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Risk Identification and Management Strategies for BIM Projects

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Abstract:

The construction industry is undergoing a digital transformation in which Building Information Modelling (BIM) is a key technology. The potential of BIM in several areas such as design optimization, time management, cost management, and asset management/facility management (AM/FM) is widely acknowledged by the AECO (Architecture, Engineering, Construction, and Operation) industry around the world. However, BIM implementation in construction projects is faced with problems such as project delay and cost overruns. The lack of identification of risks in BIM projects and standard guidelines on mitigation techniques furthers poor performance, dissatisfaction, and disputes between employers and project participants, which results in low BIM adoption rates.

Therefore, the objective of this paper is to identify the potential risks in BIM implementation under the primary categories – (1) technical, (2) contractual, (3) management-related, and (4) personnel-related risks in BIM projects and present solutions to reduce, manage, and mitigate risks. To meet the objective of this paper, a survey was designed and conducted in the Hong Kong construction industry in which over 140 respondents from different disciplines, with experience in BIM projects, have participated. Based on the analysis of the survey data, the most severe and frequently occurring BIM risks and their potential mitigation strategies were identified and discussed in this paper.

Keywords: BIM Implementation, BIM Project Execution Plan, BIM standards, Risk Management

1. Introduction

The architecture, engineering, and construction (AEC) industry, often described as fragmented, complex, and risk-oriented is undergoing a digital transformation [1]. Building Information Modelling (BIM) is one of the primary technologies driving this transformation and is regarded as the future of the AEC industry [2]. The benefits of BIM in improving the quality of AEC projects and reducing project costs and delivery periods are well recognized in the AEC industry and the BIM research community [3]. However, several issues are commonly faced during BIM implementation at a project level due to the lack of standard guidelines (at the implementation level) on BIM implementation.

The AEC industry due to its inherent characteristics is a highly risk-prone industry [5]. Extensive studies on construction project risks can be found in the existing literature. Siraj and Fayek [6] have identified the main groups of risks in AEC projects as- (1) management-related, (2) technical, (3) delivery method related, (4) resource-related, (5) site condition related, (6) contractual or legal, (7) financial, (8) social, (9) political, (10) environmental, and (11) health & safety-related. Siraj and Fayek [6] further identified the top ten risks in each category such as ‘poor coordination among various parties involved in the project’ and ‘design errors and poor engineering’ as the highest-ranked risks in the management-related and technical categories respectively. The relation of risks to the size, structural, and technical complexities of projects is well-identified in existing literature [7]. Banaitiene and Banaitis identified that controllable risk sources could be further broken down into seven sub-categories as- (1) design, (2) external, (3) environmental, (4) organizational, (5) project management, (6) right of way risks, and (7) construction which fall within the control of the project team [8]. Zou, Zhang and Wang identified that many project risks were repeated among five categories as- (1) cost-related, (2) time-related, (3) quality-related, (4) environment-related, and (5) safety-related [9]. BIM technology due to its technical complexities and widespread effect on/relation to several processes and roles in AEC projects, adds significantly to project risks, and may severely project hinder performance if not implemented effectively [10]. For example, the need for a well-defined legal framework [4] and guidelines to facilitate the transition from existing technologies (CAD) to BIM [11] to sustain/improve project quality is strongly advocated by researchers. Therefore, this research is motivated to investigate the factors of risks associated with BIM implementation to aid project stakeholders to strategize and make informed decisions to optimize BIM implementation.

The research conducts an industry-wide survey of the Hong Kong AEC industry to identify BIM implementation risks, analyze the severity and likelihood of occurrence of risks in BIM projects, and present corresponding mitigation techniques. 140 respondents with extensive experience in BIM projects have participated in this survey. Four categories of BIM implementation risks namely (1) technical (such as inefficient data interoperability), (2) contractual (such as model ownership), (3) management-related (such as inadequate top management commitment), and (4) personnel-related (such as lack of skilled personnel), identified from existing literature [10] are included in the survey.

Based on the survey results, a total of 26 BIM implementation risks are identified, ranked, and supported with mitigation techniques. A risk-analysis matrix mapping the likelihood of BIM implementation risks to their severity (effect on projects) is developed.

