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BIMp-Chart—A Global Decision Support System for Measuring BIM Implementation Level in Construction Organizations

Qurratulain Malik [1], Abdur Rehman Nasir [1], Rabiah Muhammad [1], Muhammad Jamaluddin Thaheem [2], Fahim Ullah [3,*], Khurram Iqbal Ahmad Khan [1] and Muhammad Usman Hassan [1]

[1] Department of Construction Engineering and Management, School of Civil and Environmental Engineering (SCEE), National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan; qurratulainmalik@nit.nust.edu.pk (Q.M.); abdur.nasir@nit.nust.edu.pk (A.R.N.); rabiahmuhammad@nit.nust.edu.pk (R.M.); khurramiqbal@nit.nust.edu.pk (K.I.A.K.); usman.hassan@nice.nust.edu.pk (M.U.H.)

[2] Geelong Waterfront Campus, School of Architecture and Built Environment, Locked Bag 20001, Deakin University, Geelong, VIC 3220, Australia; jamal.thaheem@deakin.edu.au

[3] School of Civil Engineering and Surveying, University of Southern Queensland, Springfield, QLD 4300, Australia

* Correspondence: fahim.ullah@usq.edu.au

Abstract: Building Information Modeling (BIM) is recognized as one of the most significant technological breakthroughs in the Architecture, Engineering, and Construction (AEC) industry. The pace of implementation of BIM in AEC has increased during the past decade with an enhanced focus on sustainable construction. However, BIM implementation lags its potential because of several factors such as readiness issues, lack of previous experience in BIM, and lack of market demand for BIM. To evaluate and solve these issues, understanding the current BIM implementation in construction organizations is required. Motivated by this need, the main objective of this study is to propose a tool for the measurement of BIM implementation levels within an organization. Various sets of indexes are developed based on their pertinent Critical Success Factors (CSFs). A detailed literature review followed by a questionnaire survey involving 99 respondents is conducted, and results are analyzed to formulate a BIMp-Chart to calculate and visualize the BIM implementation level of an organization. Subsequently, the applicability of the BIMp-Chart is assessed by comparing and analyzing datasets of four organizations from different regions, including Qatar, Portugal, and Egypt, and a multinational organization to develop a global measurement tool. Through measuring and comparing BIM implementation levels, the BIMp-Chart can help the practitioners identify the implementation areas in an organization for proper BIM implementation. This study helps understand the fundamental elements of BIM implementation and provides a decision support system for construction organizations to devise proper strategies for the effectual management of the BIM implementation process.

Keywords: building information modeling (BIM); BIM implementation; critical success factors (CSFs); indexes; construction organization

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Citation: Malik, Q.; Nasir, A.R.; Muhammad, R.; Thaheem, M.J.; Ullah, F.; Khan, K.I.A.; Hassan, M.U. BIMp-Chart—A Global Decision Support System for Measuring BIM Implementation Level in Construction Organizations. *Sustainability* **2021**, *13*, 9270. https://doi.org/10.3390/su13169270

Academic Editors: Ana Blanco Álvarez, Francesc Pardo Bosch and Pablo Pujadas Álvarez

Received: 18 June 2021
Accepted: 17 August 2021
Published: 18 August 2021

1. Introduction

Due to its complicated and innovative projects, the construction industry is globally regarded as fragmented, uncertain, and complicated [1,2]. To overcome the problems and associated risks, numerous initiatives were launched to realize continuous improvement [3]. These efforts range from the adoption of new contractual/procurement arrangements such as partnering, concurrent engineering, and integrated project delivery to technological innovations in design and construction processes such as building information modeling (BIM) [4–7]. BIM is a digital representation of a facility's physical/functional characteristics that serves as a shared knowledge resource used for reliable decision-making during the life cycle [5]. BIM is adopted extensively in construction as it incorporates the technical aspects, knowledge disciplines, and implementation systems of a facility in a shared representation and virtual models as defined by ISO. It allows all team members to communicate, collaborate, visualize, and manage construction work better to ensure successful project delivery [8]. BIM allows superimposition of multi-disciplinary information in a virtual model, thus creating an opportunity to address sustainability measures and execute performance analyses from the planning to the operation stages [9]. These benefits of BIM, recognized by owners, persuade construction firms, construction managers, and other design professionals to implement it in their projects for sustainable construction [10].

BIM implementation rates have sharply increased around the developed economies [11]. A survey conducted between 2007–2012 in North America shows that BIM usage has increased from 28% in 2007 to 71% in 2012 [12]. In the UK, the BIM implementation rate was 13% in 2011 which grew to be 69% in 2019 [13]. Similarly, BIM implementation in Germany has reached up to 90% [14]. Furthermore, plenty of research has been conducted to explore the benefits of BIM implementation. By analyzing data from multiple construction companies, Yan and Demian [15] concluded that BIM implementation on construction projects leads to massive cost reduction and significant time-saving in the design and construction and during the operation phase. To investigate the benefits of practical BIM implementation, Azhar et al. [5] reviewed the case studies of two real projects. They indicated that BIM implementation provides significant time and cost savings on a construction project through early detection of clashes and enhanced design coordination. Similarly, Arayici et al. [16] analyzed the data of a construction firm to investigate the effects of BIM implementation in its projects and indicated that enhanced collaboration between team members and clash detection are major advantages through BIM, which contribute to time and cost savings and achieving a better quality of the project. Another study concluded that BIM implementation improves sustainability in the Indonesian construction industry [17]. This implies that the implementation of BIM is beneficial for the projects to enhance construction processes and sustainability.

Although BIM implementation is rising, its usage within construction organizations is highly dependent on many critical success factors (CSFs), such as government-led initiatives, support from leadership, unavailability of technological and financial resources, and availability of BIM expertise [3,13,18,19]. These CSFs can enhance or hinder the successful implementation of BIM in construction [18]. However, these present implementation challenges in BIM implementation in construction organizations lead to certain organizations backing off or being reluctant to adopt and implement BIM. The trend is more evident in developing countries or organizations with limited budgets and resources in developed countries such as small and medium-sized enterprises [13]. To evaluate and solve BIM implementation challenges, understanding its current implementation levels in construction organizations is essential [14]. Since BIM implementation is highly dependent on CSFs, their consideration is essential for the proper measurement of BIM within construction organizations.

Numerous researchers have attempted to measure the level of an organization's engagement with BIM. For this purpose, various BIM models have been developed. These models provide a detailed analysis of the BIM maturity level within the organization [20]. Moreover, some indexes were also developed to measure the BIM implementation level. These include depth of BIM implementation, expert users′ percentage, usage experience, and adoption rates [21]. McGraw-Hill Construction [12] proposed the BIM engagement index to represent its implementation levels based on these indexes. Furthermore, a study developed BIM charts to visualize and measure its adoption and implementation levels [20].

The worldwide status of BIM adoption and implementation was also reported using the technology diffusion model [22], hype cycle model [23,24], BIM services [25], and the indexes mentioned above [26]. Most of these studies and surveys have employed similar indexes such as proficiency, years of using BIM, and its adoption rate [1,16,18]. Regardless of the similarities between the indexes used in previously conducted surveys, the focus of each survey was primarily on a single country or region at a particular time, concluded specifically for their particular context. These studies and surveys about specific regions might not provide much assistance to construction organizations located out of the studied zones. Further, due to the contextualized nature of the construction industries, some indexes might be inapplicable on a wider or global scale. This limitation necessitates a study to develop a measurement tool that uses a logical reason for selecting the indexes for measuring the BIM implementation level in a construction organization by taking a global perspective instead of restricting it to a locality or region. Such a study will allow the construction practitioners and researchers to compare and assess the BIM implementation level of multiple organizations according to a global scale rather than contextualizing it to a locality and struggling with another locality or region.

