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Critical Success Factors for BIM Implementation

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The purpose of the bachelor's thesis was to identify the critical success factors (CSFs) for BIM implementation and discuss their basic relationships and ranking. This thesis also aimed to suggest different critical success factors for the implementation of BIM in developing countries.

To identify the different (CSFs) for BIM implementation, a literature review was carried out. In order to validate the identified critical success factors, a questionnaire survey was conducted among experts practicing BIM in various developing countries. The top five critical success factors that were ranked after the review of a findings questionnaire survey are in descending order, BIM training programme, return on investment, legal aspects, stakeholder involvement, and industry culture.

The basic relationships between the critical success factors established in this thesis could allow stakeholders in the industry to determine the right approach to follow when adopting BIM in developing countries at the industry level.

Keywords	building information modeling, critical success factors, implementations

Contents

List of Abbreviations

AEC	Architecture, engineering, and construction.
BIM	Building information modeling.
CAD	Computer-aided design.
CSF	Critical success factor.
HVAC	Heating, ventilation, and air conditioning.
ICT	Information and communications technology.
IEEE	Institute of Electrical and Electronics Engineers.
IFC	Industry foundation class.
IT	Information technology.
MEP	Mechanical, electrical and plumbing.
NBIMS	National building information model standard project committee.
SME	Small and medium-sized enterprises.

1 Introduction

The building or construction industry is competitive as every project is diversified with various stakeholders and SMEs (small and medium-sized enterprises) participating. Building organizations and partners also require new resources and expertise to succeed in the competitive industry. The architectural, engineering, and construction (AEC) industry is made up of various and diverse players generating a "stiff and intense market," which each has its own peculiar qualities. Nevertheless, the adoption and implementation of Building Information Modelling (BIM) in the AEC industry has introduced greater cooperation and stronger communication among the different disciplines and stakeholders and helped to solve the problems that pervade the industry. [1.]

BIM adoption has brought significant benefits and impressive results on the design, construction, and operation processes and activities of both infrastructure and building projects. It has changed the way projects are designed and carried out bringing in a new way of working in the industry. As a result, numerous developed nations such as the USA, the Netherlands, Australia, Finland, and Norway have made BIM mandatory for built environment projects [25]. Abanda et al [2]. identified BIM as a tool in the construction industry for "facilitating collaboration and improving delivery efficiency and project quality." However, improper implementation of BIM might result in problems and obstacles.

Critical success factors (CSFs) are considered important and they play an active role in the introduction and application of new knowledge and processes. CSFs and the relationship between different aspects of BIM are essentially needed to identify the success of a project. Therefore, in the sense of a developed economy, CSFs need to be addressed for the introduction and application of BIM. Although the Critical Success Factors (CSFs) have been analysed in many ways in developing economy, Morlhon et al. [3]. considered as elements that are essential and that facilitates successful implementation of new systems in the construction industry.

This thesis aims to examine the view of business professionals on the CSFs when applying and embracing BIM in the field of evolving construction industry. The research applied many statistical methods, as described in chapter 2, to analyse the data and opinions gathered by an organized questionnaire survey. This research aims to contribute to the advancement of more realistic and successful approaches to facilitate full awareness and adoption of BIM in the developing world.

2 Building Information Modelling (BIM)

BIM, also known as n-D modelling, virtual modelling or virtual prototyping technology, can be described as a collaborative framework for designing, creating, interacting, and evaluating construction projects during the life cycle of the project using a digital information model [4]. BIM is classified as "a methodology with technical, agency and managerial components" according to M. Oraee et al. [5]. BIM was introduced by the incorporation of Information and Communication Technology (ICT) into the process in the building industry. In the early 90s, BIM was developed for Architecture, Technology, and Building. This has since been regarded as a catalyst for creativity and efficiency in the construction industry [6]. BIM is listed as an efficient mechanism that results in fewer environmentally harmful buildings, reduces uncertainty, and reduces conflicts over project management [7].

It can be clearly seen that scholars and business experts, holds a belief that BIM technologies can increase profitability and performance, boost constructability, reduce mistakes and save time and cost. These qualities help to create a more efficient construction [8].

2.1 Why BIM?

BIM technologies can promote changes in other building industry-related best practices. One of these is how the flow of information between players in a construction project can be improved to make it more successful. The information flow diagram in figure 1shows the typical model of communication in a construction project. In many respects, this approach is faulty, although it has long been the existing feature of the industry. Data is distributed independently to and from each discipline, various editions of documents are distributed simultaneously. [9.]

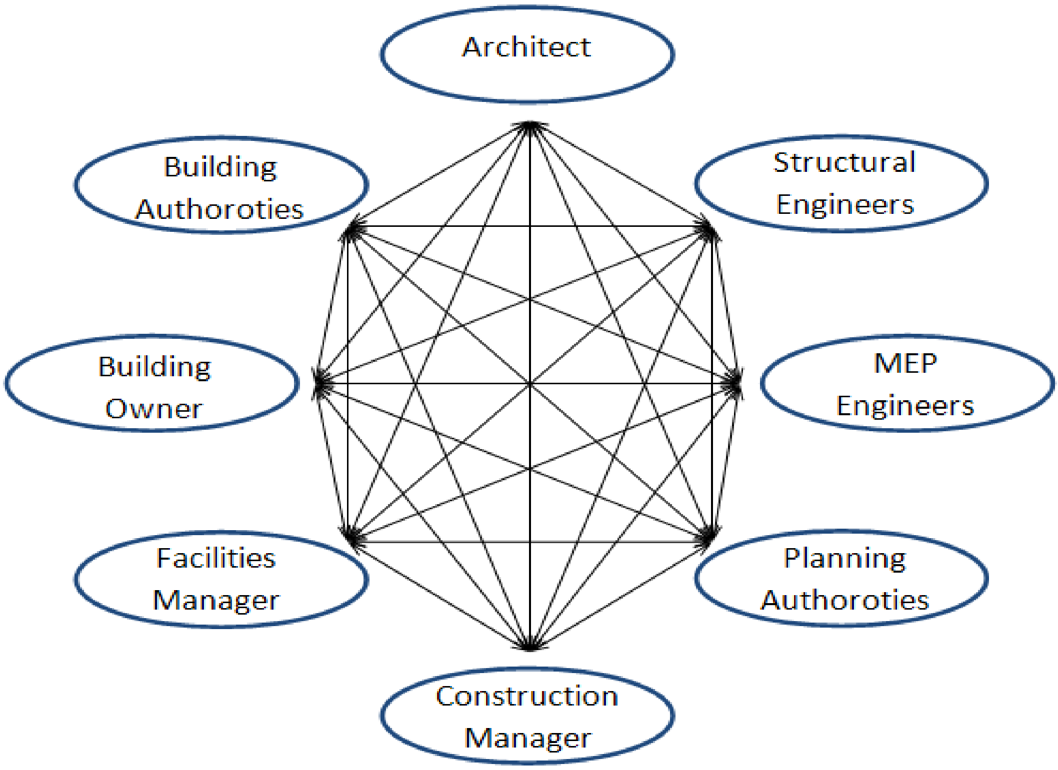

Figure 1. The traditional way of information distribution in a construction project [9].

The information flow depicted in figure 2 looks considerably simpler. Here, a centralized BIM database coup the interaction between the disciplines, i.e. a place where all parties have access to all relevant information when they need it. With the inherent database-thinking BIM method, every piece of information is stored in a single location, the organization and productivity of the entire project can be enhanced. For example, the risk of losing designs and lists of quantities can be avoided as they are built on the same pieces of information and are stored in the same place. The main difference, however, is that traditional methods are typically document-based so, the project information is stored in separate files or records, as previously mentioned. Whereas BIM technology deals with database solutions. [9.]

