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Building Information Modeling in the Architecture and Construction Industry

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Abstract

This study aims to investigate the benefits, risks, barriers, and approaches of building information modeling (BIM) implementation in the architecture, engineering and construction (AEC) industries. Descriptive research methods such as surveys and key informant interviews are used to gather data. Respondents in the survey come from different AEC companies and are selected with a purposive sampling method. Descriptive statistics and one-way analysis of variance (ANOVA) are utilized to analyze the data. The narrative analysis method is also performed to validate the research findings through a desk review of secondary data. The result shows that the major benefit of BIM is earlier and more accurate design visualization, while the main risk is accountability and control of data entry into the model. Moreover, the major barrier to BIM implementation is the high acquisition cost, and the most recommended approach is to increase the availability of BIM technology.

Keywords: building information modeling, digitized construction, BIM technology, AEC industry, BIM framework

1. Introduction

The construction industry is considered one of the most complex and fragmented industries. Its management processes are known to be complicated since uncertainties and risks are mostly inevitable in any construction project [1]. According to Leeds' research [2], construction companies confront many challenges in the productivity, profitability, labor, performance, and sustainability of their projects. Most of these companies experience a profit reduction and low productivity due to several factors, such as delays in project completion and changes in the design and construction schedules. In addition, inconsistency in generating information also increases the difficulty of project planning, resulting in misinterpretation of plans and misunderstanding among project stakeholders.

Increasing productivity and efficiency has been the primary goal in the architecture, engineering, and construction (AEC) sector. Likewise, contractors and designers find ways to eliminate errors, omissions, and changes in project plans as well as designs while managing a vast amount of building information throughout the project life cycle. Information management is one of the best approaches to achieving these goals [3]. However, due to a lack of information technology (IT) adoption and utilization, information management needs to be improved in the AEC sector in developing countries like the Philippines. Although IT is currently being applied in the construction project life cycle, its usage is partial and isolated. It does not support collaboration and coordination between different systems and disciplines. However, over the past three decades, the construction sector has experienced considerable advancements in using information technology to improve design and construction operations [4]. The most promising development during this period is building information modeling (BIM) [5].

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BIM is a state-of-the-art technology steadily making its way into various AEC industry operations. It comprises the process of creating and application of a computer-generated model to replicate and simulate a facility's planning, design, building, and operation [6]. BIM models are now changing how buildings and infrastructures work. BIM has recently attracted increased attention, particularly in the AEC sector. Many projects have successfully implemented BIM because of the perceived significant benefits, such as decreased construction cost and duration, increased design quality, improved field productivity, and reduced conflicts and changes, to name a few [7-8]. In more advanced countries like the USA, Japan, Australia, and Singapore, BIM is already mandated for all construction projects, but BIM awareness of the construction industry in the Philippines still needs to improve. Several factors contribute to this slow adoption of BIM in the country. Aside from financial constraints, a lack of awareness and knowledge of BIM makes the Philippines lag behind its neighboring countries in digitizing construction.

In the Philippines and other developing countries, the use of BIM in the construction sector is still in its early stages. This lack of widespread acceptance of BIM is related to the risks and challenges hindering its effectiveness [8]. Most of the construction projects in the country are still entrenched in traditional processes, and fully adopting BIM is difficult due to a shortage of skilled manpower and resources to build BIM capabilities. More importantly, there is no government mandate to support the implementation of BIM in all construction projects.

Based on the foregoing, this study analyzes the benefits, risks, barriers, and challenges associated with BIM and provides recommendations for future BIM adoption. The purpose of this study is to contribute to the limited but increasing empirical pieces of literature and studies on BIM. Moreover, it aims to discuss the practical application of BIM in the Philippine construction industry, especially the industry stakeholders' current levels of BIM deployment. It also identified the benefits of BIM and the problems that come with it. It would be helpful to address the prevailing issues and problems related to BIM in the construction industry after providing recommendations and formulating guidelines. The proposed framework of guidelines for adopting and implementing BIM is hoped to significantly improve the design, construction, and operation of different infrastructures in the country.

2. Literature Review

2.1. Main concepts of BIM

For the past decade, the AEC sector has been at the forefront of the digital revolution. At this level of development, BIM was introduced. BIM is a digital tool for communication, collaboration, scheduling, and visualization among project participants across the whole project life cycle [5, 9]. According to Azhar et al. [6], a computer-generated model was proposed and used in the BIM process to simulate facility planning, design, building, and operation. BIM aids the construction sector by improving user productivity and bringing notable advantages throughout the life cycle of a structure, particularly in facilities management, construction, and design. Ismail et al. [10] stated that BIM's accurate geometrical representation of building components in a digital form is its most important advantage. In the case study conducted by Yan and Demian [7], the shortening of project duration was the main advantage of BIM deployment while reducing human resources and project cost, sustainability, quality improvement, and creativity came next.

