Management of the Organizational and Contractual Risks of BIM Projects in the Architecture, Engineering and Construction Industry (AEC)

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Abstract. The Architecture, Engineering and Construction (AEC) industry has witnessed a revolutionary journey throughout the past few decades in the UAE and more specifically in the Emirate of Dubai, despite the numerous advancements in the tools and technologies used for designing and constructing buildings; there has always been an ambition to increase the efficiency of this process and reduce the time and resources consumed to deliver project products. One of the fastest growing technologies in the global AEC industry is the Building Information Modelling (BIM); a technique that revolves around the idea of integrating different engineering disciplines into a single unit of collaboration. As with all new technologies, there is still a large number of limitations of the BIM application that might jeopardize the benefits and opportunities of implementing it. Aiming to find BIM risks and propose mitigation strategies for them; this research paper begins by providing a brief background about the Building Information Modelling application and its significance in the design and construction processes, after that it identifies the main organizational risks associated with the BIM application, it concludes the findings from the literature review into a conceptual framework that acts as a guideline for managing the BIM organizational risks, reducing their impact and enhancing the overall BIM process, the study then uses a research tool that consists of a questionnaire examining the feedback of architects from the industry about the importance of the BIM organizational risks and their prevention strategies suggested in the research, finally the results of this survey are analyzed in the SPSS software in order to reach useful conclusions and findings.

Keywords: BIM · Building information modelling · Risk management AEC industry

1 Introduction

The concept of BIM can be traced back to the 1960s when an American Engineer/inventor named Douglas C. Englebart described the idea of entering realistic building data such as dimensions, materials and other specifications into a software, allowing for the examination and control of the integrated model which mimics the

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completed form of the building [25]. Since then, many designations have been given to the BIM application but the most recognized one was stated by The US National Building Information Model Standard Project Committee as: "A digital representation of physical and functional characteristics of a facility" [21]. The committee also claimed that BIM is a means of collective information which creates a solid foundation for decision making throughout the facility's life-cycle. As a result of the speedy growth of the BIM process, a gap has been created between the long-time prospects and future benefits that BIM offers for the AEC industry and the risks that are imposed from its relatively new existence and the industry's reluctance to accept and endorse it. It is widely argued that the BIM process is the future of the Architecture, Engineering and Construction industry [30].

2 Literature Review

2.1 BIM Application Versus Traditional Application (CAD)

The introduction of BIM created many advantages over the typical design process of CAD (computer-aided design); the advantages that BIM offers vary throughout the different phases of a project's lifetime. According to Azhar [3], some of the main advantages that BIM has when compared to the traditional process include its integrated project documents, better model visualization, error/clash detection, and cost estimates. Jones [10] argues that the industry's BIM incorporation has reduced risks in construction projects as well as decreasing overall project budgets; it has also minimized information requests and variation orders and led to improved decision-making.

2.2 Types of Risks of BIM Projects in the AEC Industry

Introducing new technologies always brings a number of risks and uncertainties with it, so is the case of the evolving BIM application; according to Abdelhady [1], the challenges associated with BIM can be grouped within each of the three BIM domains shown in Fig. 1: (non-technical risks; the main focus of this research) includes two types (policy domain risks), which contains all issues between the stakeholders in a BIM project and their contractual arrangements and liabilities and (process domain risks) consisting of risks within the management of the BIM execution process in a company, the ownership of BIM documents amongst stakeholders and BIM knowledge management. The other type is technical risks (technology domain risks) which are linked to the software aspects such as file sizes, software developments and network systems.