To overcome this limitation, this study adopts four main objectives: (1) to identify and validate CSFs for BIM implementation in construction organizations by capturing global BIM experts perspective, (2) to establish a set of indexes based on CSFs for the measurement of BIM implementation levels in different construction organizations, (3) to develop a BIM implementation chart based on the established indexes, and (4) to assess the applicability of the proposed implementation chart by comparing and analyzing datasets from different global organizations. The research outcomes are expected to deliver an improved global decision support system for BIM implementation that can help construction organizations define directions for future development regardless of their location or region.

2. Literature Review

Several studies have been conducted to measure the level of an organization's involvement with BIM [18,20,27,28]. Different models such as bimSCORE [24], BIM I-CMM [25], and BIM QuickScan [26] have been developed to facilitate the measurement of such involvement [25]. A summary of these models is provided in Table 1. These BIM models provide a detailed analysis of its maturity level, corresponding to the dexterity of its organizational use [20].

Table 1. Previously developed models for measuring BIM involvement in organizations.

Sr.	Model	Methodology/Overview/Purpose	Outcome	Limitations
1	bimSCORE	bimSCORE acts like a "GPS Navigator" for any enterprise or project team charting a course for BIM. This online questionnaire assists project teams and enterprises in optimizing the value of BIM in four areas: Planning, Adoption, Technology, and Performance.	Provides an analysis of the BIM maturity level within the construction organization.	Very complex and require over 200 variables to function.
2	BIM I-CMM	BIM I-CMM is an interactive version of the static excel maturity matrix originally created by NIBS to evaluate information management maturity on a scale in 11 different categories. The tool's primary purpose was to show how well BIM demonstrated the disparate stakeholders of a facility collaborated through their information management practices.	Provides an analysis of the BIM maturity level within the construction organization.	Same as above
3	BIM QuickScan	BIM Quickscan consists of an online questionnaire with almost 50 questions in 4 chapters (also called "categories"): Organization and Management; Mentality and Culture; Information structure and Information flow; Tools and Applications.	It provides insight into the current BIM performance and maturity of a construction organization.	Same as above

Table 1. *Cont.*

Sr.	Model	Methodology/Overview/Purpose	Outcome	Limitations
4	BIM Engagement Index	BIM Engagement index quantifies the user's engagement with BIM with a numerical score. The score is derived using three types of indexes: Experience, Expertise, and Implementation.	Measure the level of construction organization's engagement with BIM.	Use a similar set of commonly available variables that do not cover all the critical areas of an organization.
5	Slim BIM Charts	Slim BIM charts, namely diamond, triangle, and ball charts, measure BIM adoption and implementation levels using four types of indexes: BIM adoption rate, years of using BIM, level of proficiency, and depth of implementation.	Measure the level of BIM adoption and implementation within the construction organization.	Same as above

Moreover, various indexes have also been developed to measure the levels of BIM implementation that correspond to BIM usage levels in an organization [20]. By exploring the published literature, it was noted that the level of involvement, level of proficiency, and years of using BIM is regularly used indexes for measuring BIM implementation [20,23,24]. These indexes were first developed by Jung and Lee [24] for the measurement of BIM adoption and implementation in construction organizations. These have been used in subsequent surveys along with the BIM adoption rate. The technology diffusion model and the hype cycle model were utilized to measure BIM implementation [26].

McGraw-Hill Construction Research & Analytics has described several survey results on adopting and implementing BIM in the SmartMarket Report since 2007 [24]. They were the first to introduce the BIM adoption rate as one of the BIM adoption and implementation measures. In 2009, the SmartMarket report classified the same into two values, i.e., BIM adoption rate for measuring the adoption and the level of involvement for the measurement of BIM implementation [20,24]. The BIM adoption rate was aimed at the percentage of respondents using BIM, while the depth of involvement referred to the percentage of BIM projects. 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%) [20]. Since 2008, this classification has been utilized in several surveys reporting BIM implementation levels [20,26].

Another index commonly used to measure BIM implementation is years of using BIM [20,24,26]. This index shows the percentage of BIM users within the target group that has used BIM for more than five years [8]. McGraw-Hill Construction [12] proposed the BIM engagement index to represent the BIM implementation levels based on these indexes. Other models are also available for measuring BIM implementation. These include the hype cycle model [23] and the technology diffusion model contextualized to BIM [29]. The hype cycle model is used to measure the potential and maturity of the technology, BIM in this case. It comprises five phases: phases 1 and 2 are generally regarded as "early phase", while phases 3,4, and 5 refer to "moderate", "mature", and "very mature" phases, respectively [26]. On the other hand, the technology diffusion model determines the major users of new technology (BIM). It also consists of five groups: "innovators" or the first 2.5% users, "early adopters" or the additional 13.5%, "early majority" or the additional 34% (first 50%), "late majority" or the next 34% (initial 84%) and "laggards" or the last 16% of all the users.

Jung and Lee [24] proposed three types of BIM charts, namely diamond, triangle, and ball charts, to measure BIM adoption and implementation levels using four types of indexes. These include BIM adoption rate, years of using BIM, level of proficiency, and depth of implementation. These charts were then exercised to report BIM adoption and implementation in North America, South Korea, and Western Europe. According to the results, BIM was most widely adopted and implemented in North America compared to the other two regions.

The analysis of the relevant studies revealed that these developed models still lack the required efficiency. Models such as bimSCORE, BIM I-CMM, and BIM QuickScan are very complex and require over 200 variables to function [24]. Furthermore, BIM Engagement Index [12] and Slim BIM charts [24] were developed to measure BIM adoption and implementation levels, ease the process using fewer variables, and relatively simple calculation methods. However, these models use a similar set of commonly available variables that do not cover all the critical areas of an organization. None of these studies shortlisted the critical variables that need to be addressed and then develop indexes around them covering all the key aspects of BIM implementation in an organization.

Hence, there is a need for a tool that can measure BIM implementation levels based on a critical set of variables by using indexes covering all the key aspects of BIM implementation rather than only using commonly available indexes. The research team first proposed the concept of a BIM chart related to BIM implementation at Yonsei University in 2012 [20,24]. The main objective of these charts was to visualize and quantify levels of BIM adoption and implementation rapidly. Similarly, the BIMp-Chart in this study, implying BIM-Implementation Chart, is proposed to help measure the overall BIM implementation level in an organization, aiming to make the procedure easier and achieve more accurate results. This chart will also help organizations to compare their BIM implementation level with other organizations. This comparison will boost the organizations to improve their implementation level and achieve maximum benefits from BIM through proper implementation.

3. Materials and Methods

A comprehensive research methodology comprising three qualitative stages was adopted to achieve the defined objectives, as shown in Figure 1.