2. Research Methodology

The methodology of this research includes a systematic survey of the Hong Kong AEC industry. By conducting a systematic survey, this study identifies the most important risk factors of BIM adoption in construction projects and proposed mitigation approaches. The survey questionnaire has mainly three parts. The first part collects personal particulars of the survey respondents such as business nature, position, duties in their organizations, year of practical experience in using BIM, and the number of BIM projects worked in. The second part provides the respondents with a list of 26 types of risk (identified from existing literature) categorized under 4 categories namely, (1) technical, (2) contractual, (3) management-related, and (4) personnel-related. The four categories of 26 types of risks are summarized in this study based on literature review and considerations of the aspects about legal, contractual & legislation, the responsibility of stakeholders, reliability of data, standardization of BIM, BIM model/data ownership, intellectual property rights, and technical issues through literature reviews. The survey respondents have the option to choose the most important risks from the list provided to them or may specify additional types of risk based on their experience. The third part of the survey provides the respondents with a list of 11 risk mitigation strategies in total, which are derived in this study based on practical experience. The respondents are allowed to specify additional methods of mitigation if they consider appropriate.

The targeted survey respondents are on an individual basis. The majority of survey respondents have practical experience of working in BIM projects and are from different backgrounds and disciplines. In the survey, respondents need to specify the business nature of their occupations. Table 1 shows the options of business natures in the survey questionnaire, the group of which is based on the common knowledge of the authors on the industry. Multiple selections of business nature are allowed if the respondents consider appropriate. The survey questionnaire was distributed in a Word document format for the respondents to return by either handwriting or computer typewriting. The channel of distribution of the survey questionnaire was mainly electronic mail and hardcopy. The targeted number of returns of the completed survey questionnaire with valid input in this research is a hundred.

Table 1. Grouping of Business Nature

No.	Group	Inclusion
1	Government or Statutory Body	Government or Statutory Body
2	Developer	Developer
3	QS Consultant	QS Consultant
4	AEC Consultant	Architect, Designer, Engineer
5	Contractor	Main Contractor, Sub-Contractor
6	Supplier	Material Supplier, Manufacturer
7	BIM Consultant	BIM Consultant, BIM Trainer
8	Software Vendor	Software Developer, Information Technology (IT) professional
9	Insurance Provider	Insurance Provider
10	Academia	Academia

3. Results and Discussions

The survey questionnaire responses were collected via emails from February 2019 to March 2019. Every survey questionnaire was given to the respondent only upon s/he had confirmed his/her willingness of support. A total of 165 persons were contacted and a total of 149 completed survey questionnaires were collected. The distribution of the years of experience in BIM projects of the respondents is shown in Table 2. From the result, most of the respondents (69.8%) have over 3 years of experience, while 21.5% of the respondents have over 10 years of experience.

Table 2. Years of Experience in BIM projects of Respondents

Years	Count of Respondent	Percentage
0 – 3	45	30.2
4 – 6	38	25.5%
7 – 10	34	22.8%
11 – 15	22	14.8%
>15	10	6.7%
Total	149	100%

Table 3. BIM Projects involved of Respondents

Nos. of BIM project	Count of Respondent	Percentage
0	6	4.0%
1 – 10	88	59.1%
11 – 20	27	18.1%
21 – 30	10	6.7%
31 – 50	7	4.7%
51 – 100	7	4.7%
101 – 200	3	2.0%
> 200	1	0.7%
Total	149	100%

The distribution of the numbers of BIM projects of the respondents is tabulated in Table 3. As shown in Table 3, most of the respondents had involvement in 1 to 10 projects (59.1%) or 11 to 20 projects (18.1%). 6 respondents had no past involvement in any BIM projects. Table 4 shows the numbers of the respondents per group. Multiple selections of business nature per respondent are allowed. Most of the respondents are in the groups of BIM Consultants (29.6%), Contractor (24.6%), and AEC Consultant (13.4%) respectively.