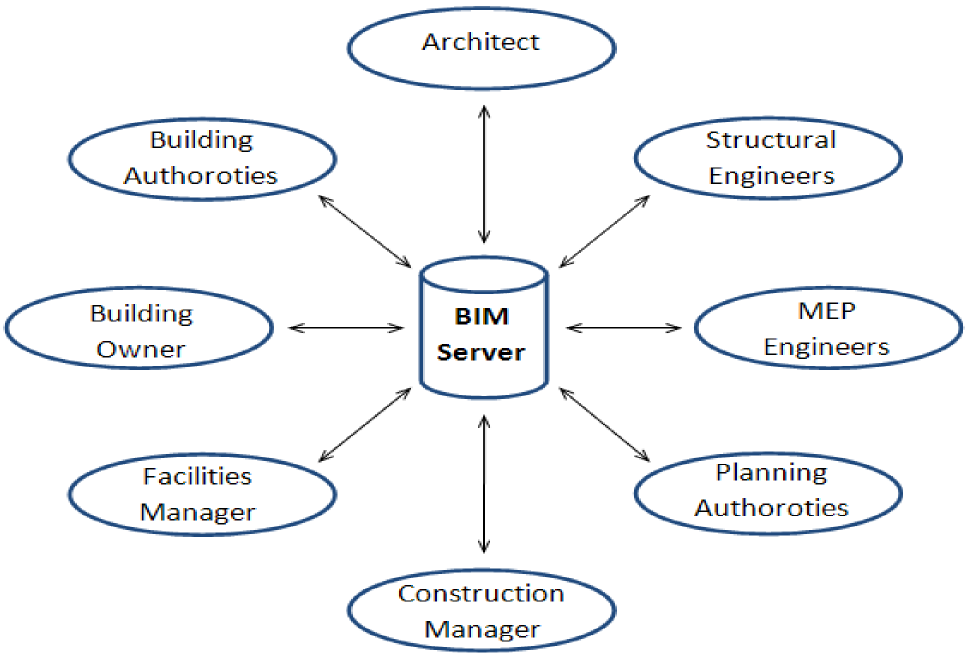

Figure 2. Information flow between parties with BIM [9].

Figure 3 visualizes the information flow and knowledge exchange in a specific way. The information received in a particular project is represented as a function of the lifetime of a building. A certain loss of data takes place when sharing the information from one process to another. Considering that consultants gathered a significant amount of information about the specific project at the end of the design process. Then, as the information is transferred through the call for tender to the next level, certain information will inevitably be lost, example those who have worked on the design will never be able to pass on all their expertise and experience learned for that specific project.

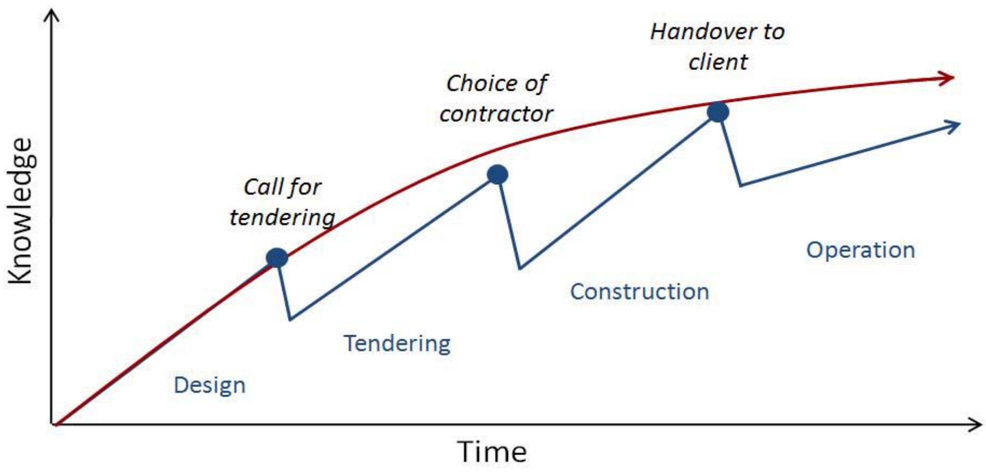

Figure 3. Information accumulation and loos is a function of time in construction project [9].

This inevitable loss of information was described as "wall" of deliverables, in which the deliverables are handed "over the wall" at the end of each step by Eastman at al. [4]. The red line in the diagram shows a more consistent information flow over the entire life cycle of a building. Through proper organization and reuse of the details, this process can be achieved. The blue line represents information accumulation as traditional procurement is. [9.]

2.2 Traditional Approach vs BIM Approach

In the building industry, the word BIM has become a familiar expression, but its concept and meaning are not very clear. Therefore, it is important to study other modelling approaches that do not support BIM technology. Much of this debate is based on Eastman et al. [4].

One basic feature of BIM is that the systems are based on object-oriented design. For example, it means that a digital representation of a building or a structure is constructed using predefined digital building components that have specific attributes attached to them. Such attributes may define some of the features of an object, such as its material characteristics of the producers. These traditional object modelling do not have object-level knowledge and can mostly be used primarily for visualization. They are good as such but provide no support for design analysis or data integration.

Another important feature of models generated with BIM technology is that parametric intelligence must be used to identify objects. This means that objects can be altered with a simple change of parametric values utilizing proportion, volume, or position. According to Johannesson [9.] objects that are not specified with this form of knowledge are more difficult to update and do not provide consistency assurance.

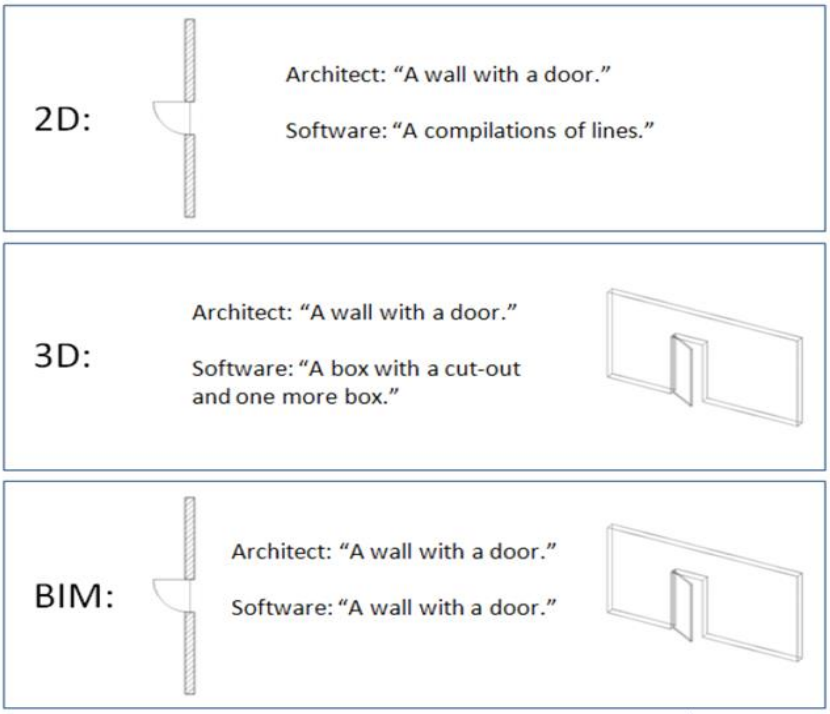

Figure 4. Interpretation of drawings by architects and software in different design techniques [9].

As an example, figure 4 shows the different models created using either the BIM method or a traditional method. The first picture shows a 2D drawing of a cross-section of a wall with a door inside created using a CAD programme. Even for an individual who has no idea about drawings, it is obvious what drawing depicts. But the machine or programme only sees just a meaningless list of lines. The second image shows a 3D drawing, created in CAD software. It shows more distinctly what the drawing aims for, but the machine still sees it as a hole in a box and another box. The last diagram shows the same part of the wall modelled using a BIM device. Again, a person sees just a wall with a door in it, but what is different is that the machine also interprets the section as the door-wall.

2.3 Benefits of BIM

BIM technology can be seen as a modern medium for project delivery. It is an invention that provides important benefits to various building domains throughout the life cycle of a project. Concurrent design is facilitated when using BIM during the life cycle of the project. This can also, of course, promote the development of a project life cycle, from the early conceptual phase through design, construction, and operation to demolition [6.]

Several studies have identified the significant benefits of introducing BIM as improved productivity and quality. The Implementation of BIM offers key benefits of increased productivity and performance. BIM has the potential to incorporate time and expense that promotes real-time updating and measures effective tracking and monitoring processes during the project stages, and BIM can also be used in green building assessment and review. It can also be used for the identification of clashes and the optimization of the design. [10.]

The capacity to implement BIM in multiple systems and analyses makes high-performance success possible in the building sector. Recognizing and understanding the importance of BIM should make it very easy for construction players to want to utilize BIM for their ventures. Nonetheless, it is necessary to recognize and persuade players of the advantages the technology provides to achieve a more outspread use of BIM.