2.2. BIM adoption in different countries

In recent years, the adoption of BIM has significantly increased in several countries worldwide, particularly in many developed nations such as Singapore, the USA, and Japan. Singapore, for instance, is one of the leading countries considering BIM as a standard practice. The country regularly conducts BIM conferences, workshops, and seminars on the utilization of BIM in construction projects [11].

On the other hand, Lorek [12] discussed a brief history of BIM and indicated that although BIM is not yet mandated in the USA, its adoption may significantly grow in the years to come. In Japan, Ishizawa et al. [13] analyzed the BIM protocols in the country, and they found that the Japanese government has introduced the use of BIM for almost ten years already. The Japanese government issued guidelines for BIM adoption to motivate and encourage Japanese practitioners to continue BIM utilization. The review article by Kaneta et al. [14] revealed the problems of BIM implementation in Japan and the opposition by general contractors and architectural firms. The reason is that clients are often unaware of the value and incentive that BIM can bring.

Most developed countries actively employ BIM, while the implementations in developing countries are rare and less advanced than in most developed countries. Several pieces of research show how construction firms struggle with limitations such as the socio-economic and technological environment in developing countries. For instance, in India, the construction industry has only a few BIM users with limited BIM knowledge [10]. Although it was acknowledged that BIM could address many problems in the construction sector, its adoption is still considered premature. Since no specific initiatives coming from the Indian government, some private organizations took the initiative to make BIM mandatory for a few of their projects [10].

Meanwhile, in Malaysia, the Construction Industry Development Board (CIDB) has undertaken several initiatives to improve BIM implementation, such as setting up a reference project using BIM, assigning committees to monitor BIM activities, and conducting BIM seminars and workshops [15]. However, despite these initiatives, a low BIM adoption in Malaysia was still reported [10]. Similar experiences were also observed in Indonesia. According to Ismail et al. [10], Indonesians were highly aware of BIM execution in the construction industry. Nevertheless, the technology used in the country was low due to a lack of BIM implementation standards and regulations, which is why only large projects have utilized BIM in their design [10].

In South Africa, there is a lack of strong support for the implementation of BIM technology from governmental agencies. Nonetheless, there are also no uniform standards or guidelines for BIM implementation. According to a survey conducted by Kekana et al. [15], the construction industry in South Africa is technologically aware of BIM, but its application is still low due to unwillingness to change the traditional methods of practice. Furthermore, they pointed out that most of the BIM users in organizations were managers or designers only, and they usually utilized BIM for particular purposes such as cost estimation, construction simulation, and management [15]. According to Korff's research [16], BIM implementation in South Africa has slowed down on account of an underfunded public sector, disinterest in the private sector towards BIM uptake, and a cheap labor force.

In addition, Pakistan also experienced a very slow adoption of BIM technology compared to other neighboring countries. Therefore, some studies were conducted regarding the knowledge and barriers to BIM implementation among Pakistani construction players [17]. The majority of Pakistani respondents claimed that they need more knowledge about BIM and the barriers to its implementation include the belief that current practice is still serving them well and the limitation of its adoption in the local market.

2.3. Current status of BIM adoption in the Philippines

In the Philippines, 1/3 of the construction industry investors started enacting the BIM process, especially in developing 3D models with BIM software. However, the remaining 2/3 is still unaware of the BIM and all its advantages [18]. Furthermore, Gonzalez [19] stated that only about 20% of the surveying industries utilized BIM software for quantity takeoff, and the rest were content with using the traditional way. Most of the users of BIM in the AEC industry are involved in projects globally that need to be submitted in BIM formats, and they can compete internationally.

Work and skill demands in the country at a local level are mostly related to AutoCAD, and neither universities nor colleges have offered BIM-based schooling. Consequently, several construction companies and owners have not yet engaged in BIM and realized its potential. The cost of hardware and software is also a massive deterrent to updating the latest versions of BIM. As a result, local market support for BIM is very low [20]. Regarding education, some factors restrained the BIM courses from being properly included in the engineering curricula, i.e. the high cost of BIM software and hardware, a lack of certified mentors and trainers, and a low level of BIM awareness [18].

2.4. Synthesis

Even if most developing countries emphasized a low BIM adoption in certain regions, the advantages of this technology have been acknowledged as well. But more crucially, the difficulties or hurdles associated with its implementation must receive serious consideration if the BIM capabilities can be properly leveraged to raise its usage. In the past decade, the adoption of BIM has improved significantly in the AEC industry. However, the implementation of BIM in different countries could have been improved due to numerous barriers. Alreshidi et al. [21] found that the major barriers hindering companies from implementing BIM were resistance to change by senior employees, lack of training, and disintegration of the project team. Based on the foregoing review of different literature and studies about BIM, there seems a need to further investigate the benefits, risks, and barriers of BIM, particularly in developing countries such as the Philippines, where BIM implementation is still at a very low level.