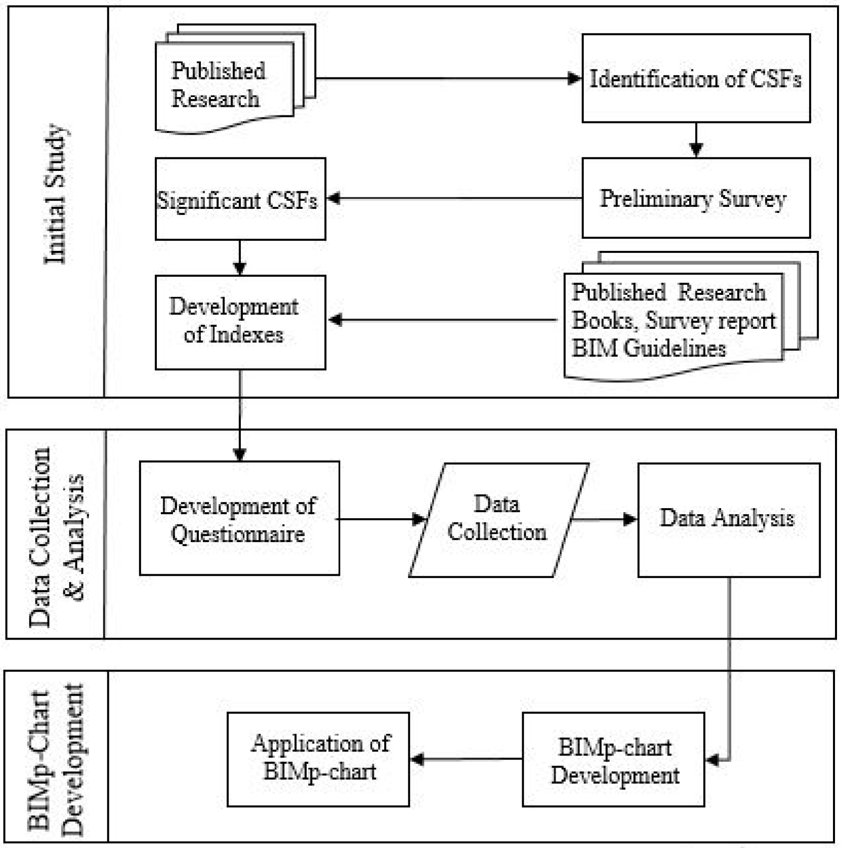


Figure 1. Flowchart of research methodology.

In the first phase, CSFs for BIM implementation were identified by a thorough literature review of 72 systematically retrieved papers. A preliminary survey was then conducted to highlight the significant CSFs by incorporating the opinions of BIM experts. The next step was developing indexes based on shortlisted CSFs identified for measuring BIM implementation level in organizations through a detailed literature review in the subsequent section.

In the second phase, indexes developed from the past research were incorporated into the second online questionnaire survey. This second survey—the main for this study—aimed to determine the extent of agreement for the developed indexes from global BIM experts. In the third and final phase, the collected data were analyzed to develop a BIM implementation chart, followed by its application and pertinent discussions.

3.1. Identification of CSFs for BIM Implementation

Many studies have highlighted critical factors that affect the successful implementation of BIM in construction. However, previous studies were mainly subjected to particular regions or economies and did not consider the global perspective. Moreover, it is also observed that BIM has better adoption and implementation in industrially developed economies than in developing countries. Furthermore, the existing factors are mostly identified and tailored for developed countries and cannot be implemented in developing economies due to contextual and logistic reasons. This warrants a new and customized identification of CSFs for BIM implementation by incorporating the global perspective. However, since the technical vigor and robustness cannot be compromised, experts from both the developing and developed parts of the globe must come together to inform and advise in identifying unified CSFs for BIM implementation.

3.1.1. Review and Synthesis of Existing Research

Based on the previous research regarding BIM implementation, critical success factors have been recognized from published literature. For searching the literature, Web of Science and Scopus repositories were used as shown in Table 2. Keywords used in the searching process include “BIM”, “BIM implementation”, “BIM CSFs”, “BIM barriers”, and “BIM challenges”. These keywords were used in conjunction with the word “construction” and joined by Boolean operators AND or to formulate the search strings. These keywords were searched for in the title, abstract, and keywords of the articles to be retrieved by the search engines of Scopus and Web of Science. Further, the search areas were restricted to social science and engineering only and further refined to civil and construction engineering only to retrieve construction-focused articles. The document type was restricted to journal articles only as these are considered high-quality literature as claimed by Qayyum et al. [6] and Ullah et al. [7]. These resulted in 262 articles containing 142 from Scopus and 120 from the Web of Science. A total of 108 duplicates were found where both repositories indexed these articles and hence counted once. Further, 37 articles were found to have a non-construction focus when the articles were read in detail thus these were also removed.

As a result, a total of 115 articles published between the years 2010–2021 were extracted. This specific period is selected to focus on recent trends in this research domain. For the evaluation, articles were reviewed to ensure that they contain information about critical success factors of BIM implementation. This exercise resulted in a focused selection of 74 articles for further analysis. Sixty-three factors were retrieved from the literature and were reduced to 33 factors by merging and renaming some factors that appear to have a similar meaning to avoid repetition.

These systematically identified CSFs from the literature, along with their description, are listed in Table 3. Similar review and literature retrieval method has been adopted in recent review studies [6,28,30–32].

Table 2. Literature retrieval.

Sr.	Search Engine	Search Strings	Count
1	Scopus	(TITLE-ABS-KEY (bim) OR TITLE-ABS-KEY (bim AND implementation) OR TITLE-ABS-KEY (bim AND csfs) OR TITLE-ABS-KEY (bim AND barriers) OR TITLE-ABS-KEY (bim AND challenges) AND TITLE-ABS-KEY (construction))	7262
		AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "DECI"))	4830
		AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j"))	1166
		AND PUBYEAR < 2011	142
2	Web of Science	You searched for: TOPIC: (BIM) OR TOPIC: (BIM implementation) OR TOPIC: (BIM CSFs) OR TOPIC: (BIM barriers) OR TOPIC: (BIM challenges) AND TOPIC: (Construction)	11,315
		Timespan: 2010–2021. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.	3173
		Categories: (Engineering Civil OR Construction Building Technology)	1907
		Types: (Article)	1786
		AND Languages: (English)	1140
		AND Research Areas: (Construction Building Technology) AND Web of Science Index: (WOS.SSCI)	120
		Total	262
		Duplicates	108
		Non-Construction Focus	37
		Final Articles	115
		CSFS for BIM Implementation Focused Articles	74

Table 3. Identified CSFs.