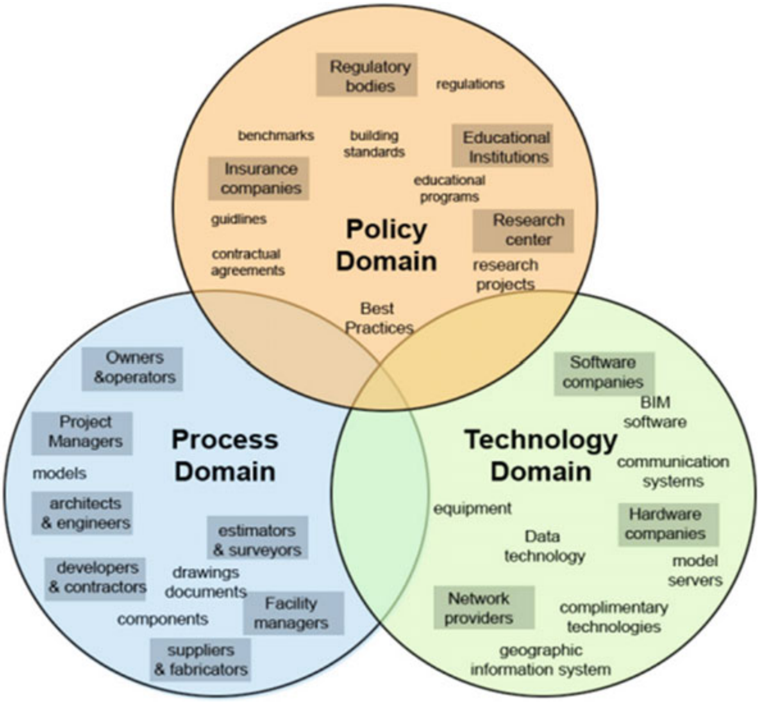

Fig. 1. The three domains of building information modelling (BIM). *Source* Abdelhady [1]

2.3 Main Organizational Risks of BIM

As mentioned earlier, the core focus of this research is on the process/organizational risks of the BIM application. Jung and Joo [11] state that the managerial challenges in construction information systems such as BIM have a greater impact than the technological ones, they also claim that the organizational benefits achieved from BIM when it comes to re-constructing or innovating the business operation must be measured and explained. It has been discussed that the risks of BIM vary based on the size of the firm [10]. Succar et al. [29] argue that the framework for achieving competency in the BIM process is split into four parts as in Fig. 2: ***Resources*** (human and physical), ***Activities***, ***Products*** and ***Leadership/management***.

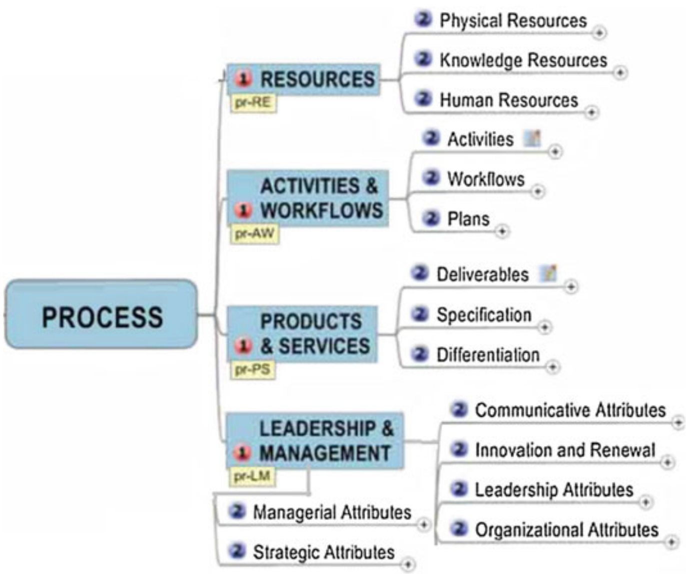

Fig. 2. The framework for achieving competency in BIM. *Source* Succar et al. [29]

Table 1 lists a total of 30 organizational risks of BIM according to the literature review and the authors' citations.

Table 1. Organizational risks of BIM

	Risk factor	Type	Citations
1	Fear of low success/high failure due to team's lack of experience in BIM	Human resources	Azhar et al. [5], Eadie et al. [7], Ku and Taiebat [15], Mayo et al. [19], Migilinskas et al. [20] and Zahrizan et al. [33]
2	Interoperability between BIM programs and loss of valuable data	Informational resources	Azhar et al. [5], Goucher and Thurairajah [9], Ku and Taiebat [15], Olatunji [23], Stanley and Thurnell [28] and Volk et al. [31]
3	Uncertain ownership of BIM model	Contractual	Azhar et al. [5], Khosrowshahi and Arayici [14], Leeuwis et al. [17], Porwal and Hewage [24], Sebastian [26] and Volk et al. [31]

(*continued*)

Table 1. (*continued*)