3. Methodology

This section describes the research design and methods utilized in the study. Additionally, it also covers the tools and techniques employed during the data collection process. It specifically outlines the research locale, sample and sampling techniques, data gathering methods and processes, statistical treatment of data, and limitations of the study.

3.1. Research design

This study utilized descriptive and survey research methods, which systematically and accurately describe the facts and characteristics of a given population to provide an accurate account of the characteristics of a particular individual, situation, and group. Moreover, survey research gathers data from a population to determine the status concerning variables or subjects under investigation, which is to determine the benefits, risks, barriers, and approaches of BIM.

3.2. Conceptual framework

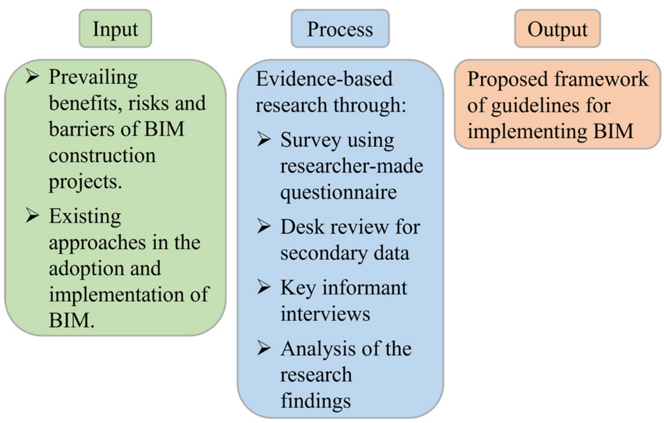

Fig. 1 Conceptual framework of the study

As presented conceptual framework in Fig. 1, the inputs of this research include the prevailing benefits, risks, and barriers of BIM and the existing approaches in adopting and implementing BIM in construction projects. Statistical treatment of data is contained in the inputs of the study, which served as the foundation for a thorough examination of research findings, conclusions, and recommendations. The process and methodology section of this study comprise evidence-based empirical research using a survey questionnaire, desk review or analysis of project documents as secondary data, key informant interviews, and analysis of findings. Finally, the output of this study is a management model that would serve as guidelines to the contractors, consultants, owners, and construction industry professionals for adopting and implementing BIM processes in construction projects.

3.3. Research locale

This research was conducted in the cities included in the National Capital Region (NCR) of the Philippines. NCR is the ideal location for this study owing to its diversity and technological advancement. It is also a residence for the largest construction projects, owners, developers, consultancy, and engineering design companies.

3.4. Sample and sampling techniques

A purposive sampling method was applied in this study, and the data were obtained from respondents from different companies representing contractors, consultants, and their clients in selected cities in NCR, particularly Manila, Quezon, Makati, Pasig, Taguig, and Muntinlupa. Purposive sampling was used in this study to select a particular population or expert group that can answer the research questions best.

Specifically, among the types of purposive sampling methods, the expert sampling method was used since the study requires inputs and opinions from industry experts who are knowledgeable in BIM and currently working and involved in BIM implementation in their respective companies.

A total of 105 respondents, who could answer and return the questionnaires to the researcher, served as the study participants. Fig. 2 shows that 31.43% of all the respondents are clients, 35.24% are consultants, and 33.33% are contractors. The sample population is quite equally distributed among the three groups of respondents and represents a mix of private and government respondents.

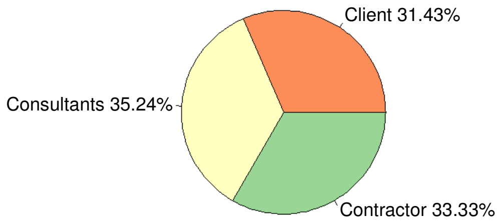

Fig. 2 Distribution of respondents

3.5. Data gathering methods

A questionnaire was developed for this study to collect data; answer the research questions; and assess the perception of contractors, consultants, and clients on BIM. This questionnaire is made up of five parts. Part I contained the demographic profile of the respondents, such as profession, years of using BIM, position in the company, and nature of their companies. Parts II, III, IV, and V include questions regarding the benefits, risks, barriers, and approaches of BIM in Philippine construction projects.

3.6. Data gathering process

Before administering the survey questionnaires to the target sample respondents, a pilot test was conducted on selected respondents who were experts in BIM. The objectives of the pilot test are to determine the validity and reliability of the questions and confirm whether the questionnaires are easy to accomplish and specific to the research questions. In addition to the survey questionnaire, key informant interviews were conducted with a select group of respondents to get first-hand knowledge of the project's background and history to learn more about how their projects adopt and implement BIM.

The important information gathered from the interviews and observations was used as evidence-based information. It is great to help assess and interpret the findings on the current state of BIM implementation in various building projects in the Philippines. Furthermore, project documents were collected, particularly those relevant to the project's commercial, contractual, and design components. These were used to validate and corroborate the study findings during the desk review of secondary data. The narrative analysis method was applied to analyze these secondary data, and the researcher used the aforementioned collected documents to interpret and explain or validate the research findings.