Sr.	Factor	Normalized Literature Score	Description	Selected Reference
1	Training of employees	0.0845	Teaching and learning activities are carried out to facilitate the members of the organization on the use of different tools and new processes of BIM.	[1,33,34]
2	Financial resources for BIM	0.0445	Availability of sufficient budget required for the implementation of BIM within the organization.	[3,35,36]
3	Awareness level about BIM benefits	0.0815	Awareness and understanding of the advantages of BIM at each stage of its process.	[37,38]
4	BIM expertise	0.0845	The availability of skilled and technological experts within the organization implementing BIM.	[8,34,35]
5	Willingness to change	0.0845	The conservativeness of organization to shift from traditional methods and averse comfortable routines.	[37,39,40]
6	BIM vision	0.0519	The vision statement of the organization sets the tone for the future of BIM and provides the staff with an outlook of its importance.	[39,41,42]
7	Top management involvement	0.0697	Involvement and commitment of the organization's top management to expedite the use of BIM.	[3,11,42]
8	Availability of IT resources	0.0282	Availability of information and technology necessary for BIM implementation within the organization.	[43,44]
9	Employer Information Requirement for BIM	0.0282	Client's interest and enforcement to use BIM for their projects.	[1,45]

Table 3. *Cont.*

Sr.	Factor	Normalized Literature Score	Description	Selected Reference
10	Government supporting initiatives	0.0726	The steps taken by the government to support the implementation of BIM.	[11,46,47]
11	Legal parameters	0.0237	Existence of guidelines on legal issues such as data sharing, ownership of data, access to BIM platforms, transparency, and licensing.	[11,48,49]
12	Coordination among project parties	0.0193	Existence of collaborative environment between project parties.	[50–52]
13	Technical supports for interoperability issues	0.0163	Existence of technical support for interoperability such as IFC, IDM, etc.	[49,53,54]
14	Organizational structure	0.0771	Assignment of new roles and responsibilities to examine and improve the application of BIM.	[40,55]
15	Incentives programs from client	0.0133	Encouragement by the client by giving incentives such as tax reduction etc.	[34,50,55]
16	Project characteristics	0.0133	The aspects of the project such as size, budget, location, etc.	[33,40]
17	Information management	0.0089	Existence of practical and well-developed strategies for the purposeful exchange of information.	[43,49]
18	Experience level within the organization	0.0741	Existence of previous experience pertinent to BIM implementation within the organization.	[40,52,56]
19	Knowledge sharing within the industry	0.0089	Existence of platforms such as conferences, seminars, workshops, etc. to facilitate learning among organizations.	[39,50,55]
20	Available capacity building support from Academia/industry	0.0074	Availability of consultancy services from other organizations, universities, etc.	[8,10,43]
21	SOP for BIM implementation	0.0074	Selection of proper BIM procedures sufficiently fulfilling the needs of the organization.	[3,5,54]
22	Time required for training	0.0059	Learning time required for the training to implement BIM successfully.	[19,35,57]
23	Risk management	0.0044	Management of risks arising when implementing BIM.	[42,48,58]
24	Trust	0.0059	Collaborative spirit and mutual trust between the members of the organization.	[43,55]
25	Suppliers using BIM tools	0.0044	Lack of understanding among suppliers for using BIM tools	[39,42,51]
26	Abundant BIM content Libraries	0.0044	Availability of BIM Object and Parametric library.	[53,59]
27	Security concerns	0.0044	Issues related to the security of the model e.g., unauthorized access, e-documents are still vulnerable to viruses, hacking	[60,61]
28	External stakeholders' involvement	0.0044	External stakeholder's engagement in BIM dynamic and facilitating the transition.	[49,62]
29	Model sharing among disciplines	0.0044	Different disciplines sharing models in a "Big Room".	[49,63]
30	Level of information	0.0030	Ability to maintain quality information in the BIM models.	[35,64]
31	Size of organization	0.0548	Size of an organization depending on the number of employees.	[40,52,65]
32	Continuous Learning	0.0025	The concept of learning new skills and knowledge on an ongoing basis exists in the organization.	[66,67]
33	Task team member's interest to implement BIM	0.0015	Field engineers perceiving the value of implementing their part of BIM.	[68–70]

To determine the Literature Score (LS), 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. In comparison, the qualitative assessment was carried out by observing the impact of factors in the views of respective researchers for placing them into three impact categories of High, Medium, and Low [50,56,71]. The LS of each factor was then converted into normalized score using Equation (1) [72].

$$Normalized\ Score = \frac{score\ of\ individual\ factor}{sum\ of\ score\ of\ all\ factors} \tag{1}$$

For example, consider the normalized score for the factor "Training of employees" from Table 1. The individual score for this factor is 0.4750 and the sum of scores for all factors is 5.6222, thus, the normalized score for this factor will be as follows.

$$0.4750/5.6222 = 0.0845$$

Using the same approach, normalized scores are calculated for all factors. This is conducted to check the extent of influence of CSFs, concerning the total number of responses. However, the subjectivity in understanding results and conclusions of published articles cannot be excluded, and consequently, the responsibility is completely assumed by the authors of this paper.

3.1.2. Preliminary Survey

After shortlisting 33 CSFs, an online questionnaire survey was conducted to rate the identified CSFs based on their importance towards BIM Implementation. For this purpose, worldwide BIM experts were contacted. Experts were located firstly through online searching of the construction companies implementing BIM and looking at their BIM experts from the company profile. Such BIM experts were contacted through official email. Secondly, BIM experts were also identified through the LinkedIn platform and contacted subsequently using both convenient sampling and snowballing approaches of sampling. The questionnaire was administered to the BIM experts worldwide who were requested to provide input on the practices and views of BIM in the construction industry. Practitioners having more than three years of experience in BIM were targeted for more reliable responses. The respondents were asked to assign scores to the CSFs based on their knowledge and experience on a 5-point Likert scale. A total of 76 completed questionnaires were received for analysis out of 231 sent out, resulting in a 32.9% response rate. The response rate is satisfactory as it is not lower than 30% [34]. These experts hail from different countries, including China (13), USA (12), UK (9), Pakistan (8), Qatar (7), Canada (7), Australia (6), Portugal (4), Egypt (4), Jordan (3), and others (3).

Afterward, the reliability of the collected data was checked through Cronbach's alpha test. The results show the inter-correlation score of 0.92, above the threshold value of 0.7 [73]. To recognize the current industry trend on the identified CSFs, the relative importance index (RII) was calculated using the formula given in Equation (2) for each factor, where I is impact assigned to each factor, n is the sample size, and H is the highest impact. RII was then normalized in reference to Equation (1).

$$RII = \sum In \times H \tag{2}$$

By merging normalized RII with normalized LS, a Total Score (TS) through Equation (3) was calculated for each factor [74]. Giving more value to industry experts, a weighting split of 60/40 ratio was used to calculate TS using Equation (3), wherein 60 percent weightage was assigned to the field survey scores and 40 percent to the literature scores to develop the final rankings of CSFs.

$$TS = (0.6 \times normalised\ RII) + (0.4 \times normalised\ LS) \tag{3}$$

The cumulative scores (CS) were then calculated for the factors using Equation (4). Based on more than 50% cumulative scores, the top 10 factors listed in Table 4 were attained by following the method adopted by Amuda-Yusuf [75].

$$CS = TS\ of\ individual\ factor + sum\ of\ its\ predecessors \tag{4}$$

Table 4. 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

3.2. Development of Indexes

BIM implementation within an organization is highly dependent on pertinent CSFs [48,64,75]. To achieve the objective of gauging the BIM implementation level in construction organizations, indexes were developed to measure shortlisted CSFs. For this purpose, on the one hand, research articles, books, and BIM guides were searched using keywords such as BIM, BIM implementation, BIM measurement, BIM training, BIM roles, etc. While on the other hand, 15 survey reports, 7 BIM guides, and 5 books were also identified for the study from the same sources as previously mentioned in the factor identification section. Initially, a total of 179 articles were retrieved. Abstracts and conclusions of the retrieved articles were studied to check if they contain any information regarding shortlisted CSFs. This exercise resulted in the selection of 132 articles. These articles were 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 shortlisting of 82 papers for further study. Data from survey reports, BIM guides, and books were studied and analyzed thoroughly to develop measurement levels regarding BIM implementation in construction organizations. The next step was to conduct a worldwide survey targeting BIM experts. There were two main goals of the survey: first, to validate the developed indexes and second, to acquire suggestions for improving indexes.