	Risk factor	Type	Citations
4	The significance of the training and recruiting costs in the BIM process	Human and physical resources	Arayici et al. [2], Azhar et al. [4], Crotty [6], Eadie et al. [7] and Stanley and Thurnell [28]
5	Lack of collaboration of stakeholders	Contractual	Azhar et al. [5], Ku and Taiebat [15], Migilinskas et al. [20] and Volk et al. [31]
6	Absence of higher management support and an organizational culture that supports BIM implementation	Managerial	Migilinskas et al. [20], Porwal and Hewage [24], Sebastian [26] and Volk et al. [31]
7	Resistance to change at cultural and operational levels and difficulty of adapting to a new system	Managerial	Eadie et al. [7], Khosrowshahi and Arayici [14], Smith [27], Migilinskas et al. [20] and Stanley and Thurnell [28]
8	Lack of contractual agreements and legal instruments for BIM	Contractual	Azhar et al. [5], Ku and Taiebat [15], Volk et al. [31] and Porwal and Hewage [24]
9	High overall initial investment costs in BIM	Physical resources	Azhar et al. [5], Eadie et al. [7], Ku and Taiebat [15] and Migilinskas et al. [20]
10	The organization as a whole lacks experience in dealing with the BIM system	Managerial	Eadie et al. [7], Ku and Taiebat [15], Kashiwagi et al. [12], Khosrowshahi and Arayici [14] and Mayo et al. [19]
11	BIM's collaborative approach increases risk sharing between stakeholders and reduces definition of clear liabilities	Contractual	Arayici et al. [2], Khosrowshahi and Arayici [14], Le Masurier [16] and Sebastian [26]
12	Time spent to learn using BIM	Physical resources	Migilinskas et al. [20] and Stanley and Thurnell [28]
13	Lack of client demand in certain industries	Strategic	Eadie et al. [7], Khosrowshahi and Arayici [14] and Zahrizan et al. [33]
14	Unawareness about BIM and its major enhancements to the project delivery process	Strategic	Khosrowshahi and Arayici [14], Newton and Chileshe [22] and Zahrizan et al. [33]
15	The fragmented nature of the construction industry (lack of high-level collaboration, integration of database and commitment to incorporate BIM)	Strategic	Masterspec [18] and Stanley and Thurnell [28]
16	Lack of electronic BIM standards for coding objects and methods of measurement	Strategic	Masterspec [18] and Stanley and Thurnell [28]

(*continued*)

Table 1. (*continued*)

	Risk factor	Type	Citations
17	Unawareness of the strict standards for BIM implementation	Managerial	Migilinskas et al. [20]
18	Unawareness of the contractual implications of BIM implementation	Contractual	Migilinskas et al. [20]
19	Need for numerous new software licenses with different languages	Product specifications and physical resources	Jones [10] and Khosrowshahi and Arayici [14]
20	Long project lifetimes cannot keep up with rapid BIM technological change	Innovation and renewal	Volk et al. [31]
21	Discrepancy in legal BIM frameworks between different countries	Strategic	Volk et al. [31]
22	Lack of distribution of operational/developmental costs of BIM between industry stakeholders	Contractual	Azhar et al. [5]
23	BIM's collaborative approach makes project participants assume accurate input from others	Human resources	Porwal and Hewage [24]
24	BIM's added dimensions (cost and scheduling) creates difficulty in unifying the software and analysis platforms between stakeholders	Product specifications	Azhar [3]
25	The need for sophisticated equipment and programming services requires radical changes in the organization's working system	Product specifications	Arayici et al. [2]
26	BIM specialist usually require higher salaries than traditional CAD designers	Human and Physical resources	Arayici et al. [2]
27	Gap in staff skills in cost estimating and 4D modelling which both have great value to project and organization	Human resources	Wei and Raja [32]
28	Difficulty of BIM adoption in small firms due to investment costs	Managerial	Newton and Chileshe [22] and Zahrizan et al. [33]

(*continued*)

Table 1. (*continued*)

	Risk factor	Type	Citations
29	Reluctance of team members to share information and communicate effectively	Human resources	Eadie et al. [7]
30	The use of different BIM models between engineers lacks integration and reduces modelling efficiency	Managerial	Stanley and Thurnell [28]

2.4 Prevention/Mitigation Strategies of BIM Risks

According to the literature that has been examined, the mitigation strategies of the organizational risks of BIM come at four levels (Strategic/Market, Contractual/Stakeholder, Organization and Project Team). Some of the strategies mentioned for those levels include:

Strategic/Market Level: The first step in efficient BIM implementation is the involvement of the external drivers such as governmental and public authorities as well as the formation of international committees concerned with the BIM execution process.

Zahrizan et al. [33] describes the push-and-pull elements of implementing BIM where governments act as the main pushing component towards increasing the use of BIM by mandating it and giving additional support to the private sector, on the other hand the goal of having an efficient industry is what's pulling the BIM incorporation due to the major benefits of BIM to the industry as whole.