3.7. Statistical treatment of data

A series of questionnaires were distributed to the intended respondents to achieve the research objectives. The data gathered from the administered questionnaires were tallied, classified, categorized, and evaluated by the study's objectives. Percentage and weighted mean were utilized as descriptive statistics in this study. The percentage can be found by:

$$p = \frac{f}{N} \times 100\% \tag{1}$$

where p is the percentage, f is the frequency of responses and N is the total number of cases. The weighted mean can be found by:

$$\overline{x} = \frac{\sum f_x}{N} \tag{2}$$

where $\bar{x}$ is the computed value of the weighted mean, f is the frequency, x is the unit weight, and N is the total number of respondents.

The one-way analysis of variance (ANOVA) was also performed to find out if there were any significant differences in perceptions regarding the benefits, risks, and barriers of BIM among all the respondents. ANOVA can be computed as follows:

$$F = \frac{MST}{MSE} \tag{3}$$

where F is the ANOVA coefficient, MST is the mean sum of squares of treatment, and MSE is the mean sum of squares of error. MST can be computed as:

$$MST = \frac{SST}{p-1} \tag{4}$$

$$SST = \sum n\left(x-\overline{x}\right)^2 \tag{5}$$

where SST is the sum of squares of treatment, p is the total number of population, and n is the total number of samples. Lastly, MSE can be found by:

$$MSE = \frac{SSE}{N-p} \tag{6}$$

$$SSE = \sum\left(n-1\right)S \tag{7}$$

where SSE is the sum of squares of error, S is the standard deviation of the samples, and N is the total number of observations.

3.8. Limitations of the study

The unit of analysis is based solely on the perception and opinions of the respondents from different AEC companies. The first limitation is related to the data used for construction projects which are limited to only five selected cities and municipalities in the capital region of the Philippines. It could only cover part of the area due to difficulty in the retrieval of questionnaires and the unavailability of the respondents. Thus, the statistical strength of the total sample is relatively moderate owing to the small sample size used in the analyses. Nevertheless, the perceptions and opinions gathered and generated from the three groups of respondents represented the entire study population.

4. Results and Discussion

This section presents the results of the conducted research survey, analysis of gathered data, and interpretation and discussion of research findings. It also includes a proposed research-validated set of guidelines for adopting BIM in various construction projects.

4.1. Benefits of building information modeling (BIM)

Table 1 Benefits of BIM

Benefits of BIM	Mean	Std. deviation	Rank	Interpretation
Provides more accurate data visualizations at the earlier stages of the design.	4.52	0.71	1	Very often
Design errors, omissions, conflicts, and clashes are detected before construction.	4.51	0.64	2	Very often
It provides preliminary insight into design problems and presents opportunities for continuous improvement of the design.	4.44	0.71	3	Very often
Proposals are better understood through accurate visualization of plans.	4.42	0.65	4	Very often
BIM can integrate multiple design disciplines into one plan.	4.39	0.75	5	Very often
Average	4.46	0.69	-	Very often

Based on the results in Table 1, earlier and more accurate design visualization is one of the most significant benefits of BIM in the Philippine AEC industry [20, 22]. BIM allows the compilation of every discipline of a project into one complete design, including 3D models and detailed floor plans. Through this approach, project stakeholders can see or imagine the project in a real-world scenario, a feature that the traditional paper or 2D design plans fail to deliver. Moreover, accurate visualization of the plans also leads to a better understanding of project proposals, according to the respondents.

The next benefit of BIM is the detection of errors, omissions, conflicts, and clashes. According to key-informant-interviews (KIIs) and the research experience from the respondents, the BIM toolset helps in automatically detecting clashes among building elements, such as electrical conduit or ductwork that run into a beam. By modeling various electrical and mechanical utilities and structural members, clashes are discovered early in the project and thus reducing costly on-site clashes. BIM has an earlier insight into design problems as well. Since BIM can detect design errors and omissions early, engineers and architects can easily modify and improve the design according to the client's specifications.

Interestingly, the respondents' top benefits of BIM are confirmed in several pieces of research conducted in different countries [7, 20, 22-23]. According to these studies, the main advantages of BIM were precise design visualization, cost and time savings, and coordination and collaboration among many disciplines. On account of the early detection of errors, conflicts, and collisions, BIM not only can improve visualization and creativity but also reduce cost and time. Coordination and collaboration of different design disciplines were also the perceived benefits of BIM in their respective countries. Although past studies were conducted at different times and settings, the same benefits were observed in BIM implementation regardless of the location.