Initially, the study aimed at categorizing all the indexes into equal numbers of levels to avoid complications in measurement. Most of the indexes in previous studies were divided into four levels for measurement. For example, the construction companies are defined under four categories, level of proficiency, level of involvement, and under BIM maturity, all comprise four levels [35]. Therefore, this study also divided each index into four levels for the measurement of each critical factor. These indexes and descriptions of their respective defined levels are subsequently discussed and presented in Table 5.

3.2.1. Training of Employees

Due to the unavailability of an index that can measure the training of employees in the BIM context, literature was explored wherein discussions of researchers were observed regarding the type of training necessary for successful BIM implementation within construction organizations. For example, Smith [11] and Azhar et al. [5] mentioned that a critical part of education beyond the teaching of concepts and BIM applications 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. Further software training is required to fully leverage multiple integrations and interoperability benefits that BIM offers [34]. Vass and Gustavsson [76] concluded that proper model creation training, sharing, and integration are critical to enhancing BIM implementation in a project. This signifies the need for training at all employment levels: entry, foundational, intermediate, and advanced. Considering the discussion above and relevant literature about 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 and proficiency level can be used to measure BIM expertise levels within an organization. Different surveys have used this index under different classifications. However, all of them evaluate the level of proficiency by relying on the self-evaluation of BIM users about the confidence level of their BIM expertise. This highlights that categorization by users in the given levels is subjective to their understanding. To overcome this problem, literature related to expertise in BIM was investigated. The research by Wang et al. [63], which defines staff ability levels, described 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: 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 with a clear description of the defined levels, the depiction of primary and secondary BIM services proposed by Khosrowshahi and Arayici [77] is used. Accordingly, 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 are related to structural analysis, lightning 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 could 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 four uniform levels, i.e., laggards (last 16%, i.e., 85–100), late majority (51–84%), early majority (16–49%), and early adopters (first 15%). These levels were based on percentages representing the early involvement of an organization with BIM compared to other organizations in a particular industry.

3.2.4. Awareness Level about BIM Benefits

Many organizations are familiar with BIM and evaluate it actively but primarily focus on model geometry [35]. Limited organizations recognize that the value of the digital model goes well beyond its geometric representation and has more to do with its information [43]. Moreover, even fewer of them understand the value of good geometric and structured data-enriched models [78]. ISO [79] provided the basis for defining levels within this index that pertains to the perception of an organization about BIM. This resulted in the definition of four levels considered in the current study: *consideration*, *involvement*, *understanding*, and *valuing*, elaborated in Table 5.

3.2.5. Top Management Involvement

Several surveys use the level of involvement developed by McGraw-Hill Construction [21] 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 [80]. Therefore, this particular index was used to measure the involvement of management in BIM. Four levels, *namely light use*, *medium use*, *heavy use*, and *very heavy use*, were utilized for the subject index as proposed by

McGraw-Hill Construction [21]. The defined levels pertain to the application of BIM on a certain percentage of projects within an organization.

3.2.6. Organization's Structure

The successful implementation of BIM demands the development of new roles [27,43,48]. Literature and BIM guides such as Joseph [81], McArthur and Sun [82], NBS [83], McArthur and Sun [82], Kensek [84], and others 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 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 [40]. On a leading level, the BIM manager is accountable for tracking and controlling errors and making responsibilities-related decisions. The BIM manager is responsible for implementing activities of security, software, parties' agreement on model access, archiving, information, etc. [44]. BIM implementation also entails a BIM coordinator that reallocates power and decision-making [76]. Moreover, for the organizations undertaking larger and complex projects on a fast-track basis, the main technical design disciplines (structural, architectural, MEP, etc.) have BIM task team managers to synchronize their work with the entire design/construction team [58,79,83]. The role of information manager is particularly described in the Construction Industry Council BIM protocol, which is responsible for establishing and managing the information procedures, protocols, and processes for the project, including other aspects such as file management, information exchange, and common data environment for the project [85]. Although this role commonly falls under the BIM manager category, some guides define it in exclusion [86]. Considering these roles, organizational hierarchy is developed for each level: *basic, moderate, mature* and *seasoned,* as presented in Table 5.

3.2.7. Experience Level within the Organization

Many studies conducted in the BIM domain evaluate respondents′ experience level based on their years of working with BIM [8,10]. On this basis, an existing index proposed by McGraw-Hill Construction [12], i.e., the percentage of BIM users within the target group who have used BIM for more than five years, was used to measure the experience level within the organization. This percentage was divided into four levels for the current study: limited experience, moderate experience, fairly good experience, and good experience, as presented in Table 5.

3.2.8. Government Supportive Initiatives

Recently, governments of various countries have started to encourage, specify, or mandate BIM implementation in construction projects [49]. However, some laggard groups still exist because of no major involvement of their governments [85]. Several initiatives were taken by the governments of different countries, such as providing BIM training programs, certification, licenses, awareness and motivation programs, tax reduction, subsidizing training, software, and consultancy [39,42,87]. These initiatives to increase BIM implementation were studied from the published articles. Accordingly, four levels were developed to measure the supportive government initiatives, including zero role, basic role, guiding role, and leading role, with descriptions given in Table 5.

3.2.9. BIM Vision

To measure BIM vision, literature was explored, and data were gathered on how organizations define their vision. BIM vision statement is a long-term view of the organization that sets the tone for the future of the organization [88,89]. Keeping this in view, the visions of the various organizations using BIM were studied. It was noted that most organizations established their vision from the perspective of BIM levels they target. Based on BIM maturity levels, four levels were developed for BIM vision: beginner, moderate, advanced, and expert. These levels are defined in Table 5.

Table 5. Set of indexes.

Sr.	Level Type	Level Description	Selected Reference
		Training of employees	
1	Entry	Introduction to BIM and Technical education on BIM concepts and features.	[11,90]
2	Foundational	Hands-on Exercise on basic skills needed for parametric modeling and producing drawings.	[34,35,90]
3	Intermediate	Training on how to work in a shared and published information environment (common data environment).	[11,43,90]
4	Advanced	Training on the utilization of software tools to apply different dimensions of BIM.	[35,37,43]
		BIM expertise	
1	Beginner	Majority of the BIM users in the organization know about primary BIM services but cannot apply them without assistance.	[12,20,24,63]
2	Moderate	Majority of the BIM users in the organization can apply primary BIM services with little supervision but need supervision to apply secondary BIM services.	[12,20,24,63]
3	Advanced	Majority of the BIM users in the organization can apply primary and secondary BIM services without supervision and can apply new on their own.	[12,20,24,63]
4	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.	[12,20,24,63]
		Willingness to change	
1	Laggards	Organization is among the last 16% of the organizations that adopted BIM in a specific country.	[26,29,59]
2	Late majority	Organization is among 51 to 84% of the organizations that adopted BIM in a specific country.	[26,29,59]
3	Early majority	Organization is among 17 to 50% of the organizations that adopted BIM in a specific country.	[26,29,59]
4	Early adopters	Organization is among the first 16% of the organizations that adopted BIM in a specific country.	[26,29,59]
		Awareness level about BIM benefits	
1	Consideration	Still becoming familiar with the topic, actively evaluating BIM, believing it as useful, and exploring its potential.	[12,29,43]
2	Involvement	Focus lies primarily in model geometry. BIM use-cases for people in this group revolve around model creation, visualization, clash detection, and other model coordination.	[38,78,91]
3	Understanding	Recognized that the value of the 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.	[38,78,90,91]
4	Valuing	Understanding the value of good geometric and structured data enriched models. However, above all, they recognize BIM with process management, defining and executing workflows to manage digitally-enabled tasks.	[38,78,90,91]