2.4 BIM Programmes.

Although BIM is new to the AEC industry, there are plenty of options to select the software. There are numerous people involved in any project, such as architects, structural engineers, HVAC engineers, and estimator, among others. Different professionals involved in a project also have different jobs to perform and BIM tools to work on. Some of the BIM applications for various professionals are listed in table 1.

Table 1. Different BIM applications and their purpose [11]

Architecture	**Structural Design**	**Building Service system**	**Model viewing and clash detection**	**Planning and cost estimation**
Archi CAD/ Auto CAD	Tekla structure	MagiCAD	Solibri model checker	Modelspace
Revit Architecture	Revit structure	Revit MEP	Tekla BIMsight	Vico Office
Nemetschek Allplan Architecture	Vertex BD	CADS Electric	Trimble connect	Tocoman
Bently Architecture	CADS Planner House	CADS HEPAC	Solibri Model Viewer	
	Nemetschek Allplan Engineering		Autodesk Navisworks	

A vast range of information needs to be actively exchanged with various stakeholders for different activities and purposes. BIM-based information exchange from one application to another is done in the file format Industry Foundation Classes (IFC). For example, an architect may provide an owner with a new facility design model, an owner may submit the building model to a contractor to request a proposal, and a contractor may provide the owner with descriptions of an as-built model detailing the installed equipment and supplier information. The IFC format may also be used as a way of archiving project information, both incrementally through the planning, procurement, and implementation processes, or 'as-built' collection of data for long-term storage and organizational purposes. [11.]

2.5 Barriers of BIM Implementation in Developing Countries

Implementing BIM has added major benefits for the building industry, but at the same time, it has a significant impact on the existing procedures, procurement strategy, and business model. This has contributed to the reshaping of markets and organizations. However, the Implementation of BIM involves a variety of obstacles including technology issues, organizational problems, and environmental, financial and legal threats. [13.]

The relation between the construction industry and its professional is described as a push and pull relationship [14]. This relationship illustrates the need to encourage BIM adoption to facilitate information exchange between individuals, to raise awareness and improve the willingness of accepting BIM in the work environment [15]. The governments play a central role in facilitating the application of BIM. BIM implementation needs all parties to be involved first. Consequently, this study suggests that the introduction of BIM will rely on how companies can meet their goals with minimum costs and a short time.

Many of the difficulties and issues in the construction industries of developing countries ultimately lead to overrun costs and delays. Many of the enterprises in developing countries are now working hard to address these obstacles by introducing BIM. Masood, Kharal, & Nasir [17] performed a research of the Pakistan Construction Industry on the application of BIM, and their report shows that BIM professionals in Pakistan consider two main advantages with BIM, costs reduction and time savings in construction projects. Masood et al. report also states that obstacles to the introduction of BIM tend to have been weakened by a pervasive degree of understanding BIM among the companies [17].

Based on the study about the Barrier for BIM implementation in the Indian AEC industry made by CB Amarnath [18], there are obstacles that have hindered the implementation of BIM in the Indian AEC industry, Amarnath classified the obstacles into six groups: technical, people, educational, training, legal, and commercial barriers. The study further subclassifies the barriers as shown in Table 2. The study was conducted in 2017 from February to September with different Indian AEC industry stakeholders that oversee the delivery of BIM projects in their respective companies. [18.]

Table 2. Implementation barriers to BIM in AEC Industries in India [18].

in Industry	**Technical barriers**	**People barriers**	**Education & training barriers**
	Expensive software	Client driven limitations	Absence of BIM education & training
	Hardware requirements	Less importance towards BIM adoption from other team members	Skill issues
	Standard guidelines	Lack of talented workforce to operate BIM tools	Organizational efforts
	Legal barriers	**Work practice & process related barriers**	**Commercial barriers**
	Liability & copyright issues	Roles & responsibilities	Insurance
	National building codes	Change in practice & use of Information	Capital for investment
	Third party dependence for accuracy of BIModels	Inefficient regulatory	Key adopters of BIM (designers) will not get immediate benefits
in Academia	**Policy field players**	**Technology field players**	**Process field players**
	Process of introducing BIM in AEC curriculum.	Need of BIM IT laboratory facility.	Need for revising existing incomplete BIM curriculum.
	Resolving key issues in delivering BIM curriculum.	Need of BIM technical officers.	An initiative to reduce weak ties between Industry & Academia.
	Initiative in producing trained BIM personnel.	Need of standard/guidelines for BIM tools selection.	Teaching BIM as both technology & process in universities.

To pursue innovative approaches to the persistent problems they face, the Malaysian construction industry emphasizes innovation in existing building technologies, which is why the early implementation of Building Information Modelling is being tried. As the successful implementation of a BIM model depends on the joint participation of the project teams, challenges such as people, procedures, and technology are delaying the Malaysian construction industry's adoption rate. Many researchers are working to help companies plan and increase the awareness of BIM adoption in the construction companies. Many of the problems of BIM adoption/implementation are common in the construction sectors in developing countries, with minor variations between nations. [19.]

3 Methodology

Within this section of the theory, different aspects of the research methods used to construct this work are explored. In general, two approaches have been chosen as approaches to analysis. One is a study of the literature and another is survey and its analysis. The literature review was carried out to collect information relating to BIM and numerous important critical success factors for the BIM implementation. Ample materials such as books, papers, magazines, and online resources have been researched and used as source for information. The literature review provided necessary information about BIM and different critical success factors for its implementation. Later, the survey analysis was considered to validate the different critical success factors of BIM implementation from experts' points of view. The of stages research are numbered below.

1. Literature review.
2. Identifying critical success factors.
3. Questionnaire.
4. Analyzing and conclusion.

3.1 Literature Review

A study of the literature was performed through various databases of academic research articles. Especially databases such as Science Direct, Emerald Publishers, IEEE Xplore digital library and Academia; were studied to find research articles for a literature review. Of these, the first three contain articles peer-reviewed prior to publication, the fourth relies on a post-publication peer-review process. The search was conducted with the keyword "BIM", and the result was evaluated. The search was further limited with the phrase "CSF for BM Implementation" to select papers for analysis. The number of research papers found with these phrases can be seen in table 3 below. The phrase "CSF for BIM Implementation" proved relevant therefore seven papers In total were selected for further research from the process.

Table 3. Search Results from the different scientific platform.

	Search word“BIM”	Search Phrase “CSF for BIM Implementation”	Selected for review
IEEE Xplore	623	0	0
Academia	2534	35	4
Science Direct	19,120	2	2
Emerald	1463	1	1

Analyzing table 3 above, it seems that the Science Direct with a total of 19,120 findings is the data base with most BIM-related journals. The search phrase “CSF for BIM implementation” limited the number of results as seen in table 3. Finally, 33 papers were selected for further study, a total of from the databases and 26 papers found through a search on the search engine Google Scholar.

3.2 Identification of Critical Success Factors

The research on finding critical success factors for BIM implementation was carried out by reviewing and studying the selected papers. Of the 33 papers only 12 were considered for further research, Based on several requirements. For example, some of the publications were focused on criteria for BIM implementation rather than critical success factors and some were only based on literature review without empirical research. These latter publications were not considered because this might not gather an actual conclusion. In addition, publications that did not include a specific list of critical success factors for BIM implementation or the explanation of why such factors were selected were also ignored. This elimination process resulted in 12 resources that were deeply reviewed and analysed to list the critical success factors. A total of 32 critical success factors were found during the study and further 11 important critical success factors were finalized and sent for questionnaire survey to make the survey short and understandable for the respondents.

Critical success factors (CSF) are necessary for an organization or project to achieve its goal. The identified factors are necessary elements for BIM implementation in developing countries. Hence, the 11 CSFs listed in table 4 are CSFs for BIM implementation in developing countries.