4.2. Risks of BIM

Based on Table 2, it can be deduced that respondents rated the control of data entry and the responsibility for any errors and inaccuracies as the most critical risks of BIM. The risk of controlling data entry into the model and changing a BIM model has become a recent issue in large and complex construction projects [24]. Designers, consultants, and contractors may change the design according to their preferences without informing or sharing ideas with the entire project team. This would create confusion among the parties involved and cause conflicts and flawed interactions between different trade disciplines.

Another key concern about BIM is the accountability for any inaccuracies and errors in the design. Responsibilities are blurred since each party has participated and contributed in the planning stages, design, revisions, and input to the BIM model. Uncertainty about what aspect of the model each party had contributed to the project would probably lead to confusion over the liability for any mistakes and conflicts in the design.

Table 2 Risks of BIM

Benefits of BIM	Mean	Std. deviation	Rank	Interpretation
Control in entering the data into the model and accountability for any errors and inaccuracies in it.	3.49	0.98	1	Sometimes
Financial risks due to a large amount of investment in purchasing BIM software and training staff.	3.38	0.99	2	Sometimes
Software licensing issues may arise.	3.23	1.08	3	Sometimes
Experienced senior staff who are used to traditional processes may resist changes.	3.08	0.90	4	Sometimes
Unrealistic project scheduling may cause delays in project completion.	3.07	0.93	5	Sometimes
Average	3.25	0.98	-	Sometimes

In addition, another most commonly identified risk of BIM is related to financial risk which is caused by a large amount of investment and staff training. According to respondents during the KIIs, there is no assurance that they can recover the costs spent in purchasing the BIM software packages and skills training of their staff, which can be very costly.

In the Philippines, for instance, the current price for a single licensed Revit BIM software is around 6,000 to 7,000 US dollars, while the training cost is around 100 to 200 US dollars per person. According to Ham et al. [25], the percentage of BIM investment to the whole project cost ranges from 0.00% to 0.91%. This can impose much financial burden on a company, especially start-ups and small-scale construction and design firms.

Resistance to change and delay due to unrealistic project scheduling are also identified respectively as the top four and five most important risks of BIM. It is inherent to most people to resist any changes to the status quo and traditional practices. Khalil et al. [23] indicated that it is challenging to change people's behaviors once they have grown accustomed to certain ways and patterns. That is why introducing new technology such as BIM may face opposition and rejection from senior staff and thus fail its implementation. Respondents are also concerned about the reliability of the scheduling capabilities of BIM. This issue was also raised in the study of Wang and Chien [26], wherein they reported that AEC professionals need to adapt to the new BIM-based technique management process to eliminate the risk of delay caused by unrealistic scheduling.

The degree of occurrence is quite different since the identified five major risks of BIM are sometimes happening according to the data. It is observed that since BIM is just in its early stages of implementation in the country, the identified risks still need to be fully realized by project stakeholders. The respondents are more aware of the immediate benefits of implementing BIM than the risks attributed to it.

4.3. Barriers to BIM

As shown in Table 3, interesting findings can be observed from the processed data that almost all respondents agreed that the top three most important barriers are related to the costs needed to implement BIM in various construction projects fully. These costs are identified as costs derived from the acquisition of BIM software licenses and skills training of staff. With limited funding and budget, especially for government projects and small and medium-sized enterprises (SMEs), these identified costs are regarded as barriers that hinder companies from implementing or adopting BIM in their projects.

Table 3 Barriers to BIM

Benefits of BIM	Mean	Std. deviation	Rank	Interpretation
Expensive BIM software licenses.	4.25	0.90	1	Very often
High cost of personnel training and BIM implementation.	3.86	0.96	2	Often
Limited project funding and budget.	3.68	1.00	3	Often
Lack of qualified and skilled professionals to handle or operate BIM tools and software.	3.64	1.00	4	Often
Expensive human-based services costs.	3.63	0.86	5	Often
Average	3.81	0.94	-	Often

According to the respondents, it is too risky to invest much money into something that still needs to be established or proven effective in improving construction processes. However, based on the research experience, the cost is not the primary cause of the slow adoption of BIM; it is the need for more support and the willingness of project stakeholders to utilize this new technology. This is supported by Kouide et al. [27], who also found that the interest and willingness of project managers and engineers play an important role in BIM implementation apart from costs. Therefore, Khalil et al. [23] suggested that to ensure the success of BIM implementation, the government or private clients must impose it in the contract through mandatory legislation and supervision.

The next barriers to BIM are related to manpower, especially the need for more trained professionals and expensive human-based services costs such as salary for skilled BIM modelers. The lack of trained or skilled professionals is one of the major factors which hinder the full implementation of BIM [23]. Only a few professionals know or have undergone proper training and education regarding BIM. This situation may be because only a few students graduating from engineering or architecture programs have the skills and knowledge about BIM, and most colleges and universities in the country have not yet incorporated BIM in their curricula.