Table 5. *Cont.*

Sr.	Level Type	Level Description	Selected Reference
		Top management involvement	
1	Light	BIM application on up to 15% of their projects	[20,21,26]
2	Moderate	BIM application on 15 to 30% of their projects	[20,21,26]
3	Heavy	BIM application on 31 to 60% of their projects.	[20,21,26]
4	Very heavy	BIM application on above 60% of their projects.	[20,21,26]
		Organizational structure	
1	Basic	BIM manager → Model authors	[78,86]
2	Moderate	BIM manager → BIM coordinator → Model authors	[78,86]
3	Mature	BIM manager → BIM coordinator → Task team managers → Model authors	[78,86]
4	Seasoned	BIM manager → Information manager → BIM coordinator → Task team managers → Model authors	[78,86]
		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	
1	Limited	0–25%	[12,20,21,24]
2	Moderate	26–50%	[12,20,21,24]
3	Fairly good	51–75%	[12,20,21,24]
4	Good	76–100%	[12,20,21,24]
		Government supportive initiatives	
1	Zero role	Government does not play any role in supporting the application of BIM.	[36,38,87]
2	General role	Government takes full advantage of their administrative functions and actively participate in BIM promotion process.	[36,38,87]
3	Guiding role	Government has been supporting the application of BIM through incentive policies.	[36,38,87]
4	Leading role	Government has been supporting the application of BIM through compulsory policies.	[36,38,87]
		BIM vision	
1	Beginner	A Basic BIM vision has been established.	[35,58,90]
2	Moderate	To implement BIM at level 1.	[35,58,90]
3	Advanced	To implement BIM at level 2.	[35,58,90]
4	Expert	To implement BIM at level 3.	[35,58,90]
		Company size	
1	Micro	1–4 employees.	[12,36,37,39,50]
2	Small	5–19 employees.	[12,36,37,39,50]
3	Medium	20–199 employees.	[12,36,37,39,50]
4	Large	More than 200 employees.	[12,36,37,39,50]

3.2.10. Size of the Organization

The literature observes that construction companies are usually categorized as Micro, Small, Medium, and Large, mainly based on their number of employees [35,37]. The literature suggests that larger organizations are better positioned to implement BIM and standardize their business process to optimize it due to a larger number of resources and experience available with them [39,42]. There is also some evidence suggesting that small and medium-sized organizations lag behind BIM implementation [40,65]. Considering these facts, four levels for measuring CSF of an organization's size were micro, small, medium, and large, where micro-organizations are at the lower level and large organizations at the highest level, as presented in Table 5.

4. Results and Discussion

For validating the developed indexes from field experts, the main survey of this paper was conducted globally to enhance representativeness and reliability. The participants of this survey were BIM experts having a BIM implementation experience of more than three years. An online questionnaire developed in Google Forms® was sent to experts through LinkedIn® and other professional networks. The survey was conducted between August 2020 and March 2021. The questionnaire consisted of two major sections: (i) the demographics and professional information of respondents and (ii) two questions for each developed index. The first question was related to the assessment of levels for respective indexes on a five-point Likert scale. In comparison, the second question was related to suggestions for improvement of these indexes.

Out of 250 questionnaires sent to a 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. [92] and Gerges et al. [93]. These responses were collected from a range of experienced BIM professionals, as presented in Table 6. It is apparent from Table 6 that most of the respondents were BIM managers (38%) and BIM specialists (25%), with 66% of the respondents having more than five years of BIM experience. The respondents were mainly working with consultants (65%), general contractors (16%), subcontractors (7%), and clients (4%). Moreover, other respondents (8%) were representing academic institutions, suppliers, and developers. The majority of the respondents (77%) belonged to organizations with more than three years of experience with BIM, enhancing the maturity of the gathered data.

Table 6. Demographics of Respondents.

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

The next step was the analysis of the gathered data. Cronbach's alpha test was applied to measure the internal consistency of the data. The results show the inter-correlation scores of 0.94, which implies the data to be highly reliable. For ease of analysis, results were classified into three categories, i.e., agree, neutral, and disagree. This was carried out by merging the five-point Likert-scale categories of strongly agree and agree into a singular category, i.e., agree, and a similar approach was followed to merge the categories of disagreement. Table 7 shows the results for each level of the defined index. All the levels fall in the agreement category except for the last two levels of one index, i.e., experience level within the organization. The reason for this is the criticism by a majority of respondents. The respondents believe that no organization can fulfill the criteria in levels 3 and 4 of this index as BIM is a relatively new technology, and there are no organizations with 100% of employees with more than five years of BIM experience. Rather, there are few BIM experts in the majority of the organization. Thus, this scale warranted revision by reducing the number of years of the required experience.

Table 7. 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	Advanced	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 initiatives	1	Not involved	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	Advanced	69	19	11	Agree
	4	Expert	66	15	18	Agree
Organizational structure	1	Beginner	44	27	28	Agree
	2	Moderate	54	29	16	Agree
	3	Mature	57	22	20	Agree
	4	Seasoned	52	23	24	Agree

The suggestions provided by the respondents were analyzed carefully, wherein the main proposition relates to the need to address the experience level within the organization. To address the obtained suggestions, three BIM experts having BIM experience of more than five years were interviewed. The BIM experts suggested that the index needs modification to measure BIM implementation on a smaller scale. In light of suggestions from respondents of the main survey and interviews from BIM experts, the years of using BIM were reduced from five to three to measure BIM implementation at an organizational level since BIM is a new technology and to gain experience with time [93]. Hence, the revised levels of limited experience, moderate experience, fairly good experience, and good experience were based on the percentage of BIM users within the target group who used BIM for more than three years instead of previously set five years.

4.1. BIMp-Chart Development

A decagon shape, as shown in Figure 2a, is anticipated for the visualization of BIMp-Chart. As illustrated in Figure 2b, all ten indexes are placed at the corners of a decagon. The decagon consists of four levels, with the center denoting 0%, whereas the corners designating 100% implementation (fourth level) of a respective index, making each level 25% weightage. After identifying the levels of all the ten individual indexes for an organization, respective points are to be marked on a decagon for each index. The obtained points will be connected through a straight line, resulting in an irregular closed shape. The overall BIM implementation level can be represented by calculating the formed shape area within a decagon referred to as the BIMp-value.