According to Ozorhon and Karahan, [20.] BIM training programme is one of the critical success factors for BIM implementation as training and workshops are used to provide workers with relevant knowledge and expertise to promote BIM. According to Ugwu and Kumaraswamy [21]. return on the investment made, the working culture of the industry, and involvement of stakeholders are the critical success factor for BIM implementation. Bui et al. [22.] believes that legal aspects and suitable hardware and software are also important critical success factor for BIM implementation. They also mention that as BIM is a new concept, the necessary software and hardware are also critical for its implementation. Encouragement from top administration to learn and adopt BIM tools is one of the CSFs mentioned by Eneghuma and Ali [23]. Morlhon et al. [3] mention institution structure to support BIM and willingness of staff to adopt an innovation as CSFs for BIM implementation. As further explained by Morlhon et al. [3] that project staff should be ready to be able to read and understand BIM. An in-house plan and policies for incorporating BIM management into its framework are also vital. Since it is quite difficult to manage the team from inside a company during an initial phase of the implementation, outsourcing can be one of the CSFs states Arayici et al. [24]. The degree of easiness in adopting and using the system is one of the critical success factors for the implementation of BIM according to Eastman et al. [4].

Table 4. CSFs for BIM implementation in developing countries.

Code	CSFs for BIM implementation	Number of References
CSF1	BIM training programs	[20]
CSF2	Return on investment	[21]
CSF3	Industry Culture	[21]
CSF4	Suitable hardware and software	[8]
CSF5	Encouragement from top administration	[23]
CSF6	Institution structure to support BIM	[3]
CSF7	The willingness of the staff to adopt an innovation	[3]
CSF8	Outsourcing	[24]
CSF9	Stakeholders involvement	[21]
CSF10	Ease of use	[4]
CSF11	Legal aspects	[8]

During the BIM implementation phase, actions are required from national, organizational level, and project level. Hence, identified critical success factors can be classified according to the actions required from a level. BIM training programmes and legal aspects come under the national level. The national government should be involved in including BIM in the curricula and some amendments in existing laws should be made to implement BIM. Some CSFs come under the organizational level such as industry culture, suitable hardware and software, encouragement from top administration, the willingness of staff to adopt an innovation and institution structure to support BIM. An organization needs to supply suitable hardware and software to its staff for BIM implementation. The staff should be encouraged by top administration and the staff should also be willing to adopt innovations in the organization. Return on investment, ease of use, stakeholder involvement, and outsourcing are factors on the project level. Based on the literature analysis, the 11 most important critical success factors for the implementation of BIM in developing countries are tabulated in table 4.

3.3 Survey Analysis

A survey questionnaire (Appendix 1) was created with three questions mainly focusing on validating the finalized critical success factors for BIM implementation in developing countries.

The survey was conducted from November 1^{st,} 2019 to January 31^{st,} 2020 to participants working in the construction field, practicing in developing countries and practicing BIM. The survey questions were sent to individuals by email through, for example, personal contacts, various Facebook groups, and online communities. A total of 112 people participated in the survey which was more than expected.

3.3.1 Making the Questionnaire

A questionnaire is a very common tool for data gathering. It is, indeed, a series of questions. The questionnaire must be clear and logical so that all respondents can understand it and answer the questions without difficulty. The language should be neutral, and transparent. If the questions are easy and transparent, the respondents will answer them correctly and automatically assist the researcher in extracting the results. The questionnaire helps the researcher to gather information and feedback from the respondents based on their expertise, their personal experience. [26.]

The questionnaire survey for this thesis was written in English, and three basic questions were asked to make the survey short and quick. First, two questions were “category questions”. The respondents were asked about to their professional background and their years of experience in the respective field. The third question was related to critical success factors in which survey participants were asked if they agree with a given critical success factor for BIM implementation in developing countries. Altogether, 11 CSFs which were extracted from the literature review, as mentioned above, were presented to respondents and asked if they strongly disagree, disagree, are neutral to, agree or strongly disagree with the factor being critical for the implementation of BIM in developing countries. The following codes were used during the analysis.

1- Strongly disagree
2- Disagree
3- Neutral
4- Agree and
5- Strongly agree.

3.3.2 Collection of Data and Analysis.

The data for this study was obtained through the survey process. The respondents were presented with a series of three questions to give their opinion. The aim was to reach as many people as possible to collect data that would serve the study purpose. The validity of a questionnaire may depend on its ability to represent and satisfy the purpose of the research, that has an indirect association with the commitment and time used to construct it.

The results were collected using the tool called the Monkey Survey, while the queries were distributed by the website itself (www.surveymonkey.com). The data and findings were presented in graphs and pie charts, used for the evaluation of the data, and conclusions are drawn. The survey findings are summarized in chapter 4.

3.3.3 Reliability and Validity

The term validity of a test refers to calculating what is intended to measure, indicating the study design, methodology, and different tools that can help the researcher to understand the concept under analysis. To be more specific, the analysis questions should be answerable. Transparency is something that must always be kept in mind during any research. Reliability refers to a test of a concept being consistent. Reliability is also a level of accuracy of the measurements. Reliability and validity are interrelated because reliability presumes validity. One of the key concerns about reliability is the nature of the survey questionnaire and data collection. [25.]

To the degree that this thesis is considered, a questionnaire is an effective and accurate method, since the design of the questionnaires used in this study is based on careful literature analysis and then checked by the author. To ensure that the study is reliable and valid, the author of this thesis focused on different aspects of the research. The questions were designed and revised several times, starting with the questionnaire lay-out, until the final, clear, and prompt, outlook was published for the survey. The study results were correctly evaluated using the Monkey Survey database, and the responses were abstracted to evaluate and draw the conclusions.

4 Results and the Survey

Different results obtained from the questionnaire survey are explained separately in the following chapter 4.1 and 4.2. The results were obtained in agreement with the respond-ents stating that the response taken is only for research purposes, and personal infor-mation is kept secret and deleted after the thesis is completed.

4.1 Professional Background and Experience of the Respondents

The first question of the questionnaire was related to his/her professional background. The graphical representation and theoretical explanation concerning the professional background of the respondents are given below in figure 5.

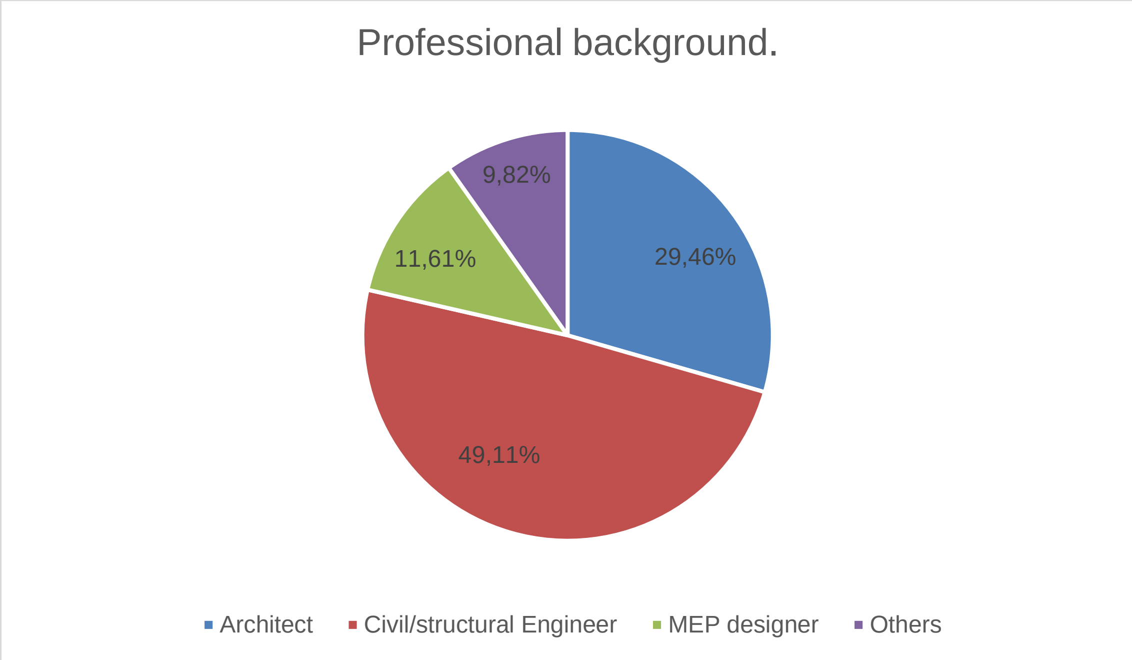

Figure 5. The professional background of Respondents.