Table 4. Business Nature of Respondents

No.	Group	Count	Percentage
1	BIM Consultant	64	29.60%
2	Contractor	53	24.60%
3	AEC Consultant	29	13.40%
4	Software Vendor	25	11.60%
5	Developer	22	10.20%
6	Government or Statutory Body	10	4.60%
7	Academia	6	2.80%
8	QS Consultant	3	1.40%
9	Supplier	2	0.90%
10	Insurance Provider	2	0.90%
	Total	216	100%

Table 5 shows the numbers of the respondents grouped by their position and duties in their BIM projects. Multiple selections per respondent are allowed. As shown in Table 5, the major position and duties groups of the respondents are Discipline BIM Team Leader & BIM Coordinator (18.6%), Project BIM Manager (14.0%), Project Director & Project Manager (13.1%), and BIM Trainer (11.0%).

Table 5. Position & Duties in BIM Projects of Respondents

No.	Position	Count	Percentage
1	Discipline BIM Team Leader, BIM Coordinator	44	18.60%
2	Project BIM Manager	33	14.00%
3	Project Director, Project Manager	31	13.10%
4	BIM Trainer	26	11.00%
5	Software Vendor	18	7.60%
6	Employer (Owner)	16	6.80%
7	QS Consultant	14	5.90%
8	BIM Modeller	14	5.90%
9	Design (Architectural) Consultants	13	5.50%
10	Engineer (Contractor Engineer)	11	4.70%
11	Engineering Consultant	7	3.00%
12	BIM Auditor	7	3.00%
13	Insurance Provider	2	0.80%
	Total	236	100%

4. Risk identification

From the total 26 types of risk, 9 types belong to technical (Identity No. from T1 to T9), 6 types belong to contractual (Identity No. from C1 to C6), 9 types belong to management-related (Identity No. from M1 to M9) and the remaining 2 types belong to personnel-related (Identity No. P1 and P2). Each respondent is allowed to select a total of five risks. The summation of the risk counts is therefore 149 respondents multiplied by 5 selected risks for each respondent, which equals to 745 in total. Table 6 shows the ranking of the total 26 risks based on their counts of being selected.

Table 6. Ranking of 26 risks based on Consequence

Rank	Count	likelihood	Risk with Identity No.	Category
1	69	3.84	C6. Poor participation / contribution from project team in BIM adoption	Contractual
2	57	3.44	C1. Unclear requirements (e.g. Employer's Information Requirements (EIR) / Asset Information Requirements (AIR) / contract) of BIM uses and specifications	Contractual
3	54	3.58	C2. Unclear roles, responsibility and liability in BIM implementation	Contractual
4	52	3.75	P1. Lack of adequate expertise in BIM	Personnel
5	45	3.64	T6. Design conflict / clashes in BIM was not revealed / unresolved	Technical
6	42	3.18	C5. Unclear legal liability	Contractual
7	41	3.15	T8. Wrong information from BIM model	Technical
8	39	3.15	C3. Unclear workflow of BIM process	Contractual
9	35	3.33	T5. Mistakes in design drawings/shop drawings generated from BIM	Technical
10	31	3.11	T4. Information loss or damage from BIM because of data exchange	Technical
11	30	3.21	T9. Lack of interoperability	Technical
12	26	3.13	M2. Incorrect cost estimation in tendering from BIM	Management
13	24	3.13	M3. Misunderstandings because of poor communication through BIM	Management
14	22	3.07	C4. Unclear definition of BIM Level of Development (LOD)	Contractual
14	22	3.23	M9. Information flooding	Management
15	20	2.79	T3. Cannot get information from BIM due to software versioning	Technical
16	17	3.40	P2. Turnover and stability of key person in BIM implementation	Personnel
17	15	3.07	M1. Poor task sequencing for inputting into BIM	Management
17	15	2.73	M6. Project delay because of preparing BIM models	Management
18	13	2.29	T2. Information loss from Common Data Environment / BIM Server	Technical
18	13	2.41	T7. Bugs in BIM software that lead to a financial loss	Technical
18	13	2.73	M4. Economic loss because of poor BIM management	Management
18	13	3.00	M7. Poor construction progress tracking	Management
19	11	2.56	T1. Information loss from BIM because of disputes	Technical
20	9	2.64	M5. Poor construction quality	Management
21	5	2.97	M8. Project cost over budget	Management
Total	745			