According to Sabongi [28], the possible reason why BIM is not yet included in the curriculum is that there is no room for new courses in the existing curriculum since there is a limit to the number of courses per degree program. There is already an increasing demand for BIM modelers but with limited trained professionals; thus, the cost of hiring such skilled manpower resources also increases. Consequently, most respondents agreed that the high cost of hiring skilled professionals hinders companies from adopting BIM.

4.4. Approaches to implementing BIM

Based on Table 4, respondents suggested that the AEC industry must increase the availability of BIM technologies and software to implement BIM. Interestingly, even though respondents find the acquisition of BIM software quite expensive, they still chose this approach to start adopting BIM in their projects. In other words, if they are given sufficient funds and budget, they would invest in BIM tools and software to establish BIM in their respective companies. Besides, another best approach towards successful BIM implementation is the establishment of BIM project execution guidelines and suggesting ways to move from traditional practices into BIM. This approach will greatly help companies with little or no idea how they would start implementing BIM.

Table 4 Approaches to implementing BIM

Approaches to implementing BIM	Mean	Std. deviation	Rank	Interpretation
BIM technology should be made more widely available.	4.10	0.82	1	Often
Develop BIM project execution guidelines to facilitate BIM implementation	4.01	0.89	2	Often
Increase BIM technology research in higher learning institutions.	3.99	1.02	3	Often
Establish feasible ways how to move from traditional practice into BIM.	3.98	0.81	4	Often
Organize BIM workshops to raise awareness among stakeholders.	3.96	1.08	5	Often
Average	4.01	0.93	-	Often

Another approach identified by the respondents is to increase research for BIM technology in colleges and universities. Azhar [22] suggested that BIM must be included in the curricula of engineering and architecture programs to increase BIM awareness among students, and the education and training of BIM software should be implemented. Additionally, research in the field of BIM must also be conducted to continuously improve BIM processes and come up with innovations in BIM technology. Finally, the respondents agree that to increase awareness regarding BIM, workshops, seminars, and training must be conducted. This approach addresses the problem regarding the need for more awareness and knowledge about BIM.

4.5. Differences in perception about the benefits, risks, and barriers of BIM between clients, consultants, and contractors

A situation is hypothesized that there is no significant difference between the client, consultant, and contractor's responses about the benefits, risks, and barriers of BIM in various construction projects in the Philippines. To test this hypothesis, the following tables show the results of the one-way ANOVA on the differences in perceptions among the respondents. To see if there is a significant difference in the respondents' responses, a 0.05 level of confidence is employed. The results in Table 5 revealed significant differences in the perceptions of clients, consultants, and contractors on one of the five identified benefits of BIM, which has something to do with the high-level customization of building systems ($p = 0.030$). The significant differences in perceptions indicated that respondents disagree on how often this identified benefit happens or is experienced in construction projects.

Table 5 Differences in perception between client, consultant, and contractor regarding the benefits of BIM

Benefits of BIM		Sum of squares	df	Mean square	F	Sig.
Project coordination and collaboration	Between groups	0.27	2.00	0.13	0.38	0.686
	Within groups	36.17	102.00	0.35	-	-
	Total	36.44	104.00	-	-	-
Constructability assessment and risk aversion	Between groups	0.50	2.00	0.25	1.10	0.337
	Within groups	23.10	102.00	0.23	-	-
	Total	23.59	104.00	-	-	-
High-level customization of building systems	Between groups	2.06	2.00	1.03	3.62	***0.030**
	Within groups	29.03	102.00	0.28	-	-
	Total	31.09	104.00	-	-	-
Optimization of project schedule and cost estimates	Between groups	3.32	2.00	1.66	2.97	0.056
	Within groups	57.04	102.00	0.56	-	-
	Total	60.36	104.00	-	-	-
Improved project documentation	Between groups	1.51	2.00	0.76	1.48	0.233
	Within groups	52.18	102.00	0.51	-	-
	Total	53.69	104.00	-	-	-

**Significant at 0.05 level of confidence*

From the foregoing exposition, it is safe to assume that the disagreement between clients, consultants, and contractors on high-level customization as one of the major benefits of BIM is due to the differences in the scope of work and contract conditions that the two groups of respondents are engaging with. Consultants are generally more engaged in revising plans and designs, while clients suggest changes in the plans. Consultants may seem to regard BIM as beneficial when it comes to customization, but clients think otherwise, as revealed by their low mean scores. Although BIM enables consultants to change and customize complex designs more easily, this would mean additional costs for clients. The same findings were observed in the study presented by Akdag and Maqsood [29]. They found that clients typically do not support the use of BIM for their projects due to a lack of knowledge and hesitancy to invest in a novel and innovative technology on the market.

As to the risks of BIM, the data revealed significant differences in perceptions about the risks related to data integrity and security (p = 0.016), as shown in Table 6. Consultants or designers, being the ones who mostly use BIM software to design and model structures, are more aware of the risks of possible loss and mishandling of BIM data and inaccuracies of the data entered into the model. On the other hand, clients seldom use BIM software and pass on to consultants or designers the task of modeling the design they want. As a result, clients mostly do not experience these risks and are unaware of them [29].