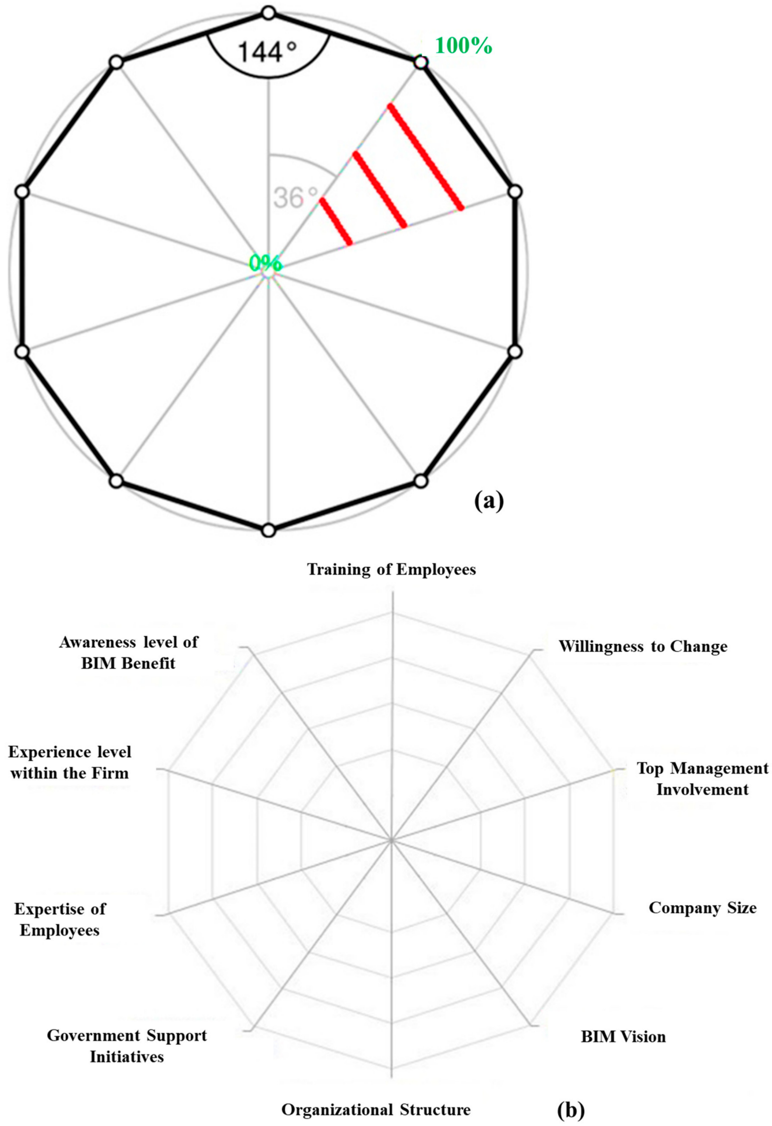
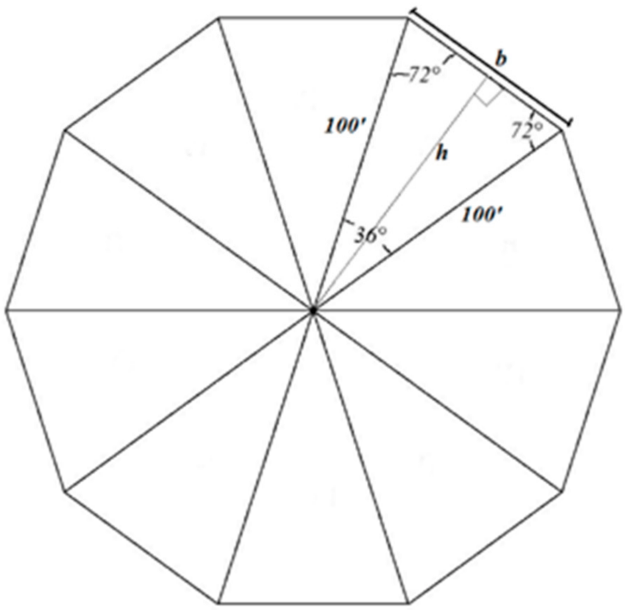


Figure 2. Visualization of proposed BIMp-Chart (**a**) decagon repesenting area through levels, (**b**) 10 indexes placed among vertices.

The maximum BIMp-value that an organization can obtain is 294 by calculating the decagon area envisaged by Jung and Lee [20], as shown in Figure 3. Depending on the BIM implementation status within the organizations, different shapes and values can be obtained. The obtained shapes can help highlight the areas that need improvements, whereas the obtained values can become useful in comparing the overall results either with previous records or other organizations.



$$h = \sin(72°) \times 100 = 95.10$$

$$b = 2 \times \sqrt{(100)^2 - (h)^2} = 61.8$$

$$\text{Area of Decagon} = 10 \times \left(\frac{1}{2} bh\right) = 294$$

Figure 3. BIMp-chart value calculation.

4.2. Application of BIMp-Chart

To assess the applicability of the developed BIMp-Chart, representatives of four organizations from four different regions were interviewed. These include Qatar, Portugal, Egypt, and a multinational respondent. The demographics details of organizations are given in Table 8.

Table 8. Demographics of representatives.

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
Organization's 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 who were asked to select a singular level instance from each index according to their organization. Table 9 shows the datasets provided by representatives. Table highlights that the experience level within organizations and employees′ expertise is on the low side due to BIM being a new technological development in the market. It is refreshing to note that three out of four organizations fell into the advanced category as the indexes of "BIM vision" and "training of employees" show a high level of top management involvement. All of this shows the interest and enthusiasm of organizations to progress and achieve high levels in BIM implementation. Four different shapes were obtained after incorporating the values into the proposed BIMp-Chart. Areas of these shapes were then calculated, and results were analyzed and compared.

Table 9. Application of framework.

Index	Organization A	Organization B	Organization C	Organization D
Training of employees	Advanced	Advanced	Advanced	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	Advanced	Advanced	Advanced	Moderate
Organizational structure	Moderate	Basic	Seasoned	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

BIMp value calculations for Organization C are illustrated in Table 10. After inserting the data of Organization C, different types of triangles are achieved in the decagon. These include five triangles of type 1, two triangles of type 2, one triangle of type 3, and two triangles of type 4. The sum of areas of all triangles will indicate the total BIMp value for Organization C.

Table 10. BIMp-value calculation for Organization C.

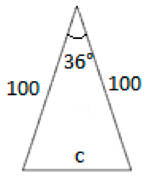
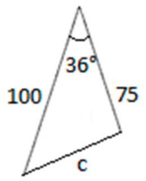
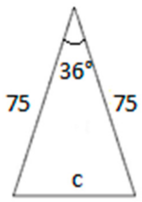
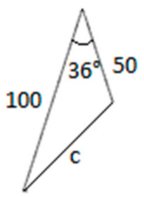
Type	Triangles	a	b	$c = \sqrt{a^2+b^2-2ab(\cos 36°)}$	$s = \frac{a+b+c}{2}$	$A = \sqrt{s\times(s-a)\times(s-b)\times(s-c)}$
1		100	100	62	131	2941
2		100	75	58	116	2100
3		75	75	46	98	1641
4		100	50	66	108	1450
Total Area = [(5 × 2941) + (2 × 2941) + 1641 + (2 × 1450)]/100 = 234						

Figure 4, developed using CAD software, represents the shapes obtained for organizations after incorporating index values. It can be observed that Organization A, with a BIMp-value of 160, needs more improvement in BIM expertise and organizational structure. For Organization B, the BIMp-value of 121 represents that few areas in Organization B are extremely good but need improvement in the number of areas for high BIM implementation. Similarly, the area calculated for Organization C resulted in 234. This shows that the organization lacks in terms of experience level within the organization. Finally, the area calculated for Organization D came out to be 81. Although Organization D is a large organization, it is evident that it needs improvement in almost all the indexes for better BIM implementation within the organization. After observing all the four shapes and comparing the calculated areas, it is visually and quantitatively observed that Organization C has the highest BIM implementation level.