As shown in Table 6, the top five risks in terms of the number of times selected by respondents (counts) are – (1) (C6) poor participation/contribution from the project team in BIM adoption, (2) (C1) unclear of requirements of BIM uses and specifications, (3) (C2) unclear roles, responsibility, and liabilities in BIM implementation, (4) (P1) lack of adequate expertise in BIM, and (5) (T6) design conflict/clashes in BIM not revealed or unresolved. The top three risks belong to the contractual risk category, the fourth risk is personnel-related, whereas the fifth risk is technical. The results indicate that the most concerning risks are contract-related which may be due to the lack of adequate contractual provisions such as clarity in obligations and responsibilities of the project participants in the contract or agreement. The current government policies include the Technical Circular (Works) issued in 2019 by the Development Bureau of the HKSAR Gorvenment for the adoption of BIM for capital works projects in Hong Kong. There are limited standards and contractual documents for BIM implementation, including those mainly issued by the Construction Industry Council, Government Works Departments and some major public and private developers in Hong Kong. The situation may be improved by clearly defining and integrating the employer information requirement and enhancing the contract or agreement for performing BIM services between the contracting parties. For example, clear obligations, liabilities, and responsibilities between project participants and the availability and enhancement of government policies and guidelines for proper implementation. The bottom-most or the least concerning risks related to BIM projects are found to be from the management-related category. As shown in Table 6, the survey has identified management-related risks such as project cost going over budget (M8) and poor construction quality (M5) as the least concerning risks related to BIM adoption. We can assume that for the success of BIM adoption, project cost over budget is not a major concern. In terms of likelihood of occurrence of the risk (chance of happening), the top five risks are the same as that in terms of count as shown in Table 6and information loss from Common Data Environment / BIM Server (T2) was identified as the least concerning risk.

Based on the survey results, a Risk Analysis Matrix (as shown in Table 7) is constructed according to the systematic risk management process introduced in the Risk Management for Public Works - Risk Management User Manual [12]. The structure of this Risk Analysis Matrix is that the X-axis indicates the level of the consequence of the risks (counts of the risk being selected) and the Y-axis indicates the level of likelihood of the risks. The two axes indicate the correlations between the consequences and likelihood of the risks. With reference to Table 6, the classification for the consequence of risk is that risks have “above 50 counts” to be first range “Catastrophic”, “between 39 and 50 counts” to be second range “Major”, “between 24 and 38 counts” to be third range “Moderate”, “between 10 and 23 count” to be fourth range “Minor”, “under 10 counts” to be fifth range “Insignificant”. Meanwhile, for each of the total 26 risks was graded by the respondent by using a 5-point Likert scale to select either “5 Frequently Happen”, “4 Likely Happen”, “3 Possible Happen”, “2 Unlikely Happen”, “1 Rare Happen”. The classification for the risk likelihood is that “above 3.60” to be first range “Frequent”, “between 3.33 and 3.60” to be second range “Likely”, “between 3.00 and 3.32” to be third range “Possible”, “between 2.56 and 2.99” to be fourth range “Unlikely”, “below 2.56” to be fifth range “Rare”.

Table 7. Risk Analysis Matrix

		Consequences of the Risk				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood of the Risk	Rare		T2, T7			
	Unlikely	M5, M8	T3,M6,M4,T1			
	Possible		C4,M9,M1,M7	T4,T9,M2,M3	C5,T8,C3	
	Likely		P2	T5		C2, C1
	Frequent				T6	C6, P1

From the Risk Analysis Matrix, it is concluded that Extreme High Risks are C6 (Poor participation/contribution from the project team in BIM adoption) and P1 (Lack of adequate expertise in BIM). Very High risks are C2 (Unclear roles, responsibility, and liability in BIM implementation), C1 (Unclear of requirements of BIM uses and specifications), and T6 (Design conflict/clashes in BIM was not revealed / unresolved). The results echo the analysis and assumptions under Table 6, indicating that stakeholders are recommended to pay attention to contractual issues to achieve their objectives of BIM adoption efficiently. Moreover, in response to P1, we can expect that appropriate BIM training and educations of BIM personnel will be the solution and both software-based training & project-based training should be considered. For T6, the solution can be the enforcement in adopting BIM software to facilitate design coordination together with appropriate training for the use of the BIM software.

