High

50. **Expert: BIM Manager → Information Manager → BIM Coordinator → Task Team Managers → Model Authors** *

Mark only one oval.

	1	2	3	4	5	
Very Low						Very High

51. **Any suggestions for the improvement of above mentioned Organizational Structure levels and their respective descriptions?** *

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