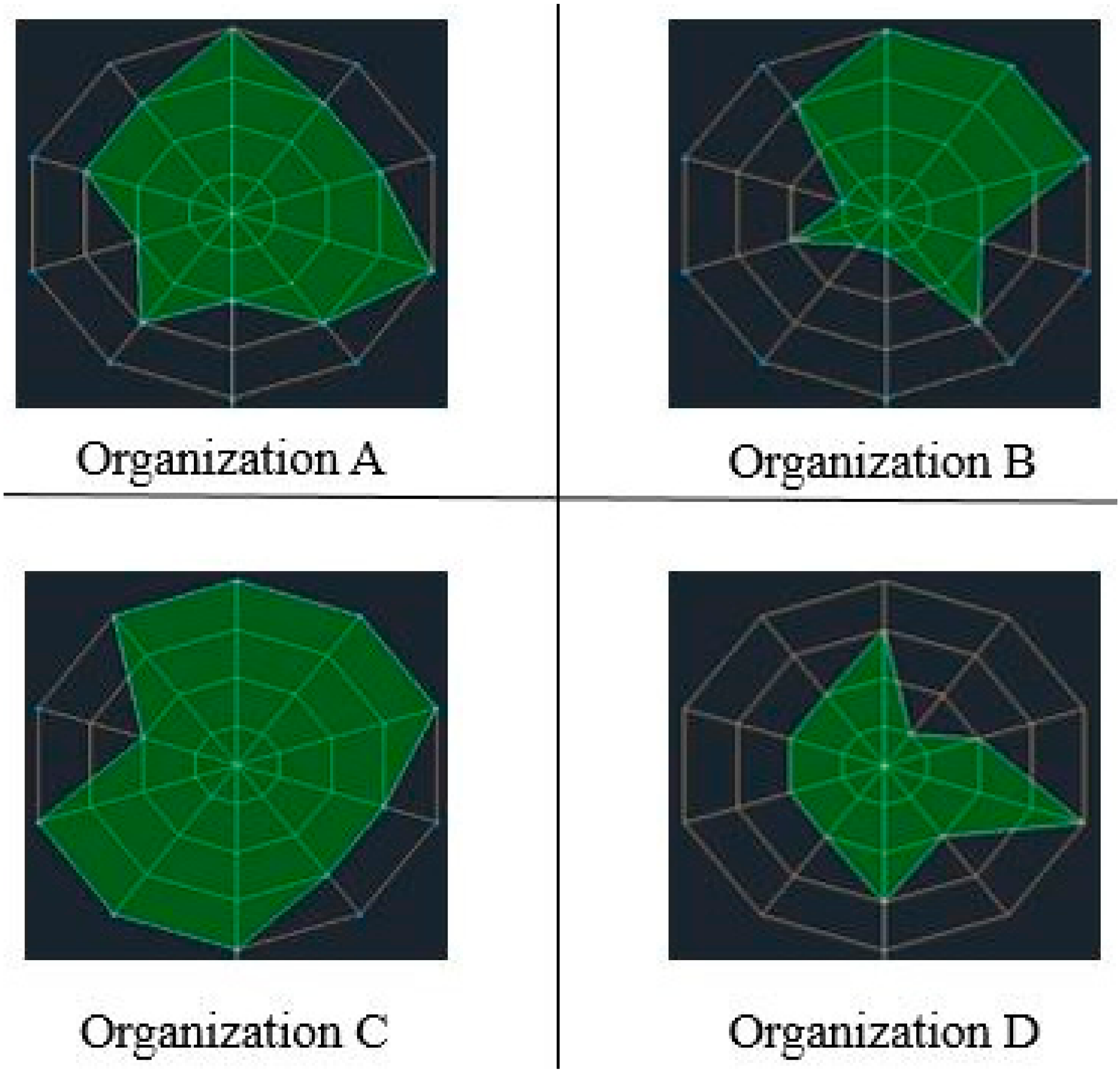


Figure 4. Application of BIMp-Chart.

This application shows that the BIMp-Chart, on the one hand, can be very helpful for comparing BIM implementation levels of different organizations. The comparison between the organizations motivates the organization for even better BIM implementation to reach higher BIM implementation levels, ultimately achieving maximum benefits from BIM. On the other hand, it enables an organization to visually and quantitatively check their implementation level (where they are standing) by calculating the area obtained after incorporating their values for all the indexes. This will help the organizations find and emphasize the areas that need further improvements regarding BIM implementation, thereby making BIM applications effective and better.

5. Conclusions

There has been an increasing interest in implementing BIM in the construction industry as it saves cost and time for project teams, elevates the quality of the project through improved coordination, planning, and lifecycle management of facilities, and enhances sustainability through energy and waste reduction using clash detection and energy simulations. However, BIM implementation is not free of challenges because of many factors. This study highlights the critical factors for the successful implementation of BIM, which will help better understand the fundamental elements of BIM implementation from a global perspective. The top ten factors are identified through a preliminary survey. The literature related to each significant factor was studied thoroughly to develop indexes comprising four levels to measure individual factors. The developed indexes were then validated by taking the perception of industry BIM experts through a global survey. A total of 99 experts from 26 different countries responded and validated all the indexes. The only disagreement was recorded in the last two levels of the index experience level within the organization since the majority believe that no organization would fall in levels 3 and 4 as there is a lower probability of employees having five years of BIM experience. This index was then revised (five years were reduced to three) by incorporating experts′ suggestions.

Based on the developed indexes, the BIMp-Chart was proposed as a tool for the measurement of BIM implementation levels within construction organizations. Finally, the test cases were presented to show that the BIMp-Chart can provide BIM owners and researchers with a means to compare the different levels of BIM implementation visually and quantitatively in the construction organization. The BIMp-Chart will help the organizations to visualize BIM implementation levels through simple figures rapidly. It will also contribute to organizations comparing their current BIM performance with the previous ones and other organizations. The proposed BIMp-Chart acts as a decision support system for the construction organizations by identifying the areas that need improvements and providing goals to work out strategies for successfully enhancing BIM implementation. The BIMp-Chart also submissively motivates the construction organizations for BIM implementation, which subsequently contribute towards United Nation's sustainable development goals including inter-alia affordable and clean energy (SDG-7), industry, innovation, and infrastructure (SDG-9), responsible consumption and production (SDG-12) and climate action (SDG-13).

This study discussed literature and field data gathered from the survey; however, it is limited to a specific approach followed for retrieving the articles. The mechanism used to retrieve and shortlist the articles may not be exhaustive, and the same study repeated at a different time in a different context may yield different results. Future studies may incorporate detailed interviews from field practitioners to achieve even more realistic results. They can use the BIMp-Chart as a basic point to develop more advanced tools by incorporating the interdependencies of used CSFs on each other. Further, the study can be expanded to include more respondents from all global regions to develop holistic BIM implantation indexes.

Author Contributions: Conceptualization, Q.M. and A.R.N.; Data curation, Q.M.; Formal analysis, Q.M.; Investigation, Q.M.; Methodology, Q.M., A.R.N., M.J.T., F.U., K.I.A.K. and M.U.H.; Project administration, Q.M. and A.R.N.; Resources, Q.M., R.M. and F.U.; Supervision, A.R.N.; Validation, Q.M.; Visualization, Q.M.; Writing—original draft, Q.M.; Writing—review and editing, A.R.N., M.J.T., R.M. and F.U. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all respondents involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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