Table 6 Differences in perception between client, consultant, and contractor regarding the risks of BIM

Benefits of BIM		Sum of squares	df	Mean square	F	Sig.
Legal risks	Between groups	1.31	2.00	0.66	1.09	0.341
	Within groups	61.60	102.00	0.60	-	-
	Total	62.91	104.00	-	-	-
Data integrity and security	Between groups	4.17	2.00	2.09	4.31	***0.016**
	Within groups	49.39	102.00	0.48	-	-
	Total	53.56	104.00	-	-	-
Project-related risks	Between groups	1.26	2.00	0.63	1.43	0.245
	Within groups	44.98	102.00	0.44	-	-
	Total	46.24	104.00	-	-	-
Financial risks	Between groups	1.79	2.00	0.90	1.32	0.272
	Within groups	69.20	102.00	0.68	-	-
	Total	70.99	104.00	-	-	-

**Significant at 0.05 level of confidence*

Table 7 Differences in perception between client, consultant, and contractor regarding the barriers of BIM

Benefits of BIM		Sum of squares	df	Mean square	F	Sig.
Social-organizational barriers	Between groups	1.01	2.00	0.51	1.13	0.327
	Within groups	45.85	102.00	0.45	-	-
	Total	46.86	104.00	-	-	-
Financial-related barriers	Between groups	3.15	2.00	1.58	2.45	0.091
	Within groups	65.56	102.00	0.64	-	-
	Total	68.71	104.00	-	-	-
Technical-related barriers	Between groups	0.13	2.00	0.07	0.15	0.863
	Within groups	45.35	102.00	0.44	-	-
	Total	45.48	104.00	-	-	-
Contractual-related barriers	Between groups	1.20	2.00	0.60	0.89	0.415
	Within groups	69.19	102.00	0.68	-	-
	Total	70.40	104.00	-	-	-
Legal-related barriers	Between groups	0.20	2.00	0.10	0.16	0.854
	Within groups	63.53	102.00	0.62	-	-
	Total	63.72	104.00	-	-	-

**Significant at 0.05 level of confidence*

Concerning the barriers, the data in Table 7 reveal no significant differences in the perception of all the identified barriers of BIM. These findings suggest that clients, consultants, and contractors agreed on the identified barriers of BIM in the Philippine AEC industry.