According to the survey result, most of the respondents, 55, came from a professional background of civil/ structural engineering, which accounts for 49.11% of the respondents. The respondents with civil/structural engineering background accounted for almost half of the responses collected by the author. The respondents stating architecture as their professional background numbered 33 responses, accounting for 29.46% of the total respondents. The third highest number of responses was from respondents with MEP design as professional background, accounting for 11.61% of the total. Finally, the smallest group of responses was from respondents with other backgrounds, supposedly people who are directly or indirectly involved in BIM implementation, like clients, owners, contractors, quantity surveyors, facility managers or the like. They were 11 in number and account for 9.82% of the total respondents.

Question number two of the questionnaire survey inquired about the respondent's years of experience in the field. The graphical representation and theoretical explanation concerning the years of experience in a related field are given below figure 6.

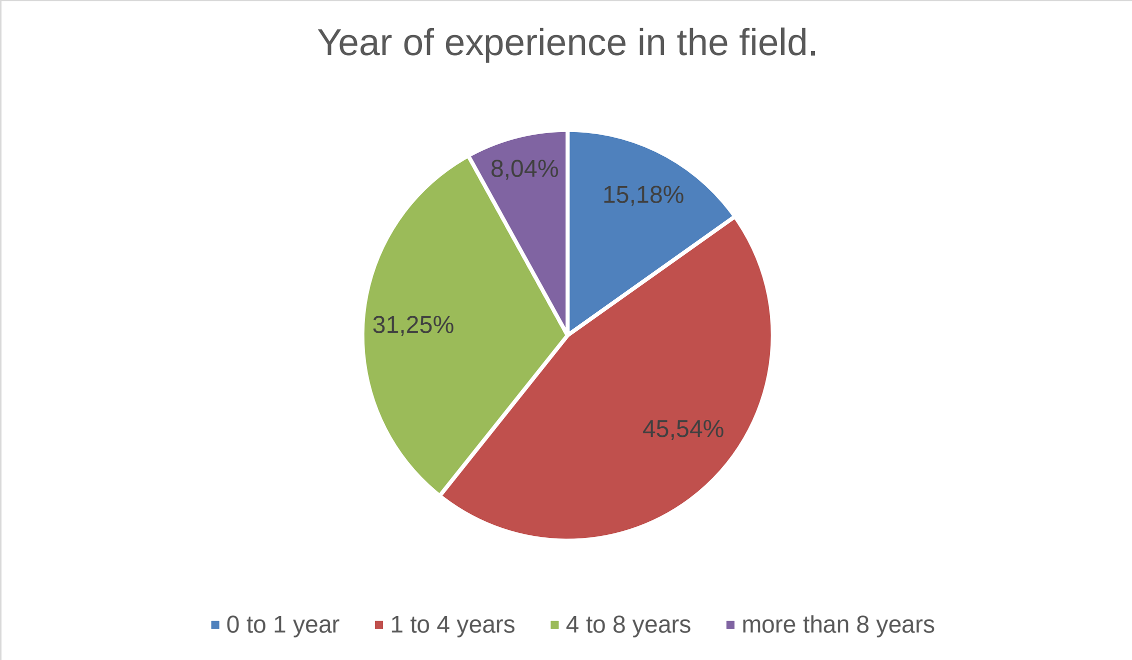

Figure 6. Respondents year of experience in the field.

Regarding the years of experience in the field, the result received from the questionnaire shows that most of the respondents had one to four years of experience in the field, with 51 respondents choosing this alternative, accounting for 45.54% of the total respondents. Respondents with four to eight years of experience numbered 35, accounting for 31.25% of the total respondents. Thirdly, the result shows that the number of respondents with less than a year of experience was 17, accounting for 15.18% of the total respondents. Finally, the respondents with the most experience, more than eight years, and the smallest in number, nine respondents accounted for only 8.04% of the respondents.

4.2 Analyzing Critical Success Factors

To validate the chosen 11 critical success factors, the respondents were asked to assess the factors and state whether they strongly agree, agree, are neutral, disagree, or strongly disagree with the factor affecting the implementation of BIM. The result of the assessed data is shown in table 5.

Table 5. Results of the survey question 3 in the questionnaire.

Code	**Critical Success Factors (CSF)**	**Strongly disa-gree**	**disa-gree**	**Neutral**	**Agree**	**Strongly Agree**	**Sum**
CSF1	BIM Training Pro-gramme	0	0	8	38	66	112
CSF2	Return on Invest-ment	0	0	11	52	49	112
CSF3	Industry Culture	0	7	63	35	7	112
CSF4	Suitable hardware and software	1	13	37	52	9	112
CSF5	Encouragement from top admin-istration	8	39	50	10	5	112
CSF6	Institution structure to support BIM	11	48	32	14	7	112
CSF7	The willingness of the staff to adopt an innovation	30	47	12	15	8	112
CSF8	Outsourcing	2	12	60	31	7	112
CSF9	Stakeholders in-volvement	1	4	14	67	26	112
CSF10	Ease of use	2	24	45	22	19	112
CSF11	Legal aspects	2	1	17	61	31	112

Briefly going through table 5 above, most of the respondents, or 66 in number out of 112, strongly agree that BIM training programme (CSF1) is a critical factor for the implementation of BIM in developing countries. It signifies that most respondents believe that providing training in BIM is very important for BIM implementation. On the other hand, the willingness of the staff to adopt an innovation is not seen as a critical factor for BIM implementation in developing countries was strongly disagreed with by most of the respondents, 30 in number. Figure 8 below shows the respondent's answers on critical success factors for BIM implementation as a graphical representation.

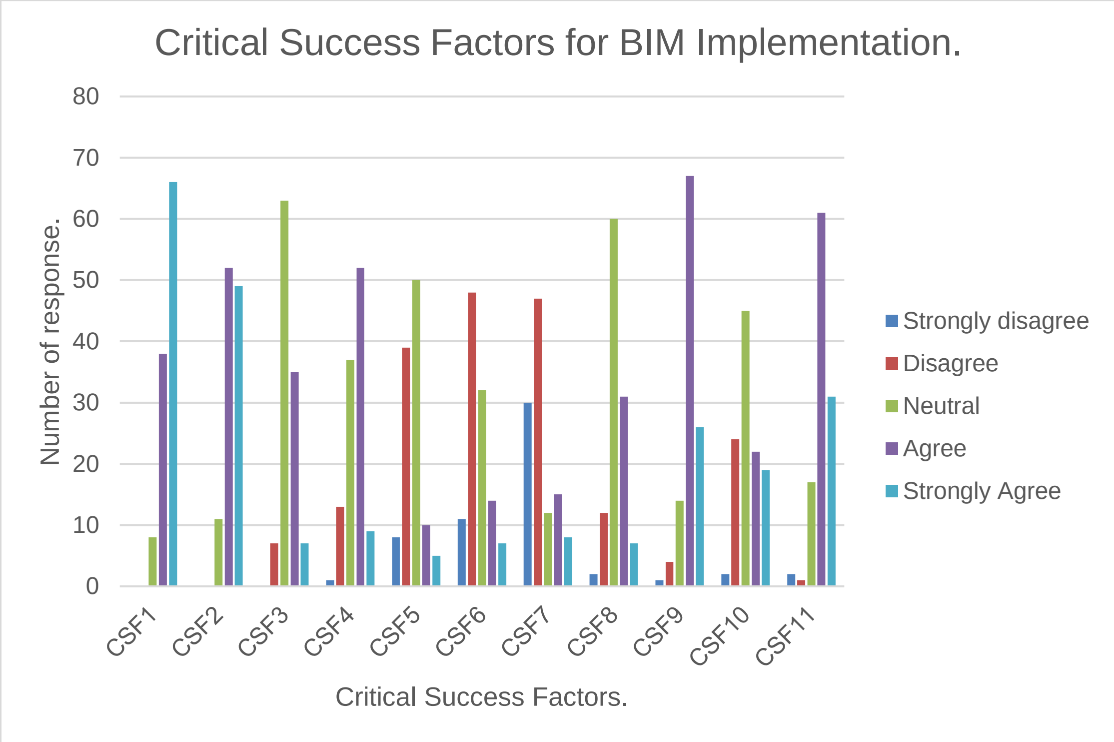

Figure 7. Graphical representation of critical success factors of BIM implementation.