5. Conclusion

According to the top-ranked three risks from the overall perspective (take into account all groups of respondents), which are C5 (Poor participation/contribution from the project team in BIM adoption), C1 (Unclear of requirements of BIM uses and specifications), and C2 (Unclear roles, responsibility, and liability in BIM implementation), it can be clearly stated that the most important risks are mainly relating to contractual issues. Contractual documents of BIM requirements play a critical concern in the Hong Kong construction industry when adopting BIM technology. Prompt availability of government policy and associated contractual documents to the industry are recommended and project clients shall play a key role to enforce such contractual documents to fully realize the potential benefits and advantages of adopting BIM technology in the projects. The results also show that the industry lacks adequate expertise in BIM and some technical risks like design conflict were not revealed or unresolved. The AEC industry and its stakeholders can consider the recommendations suggested above.

It is the first step of the survey study on the topic of Risk Identification and Management Strategies for BIM Projects. For future work, more comprehensive insights could be discovered by an in-depth analysis of the collected data. For example, analyses can be conducted within groups of respondents as well as across groups, based on factors such as business nature and years of experience. Meanwhile, some arrangements may help to produce better results by further sub-grouping the data based on the nature of the business. For example, “Main Contractor” and “Sub-contractor” could be sub-grouped in analyses as they are at different positions of the supply chain and have different interests. In addition, dividing the group “Government / Statutory Body” into “Authorities / Regulators”, “Quasi-government” and “Works Departments” may help, because they play different roles in the ecosystem of a BIM project. On the other hand, for the position and duties of Respondents, offering more options for example “Project Coordinator” and “Technical Officer” were requested by some respondents in the survey and may be considered in the future.

References

[1] Brewer, G., Jefferies, M. & Manderson, A. “Building Information Modelling and Standardised Construction Contracts: a Content Analysis of the GC21 Contract”, Construction Economics and Building, pp. 72-84, 2015.

[2] Jiang, S., Man, Q., Shen, L., Skibniewski, M. & Sun, C. “A literature review of the factors limiting the application of BIM in the construction industry”, Technological and Economic Development of Economy, 23(5), pp. 764-779, 2017.

[3] Eastman, C, Teicholz, P., Sacks, R. and Liston, K. “BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors”, 2nd ed., NY: John Wiley and Sons, 2011.

[4] Olatunji, O. “Constructing Dispute Scenarios in Building Information Modeling”, Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 2015.

[5] El-Sayegh, S.M. and Mansour, M.H. “Risk assessment and allocation in highway construction projects in the UAE”, Journal of Management in Engineering. 31(6): 04015004, 2015. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000365

[6] Nasir B. Siraj., Aminah Robinson Fayek. “Risk Identification and Common Risks in Construction: Literature Review and Content Analysis”, J. Constr. Eng. Manage. 145(9): 03119004, 2019. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001685

[7] Jones, S. W., Kiviniemi, A. & Zou, Y. “A review of risk management through BIM and BIM-related technologies”, Safety Science, pp. 88-98, 2017.

[8] Banaitiene, N., and A. Banaitis. “Risk management in construction projects: Risk management–Current issues and challenges”, InTech, pp. 429–448, 2012.

[9] Zou, P. X. W., G. Zhang, and J. Wang. “Understanding the key risks in construction projects in China”, International Journal of Project Management, 25(6): pp.601–614, 2007.

https://doi.org/10.1016/j.ijproman.2007.03.001.
[10] Chien, K-F., Wu, Z-H. & Huang, S-C. "Identifying and assessing critical risk factors for BIM projects: Empirical study", Automation in Construction, pp. 1-15, 2014.
[11] Senem Seyis. "Pros and Cons of Using Building Information Modeling in the AEC Industry", J. Constr. Eng. Manage. 145 (8): 04019046, 2019. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001681s
[12] Environment Transport and Works Bureau. "Risk Management for Public Works: Risk Management User Manual", The Government of Hong Kong Special Administrative Region, 2015