A survey created in 2012 in the UK showed that the majority of construction companies were abiding by the governmental deadlines set to implement BIM [7]. According to Smith [27], one of the governmental initiatives to increase the adoption of BIM in Australia was the creation of the 'National BIM Guide' and the 'National Guidelines for Digital Modelling' by several governmental agencies. Zahrizan et al. [33] emphasize the role of the government in Singapore to incorporate BIM training as part of the curriculum in several educational foundations; they also highlighted the government's approach to assist organizations that are implementing their first BIM project.

Another proposed strategy used by the BCA government in Singapore is the dedication of a special fund that assists in the BIM training costs as well as the costs of purchasing and implementing the required hardware/software. One of the other possible solutions that can be used are the Noteworthy BIM Publications (NBP)s that control BIM execution and gather significant BIM information and expertise [13].

The production of Noteworthy BIM Publications (NBP)s is another solution to improve the information management of BIM, NBPs are derived from the combination of the BIM fields (technology, process, policy) and the BIM lenses (conceptual attributes, geographic scoping, multi-disciplinary knowledge management); they include cumulative BIM knowledge, they are delivered by the BIM players (organizations fully involved with BIM) and they are classified based on the country and its maturity level in BIM.

Contractual/Stakeholder Level: Porwal and Hewage [24] claim that one of the most effective methods of solving the contractual and legal issues of BIM implementation is using the BIM partnering procurement contract; this framework enhances BIM model collaboration, increases the staff's capacity to adapt to the new process and maintained better client participation as well as alignment with governmental standards. With regard to the uncertainty of the BIM model ownership between project parties, Porwal and Hewage suggest investing in the creation and improvement of legal procedures that are specifically concerned with maintaining informational security. Arayici et al. [2] and Zahrizan et al. [33] state that the awareness level of the new roles of stakeholders in BIM must be raised.

Organization Level: Zahrizan et al. [33] suggest that organizations must alter the way they use information and transform their managerial structure to incorporate the new positions in the BIM application and their abilities and expertise. They also claim that companies must adopt incentives and motivational strategies as well as continuous support for their employees in order to make the implementation process faster and reduce the staff's reluctance to adopt the new system. Some of the other proposed strategies within the organization include the creation of detailed project lifecycle cost analyses to encourage clients to use BIM by showing them BIM's long-term benefits, forming positive thoughts about BIM inside the company, dedicate profits for BIM implementation budgets and focus on thorough selection of BIM team members especially high-level positions (BIM managers and coordinators)

On the other hand, companies must create alternative scenarios in the case of lost data due to operability issues, many attempts have been made to overcome the difficulty in transferring information; Porwal and Hewage [24] suggest that the Industry Foundation Classes (IFC) data exchange method can solve many of these challenges, on the other hand, they argue that the IFC method can mostly handle with the preliminary design stages and needs further development for the final and more detailed stages.

Project Team Level: Eastman et al. [8] and Zahrizan et al. [33] emphasize the role of increasing open communication and knowledge sharing between team members to not only reduce the risks of losing important data but minimize the training and recruiting time and costs for the organization as well. The input and role of each team member in the central BIM model must be controlled accurately to avoid liability issues; project managers must also increase the coordination meetings to ensure