The questionnaire survey shows the role that literature plays in critical factors for performance. Table 6 displays the mean, standard deviation, and variance coefficient estimation of the answer gathered from respondents. The calculation of the mean was done according to the method of W Alshami [27]. The coefficient of variance reflects the dispersion of data and is also the ratio of the standard deviation of the mean. Standard deviation is a function of a set of values varying or dispersing.

Table 6. Calculation of mean, standard deviation, and the variation coefficient for each critical success factor.

Code	Critical Success Factors (CSF)	Min. Value	Max. Value	Mean	Std. Deviation	Variation coefficient
CSF1	BIM Training Program	1	5	4.51	0.62	13.74
CSF2	Return on Investment	1	5	4.33	0.64	14.78
CSF3	Industry Culture	1	5	3.37	0.69	20.47
CSF4	Suitable hardware and software	1	5	3.49	0.86	24.64
CSF5	Encouragement from top administration	1	5	2.91	0.92	31.61
CSF6	Institution structure to support BIM	1	5	2.62	1.02	38.93
CSF7	The willingness of the staff to adopt an innovation	1	5	2.32	1.20	51.72
CSF8	Outsourcing	1	5	3.25	0,79	24.30
CSF9	Stakeholders involvement	1	5	4.00	0.76	19.00
CSF10	Ease of use	1	5	3.28	1.03	31.42
CSF11	Legal aspects	1	5	4.05	0.77	19.01

In table 6, the BIM training Programme (CSF1) has the highest mean value of 4.51 and the lowest coefficient of variance and standard deviation of 13.74 and 0.62, respectively making it the most important critical success factor. Similarly, the return on investment (CSF2) has the second-highest mean with 4.33 and the second-lowest variance coefficient and standard deviation accounting at 14.78 and 0.64, respectively, making it the second most important critical success factor. Third, the mean value of Legal aspects (CSF11) is 4.05 with a coefficient of variance and a standard deviation equal to 19.01 and 0.77, respectively, making it the third important critical success factor.

With the average range from 3.25 to 4.00, it is assumed that personnel outsourcing, ease of use, industry culture, appropriate hardware and software, and stakeholder participation are significant critical success factors for BIM Implementation in developing countries. The coefficient of variation of all of these factors ranges from 19.00 to 24.64, except for the ease of use, which has a coefficient of variation of 31.42, which means that the respondents' opinion on the factor varies more than about the others. For the standard deviation, the variables range from 0.69 to 0.86 except again, for the ease of use which has a value of 1.03 meaning more spread from the mean.

Encouragement from the top administration and willingness of staff to adopt innovation have a mean value 2.91 and 2.32, respectively. Moreover, according to most respondents, these factors are less important since they neutrally agreed with them being critical success factors for the implementation of BIM in developing countries. The standard deviation of these factors accounted for 0.92 and 1.20, respectively.

Furthermore, according to table 6, institution structure to support BIM appears not to be a significant factor because most participants disagree with it as being a critical success factor for BIM implementation in developing countries with a mean value of 2.62 and standard deviation 1.02.

The variation coefficient in table 6 indicates that participants have varying views about the willingness of staff to adopt an innovation factor that has the maximum variation coefficient of 51.72. They have diverse opinions about the institutional structure to support BIM, ease of use, encouragement from top administration. BIM training programmes and return on investment, on the other hand, have the lowest variance coefficient of about 14. Similarly, critical success factor variables such as legal aspects, the involvement of stakeholders, and industry culture have a fair value of the coefficient of variation, about 20.

4.3 Benchmark Metrics for Ranking the Factors

One of the aims of this thesis was to establish the five most important critical success factors for the implementation of BIM in developing countries. Mean, standard deviation and variation coefficient calculated in table 6 mainly focus on the nature of the data obtained from the survey. Therefore, this chapter focuses on the ranking of the data about the critical success factors for the implementation of BIM in developing countries with the formula discussed below. The formula used to measure the BIMbi is as below:

$BIM_{bi} = \Sigma W/AN,\ 0 < BIMbi < 1$

Where,

W= Weighting assigned by the respondent for each object, ranging from 1 = Strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

A= Is considered the highest rating which is taken as 5 and

N= Total number of participants in the survey.[28].

In analyzing the data, rankings obtained from the respondents were used to establish whether a "BIM benchmark index" (BIMbi) for the key CSFs they perceive could promote the adoption of BIM in developing countries. During the calculation of the BIMbi, all the numerical scores in table 7 for the primary enablers were manually tabulated to reach their relative rankings.

Table 7. Ranking of critical success factor.

Code	**Critical Success Factors**	**BIMbi**	**Rank**
CSF1	BIM training programme	0.90	1
CSF2	Return on investment	0.87	2
CSF11	Legal aspects	0.81	3
CSF9	Stakeholders involvement	0.80	4
CSF3	Industry culture	0.67	5
CSF10	Ease of use	0.66	6
CSF8	Outsourcing	0.65	7
CSF5	Encouragement from top administration	0.53	8
CSF4	Suitable hardware and software	0.52	9
CSF7	The willingness of staff to adopt an innovation	0.46	10
CSF6	Institution structure to support BIM	0.43	11

Based on the findings given in table 7**,** the CSFs for BIM implementation in developing countries are, in a descending order, BIM training programme (CSF1), return on investment (CSF2), legal aspects (CSF11), stakeholders involvement (CSF9), industry culture (CSF9), ease of use (CSF10), outsourcing (CSF8), encouragement from the top administration (CSF5), suitable hardware and software (CSF4), willingness of staff to adopt an innovation (CSF7) and institution structure to support BIM (CSF6).

4.4 CSFs Factor Analysis

One of the oldest structural models is factor analysis, which was developed by Spearman in 1904. Factor analysis is used in two data analytical contexts: supporting or negating the hypothesized structure, or seeking to discover a structure, in which case the study is considered exploratory [28]. Since the analysis in this thesis is exploratory factor analysis, the naming of the factors was based on the researcher's "knowledge of the under-study phenomenon". The idea of factor analysis is influenced by G. Yusuf [28]. Four factors are extracted as shown in table 8 and the discussion about the factor analysis is provided in the later part of chapter 4.4.

Table 8. Grouping of Critical Success factors.

S.N.	**Components**	**Critical Success Factors (CSF)**
1.	Commitment and awareness of BIM by industry stakeholders. (C1)	CSF1, CSF7, CSF9
2.	Cultural-orientation and building capacity to embrace technology. (C2)	CSF2, CSF3, CSF4, CSF10
3.	Organizational support. (C3)	CSF5, CSF6
4.	Collaborative collaboration among the professional in the industry. (C4)	CSF8, CSF11

In factor analysis, it is of great importance that the name given to any a component factor must be able to conveys a sense of what the things matters that were loaded included in it into a factor represent both theoretically and in reality. The first component in this study was is called Commitment and awareness of BIM by industry stakeholders. are shown in Table 7 (CSF1, CSF7, CSF9). The first component, C1, indicates that company stakeholders must be committed to modern, creative technologies, such as BIM, being launched. The CSFs that are included in C1 suggest that particular consideration needs to be paid to re-engineering the whole method of doing business in the building industry to facilitate the emergence of transformative BIM technologies. According to Lee and Sexton [29], education and training prove to be the most effective way of acquiring information and skills to adopt emerging technologies.

The second component, C2, is Cultural-orientation and building capacity to embrace technology. It consists of four of the CSFs: CSF2, CSF3, CSF4 and CSF10. Capacity building is necessary for implementing any new technology, especially in the ICT market. To promote the gradual adoption of BIM by business practitioners, deficiencies created by the non-availability of trained professionals to manage the availability and affordability of BIM resources and applications must be tackled to ensure smooth adoption. Culture can be defined as the way of life of a community (i.e. the way people in their traditional setting have done things). In the construction industry, workers have over the years looked at their jobs from their own viewpoint without taking any other viewpoints into consideration. However, this has generated difficulties because there is a lifecycle difference between one career and the other in construction projects. Human beings are static in terms of implementing new approaches that they believe are contradictory to the old ways they have done things, and this is a big obstacle that militates against BIM implementation and must be solved if BIM is to be introduced effectively [29].