4.6. Proposed framework of guidelines for implementing BIM

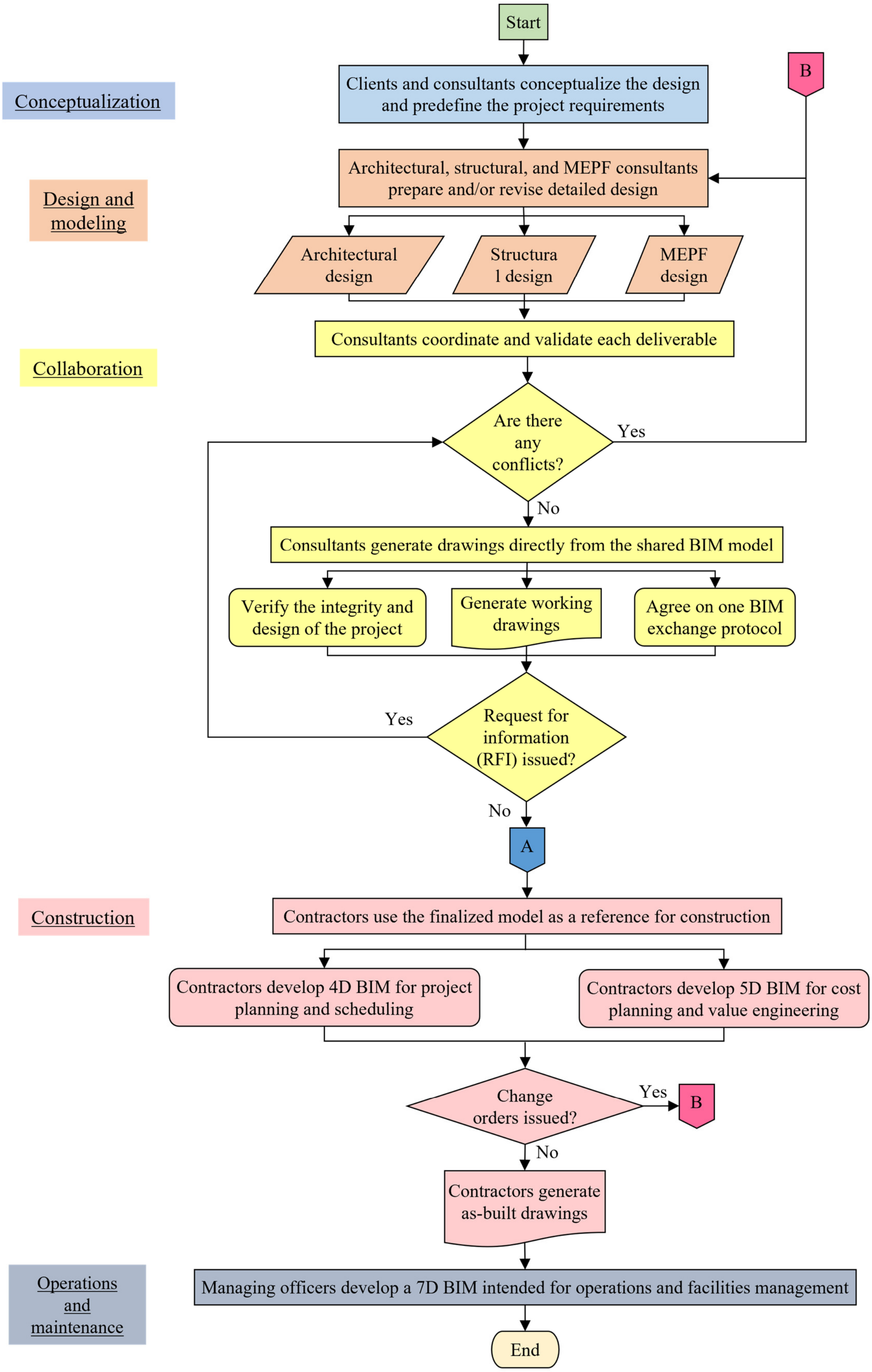

Fig. 3 BIM implementation guidelines

To effectively adopt and implement BIM in building construction projects in NCR, the following step-by-step procedures on using BIM in designing, constructing, and operating building and infrastructure projects are therefore recommended. Fig. 3 shows a research-validated guideline that provides companies with a comprehensive approach to adopting and implementing BIM in their projects.

5. Conclusions

In this research, the small but growing pieces of literature and studies regarding BIM were analyzed. The descriptive research method was applied to investigate the benefits, risks, barriers, and approaches of BIM implementation. Research findings were then used to formulate recommendations and design guidelines for implementing BIM in construction projects. In light of the previous findings, the following conclusions were drawn:

(1) The benefits of BIM were visualizations of a design earlier and more accurately and the detection of design errors, omissions, and clashes. Other benefits were providing preliminary insights into design problems, a better understanding of proposals, and integrating multiple disciplines into one plan.

(2) The risks were the responsibility and control of data entry of the model, financial risks, and software licensing issues. Other risks such as resistance to change by senior staff and delays in project completion were also experienced.

(3) The barriers to BIM implementation were the expensive acquisition of BIM software licenses, high cost of personnel training and BIM implementation, limited project funding and budget, lack of trained professionals to handle BIM tools and software, and expensive human-based services costs.

(4) The most common practices or approaches in addressing the challenges of BIM implementation were: increasing the availability of BIM technology, establishing BIM execution guidelines, innovating research for BIM technology, organizing the transition process from traditional practice to BIM, and conducting workshops on BIM.

(5) The respondents have significantly different perspectives on the benefits of BIM, particularly on BIM's high level of customization of building systems. However, fewer differences in all of the top five risks of BIM were observed, except for data integrity and security.

(6) A research-validated framework or guidelines was designed to help the AEC sector implement BIM in their construction projects. This framework will give clients, consultants, and contractors a thorough plan for how to start using BIM in their projects.

6. Recommendations

One of the objectives of this study is to recommend how to adopt and implement BIM in the AEC industry, particularly in construction projects. Therefore, considering the results of the study as reflected in the findings and conclusions, the following recommendations are offered:

(1) To immediately start implementing BIM in the Philippine AEC industry, BIM technology should be required in the construction contracts for consultants and contractors to adopt this new technology. It is also necessary that an information manager should be assigned to each project to manage the processes and procedures for information exchange, initiate and implement project and asset information plans, assist in the preparation of project outputs, and implement the BIM information exchange protocol.

(2) It is also recommended that AEC companies conduct BIM awareness seminars and workshops to educate their respective employees and spread awareness and appreciation of the benefits of BIM. Benchmarking other companies already using BIM is also an effective way to motivate senior employees to embrace change and consider adopting and using BIM technology.

(3) It is highly recommended that companies look for ways to increase their funds and budget to acquire and implement this new technology. AEC companies should treat these BIM-related expenses as investments toward realizing the benefits, which would eventually outweigh the costs.

(4) AEC companies should start conducting training and workshops for their employees. They can also hire trainers from institutions offering courses for BIM and/or send some of their employees abroad for exposure and learn about benchmarking BIM implementation. Moreover, institutions of higher learning should start BIM courses and increase research on utilizing BIM in various projects.

Conflicts of Interest

The author declares no conflict of interest.

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