The third component is Organizational support includes two critical success factors, CSF5 and CSF6. This implies that the assistance that the building and construction workers receive from their respective organizations is very important for the adoption of BIM in the developing countries. The encouragement could come from the management through the recruitment of staff and investment in fields that could encourage BIM implementation. When a company has a general understanding that the implementation of BIM would increase its profitability and performance, it will provide more encouragement for achieving this objective. According to Ugwu et al. top management support is one of the most critical enablers for the introduction of innovation in construction companies. Moreover, any building companies that build an empowering working atmosphere through effective management strategies is likely to execute IT and information management effectively [21].

The fourth and last component in the factor analysis is Collaborative collaboration among the professionals in the industry. Two critical success factors, CSF8 and CSF11, belong to this component. To tackle the challenge of heterogeneity in the construction industry, collaboration is required among industry professionals in areas related to legal aspects and outsourcing [30]. From the previous study from Singh et al. pointed out that the higher the degree of collaboration of team members during the early phases of a building process, the greater the prospects of optimizing the advantages of using BIM [30].

The chart below in figure 8 shows the different components and critical success factors of the components.

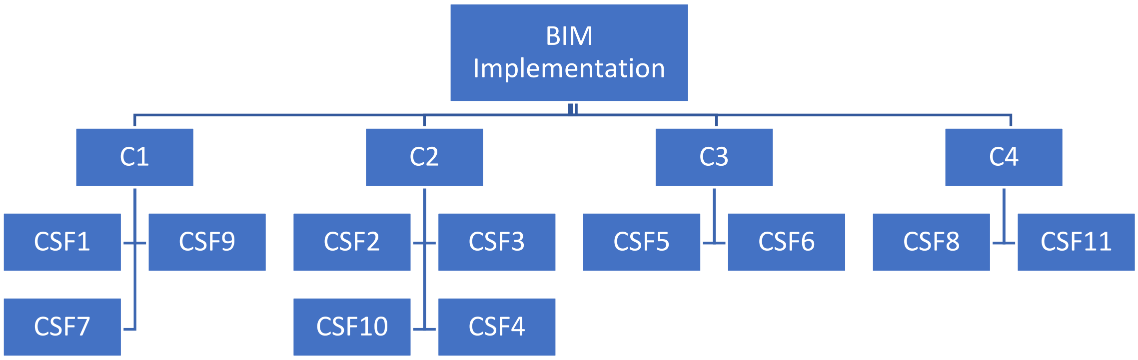

Figure 8. Division of critical success factors into the factor analysis components for BIM implementation.

In the chart in figure 8 above, C stands for the factor analysis components and CSF stands for the critical success factors introduced in chapter 3.2 above. In chart, the abbreviations are the same as above in the discussion about the components. C1 is the commitment and awareness of BIM by industry stakeholders, C2 the cultural-orientation and building capacity to embrace technology, C3 the organizational support, and C4 the collaborative collaboration among the professional in the industry. Of the critical success factors, CSF1 is BIM Training Programme, CSF2 is the return on Investment, CSF3 the industry culture, CSF4 stands for suitable hardware and software, CSF5 for encouragement from top administration, CSF6 for institution structure to support BIM, CSF7 for the willingness of the staff to adopt an innovation, CSF8 for outsourcing, CSF9 for stakeholder's involvement, CSF10for ease of use, and, finally, CSF11 for legal aspects.

5 Conclusion

In the AEC sector, BIM is an innovative concept that has gained major popularity in a short time. When BIM is implemented in the planning process, performance in the projects is enhanced. BIM helps to reduce costs, encourages better time management, and strengthens workplace partnerships. Starting a successful initiation for a country's growth is never late to work.

This research addressed the findings of a questionnaire survey with the main objective of determining critical success factors (CFCs) for implementing BIM in developing countries and examining among the factors their rankings and underlying associations. In this study, 11 factors were identified by the literature review as ways of evaluating important CSFs. A questionnaire survey for industry practitioners was introduced. BIM benchmark measures were developed and used to evaluate critical success factors in the order of importance. The five most important success factors were identified as BIM training programmes, return on investment, legal aspects, stakeholder involvement, and industry culture.

This research has led to understanding the situation of BIM in the construction sector of emerging countries with key CSFs for its implementation. The ranking of CSFs has strategic consequences as it offers a framework for identifying the most important factors that business leaders should focus on to effectively implement BIM. Since the main objective of the thesis was to identify the critical success factors of BIM implementation in developing countries, it can be concluded that BIM training programmes and return on investment are the most important critical success factors for the BIM implementation in developing countries, along with nine other, minor factors.

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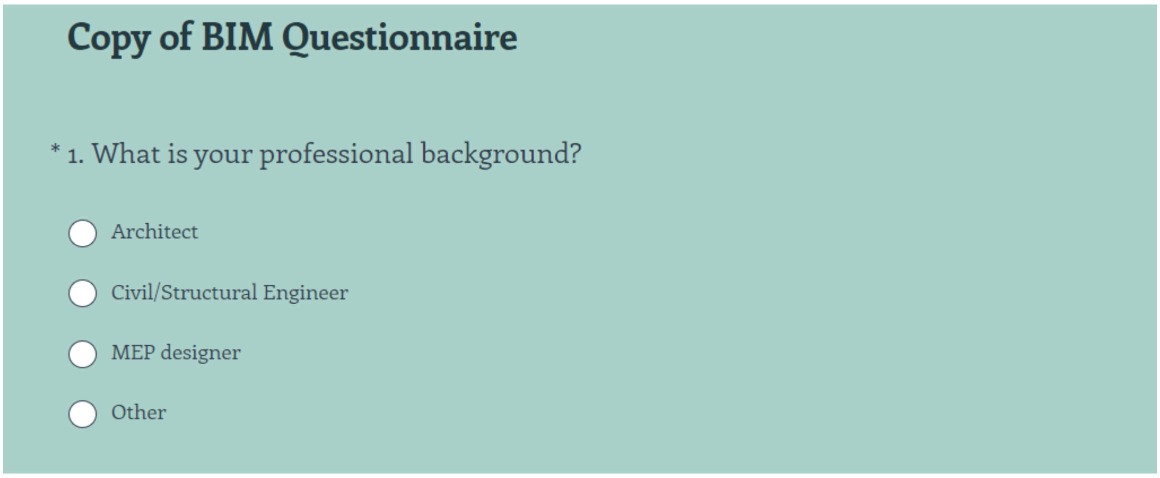
Survey Questionnaire

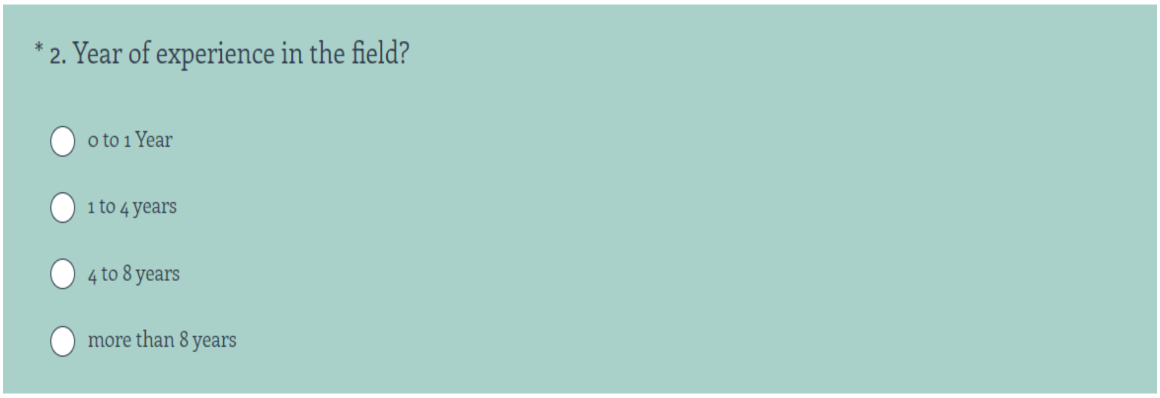
Questionnaire survey template from monkey survey.


Copy of BIM Questionnaire

* 1. What is your professional background?

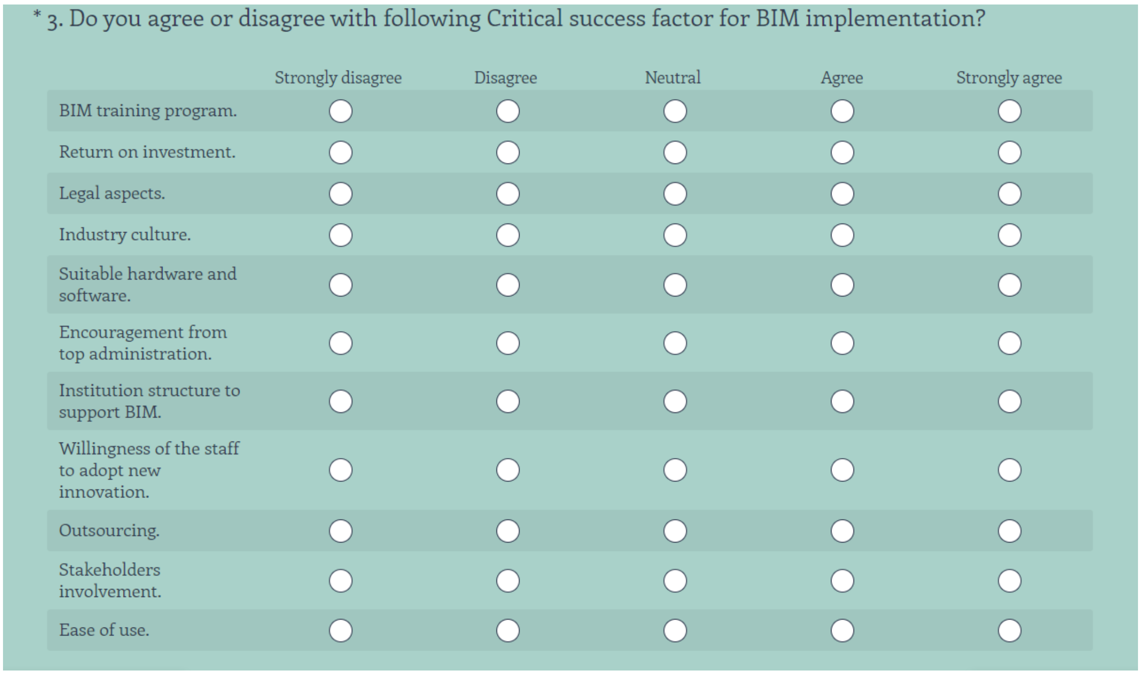
- Architect
- Civil/Structural Engineer
- MEP designer
- Other

Figure 1. Question number 1 of the questionnaire survey.


* 2. Year of experience in the field?

- 0 to 1 Year
- 1 to 4 years
- 4 to 8 years
- more than 8 years

Figure 2. Question number 2 of the questionnaire survey.



* 3. Do you agree or disagree with following Critical success factor for BIM implementation?

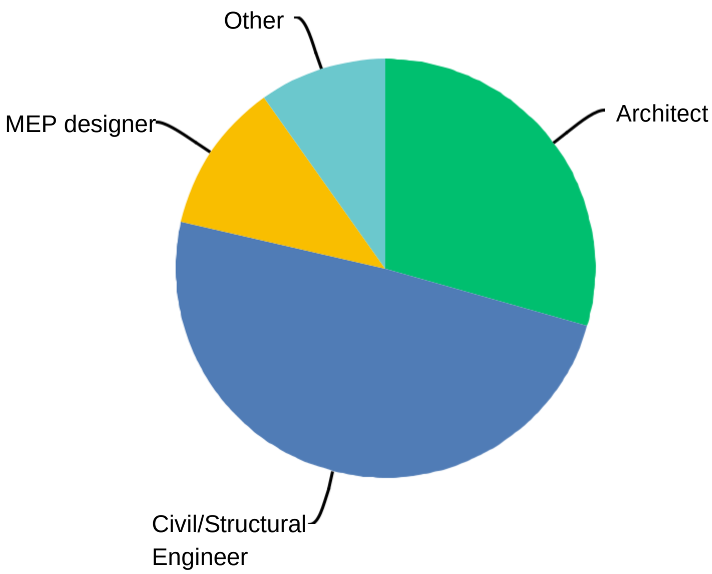
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
BIM training program.	○	○	○	○	○
Return on investment.	○	○	○	○	○
Legal aspects.	○	○	○	○	○
Industry culture.	○	○	○	○	○
Suitable hardware and software.	○	○	○	○	○
Encouragement from top administration.	○	○	○	○	○
Institution structure to support BIM.	○	○	○	○	○
Willingness of the staff to adopt new innovation.	○	○	○	○	○
Outsourcing.	○	○	○	○	○
Stakeholders involvement.	○	○	○	○	○
Ease of use.	○	○	○	○	○

Figure 3. Question number 3 of the questionnaire survey.

Respondents Response.

Q1 What is your professional background?

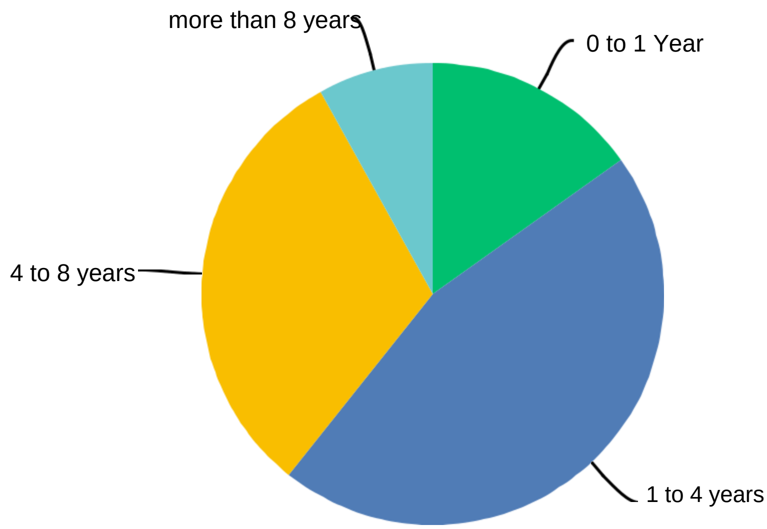
Answered: 112 Skipped: 0



ANSWER CHOICES	RESPONSES	
Architect	29.46%	33
Civil/Structural Engineer	49.11%	55
MEP designer	11.61%	13
Other	9.82%	11
TOTAL		112

Q2 years of experience in the field?

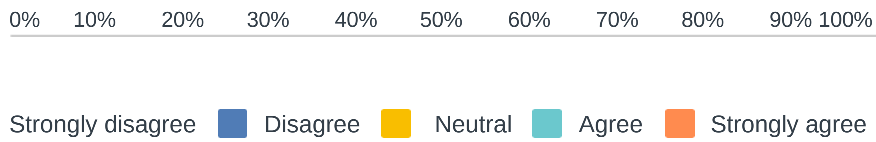
Answered: 112Skipped: 0



ANSWER CHOICES	RESPONSES	
0 to 1 Year	15.18%	17
1 to 4 years	45.54%	51
4 to 8 years	31.25%	35
more than 8 years	8.04%	9
TOTAL		112

Q3 Do you agree or disagree with the following Critical success factor for BIM implementation?

SurveyMonkey



	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE	TOTAL
BIM training program.	0.00% 0	0.00% 0	7.14% 8	33.93% 38	58.93% 66	112
Return on investment.	0.00% 0	0.00% 0	9.82% 11	46.43% 52	43.75% 49	112
Legal aspects.	1.79% 2	0.89% 1	15.18% 17	54.46% 61	27.68% 31	112
Industry culture.	0.00% 0	6.25% 7	56.25% 63	31.25% 35	6.25% 7	112
Suitable hardware and software.	0.89% 1	11.61% 13	33.04% 37	46.43% 52	8.04% 9	112
Encouragement from top administration.	7.14% 8	34.82% 39	44.64% 50	8.93% 10	4.46% 5	112
Institution structure to support BIM.	9.82% 11	42.86% 48	28.57% 32	12.50% 14	6.25% 7	112
Willingness of the staff to adopt new innovation.	26.79% 30	41.96% 47	10.71% 12	13.39% 15	7.14% 8	112
Outsourcing.	1.79% 2	10.71% 12	53.57% 60	27.68% 31	6.25% 7	112
Stakeholders involvement.	0.89% 1	3.57% 4	12.50% 14	59.82% 67	23.21% 26	112
Ease of use.	1.79% 2	21.43% 24	40.18% 45	19.64% 22	16.96% 19	112
Outsourcing.	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0