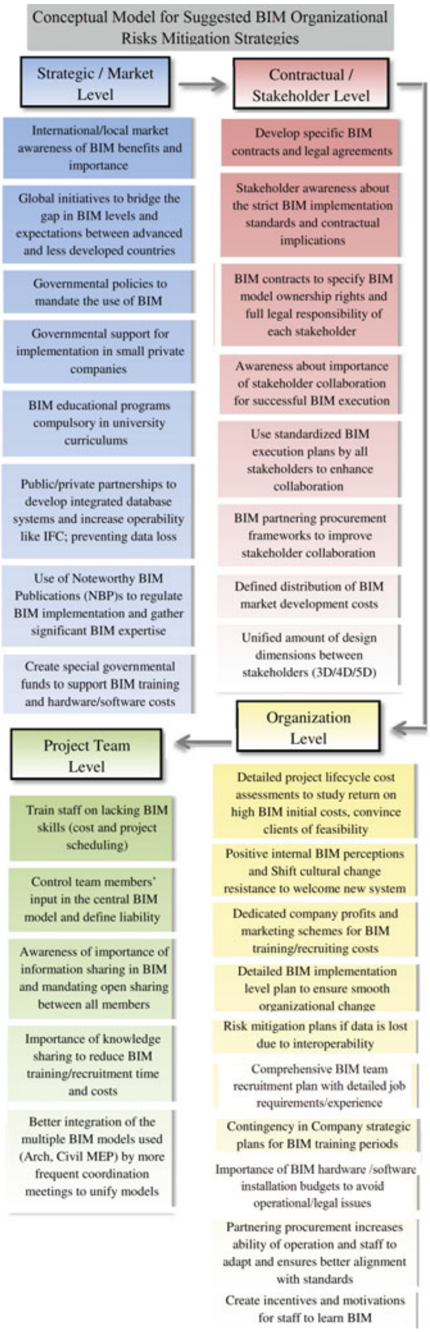

Fig. 3. Conceptual model for suggested BIM organizational risks mitigation strategies. *Source* Researcher

integration of the different BIM models between departments due to the criticality of the information in each one.

Companies must invest in improving its employees in the added BIM design dimensions (project scheduling and cost estimating) as their benefits are very important to the project. According to Khosrowshahi and Arayici [14], a survey was conducted in contracting firms in the UK to study the employees' feedback on how to encourage them to use BIM, some of the responses included attending workshops to follow BIM progress and advise on software/hardware tools, more company involvement in BIM projects and the integration of databases between project participants.

2.5 Conceptual Model

After the theoretical review of the literature concerning the BIM application, its major operational risks and their respective mitigation strategies at the strategic, contractual, organizational and project team levels, the conceptual framework in Fig. 3 represents a guideline for managing those organizational risks of BIM.

3 Quantitative Analysis

This section uses the theoretical data found in the literature in a measurable tool (survey) and then examines the results of this survey to reach certain conclusions.

3.1 Research Methodology

The analysis process begins by grouping the risk factors and prevention strategies based on their types mentioned earlier, then a questionnaire is sent to construction professionals to study their feedback on the importance of the BIM operational challenges as opposed to their suggested ranking in the literature review (based on their citation), the survey also examines the respondents' perceptions of the proposed mitigation strategies in the conceptual framework, the dependent and independent variables are identified and a software analysis of the results is conducted using the Statistical Package for Social Sciences (SPSS) where first, the reliability of the surveyed factors is tested using the values of Cronbach Alpha, then the interrelatedness of the factors is examined using factor analysis and correlation and finally, the proposed significance of the factors is questioned using regression.

3.2 Statistical Instrument: Survey

Targeted Survey Sample: For the goal of having representable and accurate data; the chosen sample frame for the questionnaire included any architect or engineer who has been exposed to BIM by some means; either by experience in official BIM projects or at least a basic background about BIM and its applications. The sampling method is "Random Sampling" which means that respondents were selected randomly from the larger sample frame. The survey was sent using two methods: paper-based (distributed to employees of different companies) and online (sent to candidates using social media posts/messages and phone messages), the respondents were assured full confidentiality and assistance was given when any of the factors were unclear, finally the response rate reached approximately 60–65%. The achieved sample size was 21 people where 3 responses were incomplete and the majority of the respondents were reached online, there were two reasons behind not achieving a considerable sample size: first because most of the small firms that were visited do not use the BIM system and second because of the difficulty of entering into larger firms and the missing cooperation from managements due to the need to occupy the time of their employees.

Structure of Survey and Scale of Data: The original wording of the BIM risks from the literature was simplified and shortened in the survey and technical terms were omitted; the survey starts by introducing the BIM technology and stating that it usually faces challenges when implemented in construction companies, then two main questions are presented: Part one; studies the level of respondent agreement on the importance of the BIM organizational challenges on an Ordinal Scale of 1–5 (Strongly disagree, Disagree, Neutral, Agree and Strongly agree), Part two; examines the rate of agreement of the respondents about the proposed mitigation strategies in the conceptual framework with the same scale in part one.

Dependent and Independent Variables: The dependent variable being examined is the assumed significance of the BIM organizational risks and their prevention methods suggested; this variable is categorical (established significance value (1–5) from literature citation) and it is dependent on the feedback of the respondents (the independent variable) which is also categorical (strongly disagree to strongly agree).

3.3 Key Outcomes of Survey

The main findings of the survey show the importance of the BIM risks and their mitigation strategies in Figs. 4 and 5.

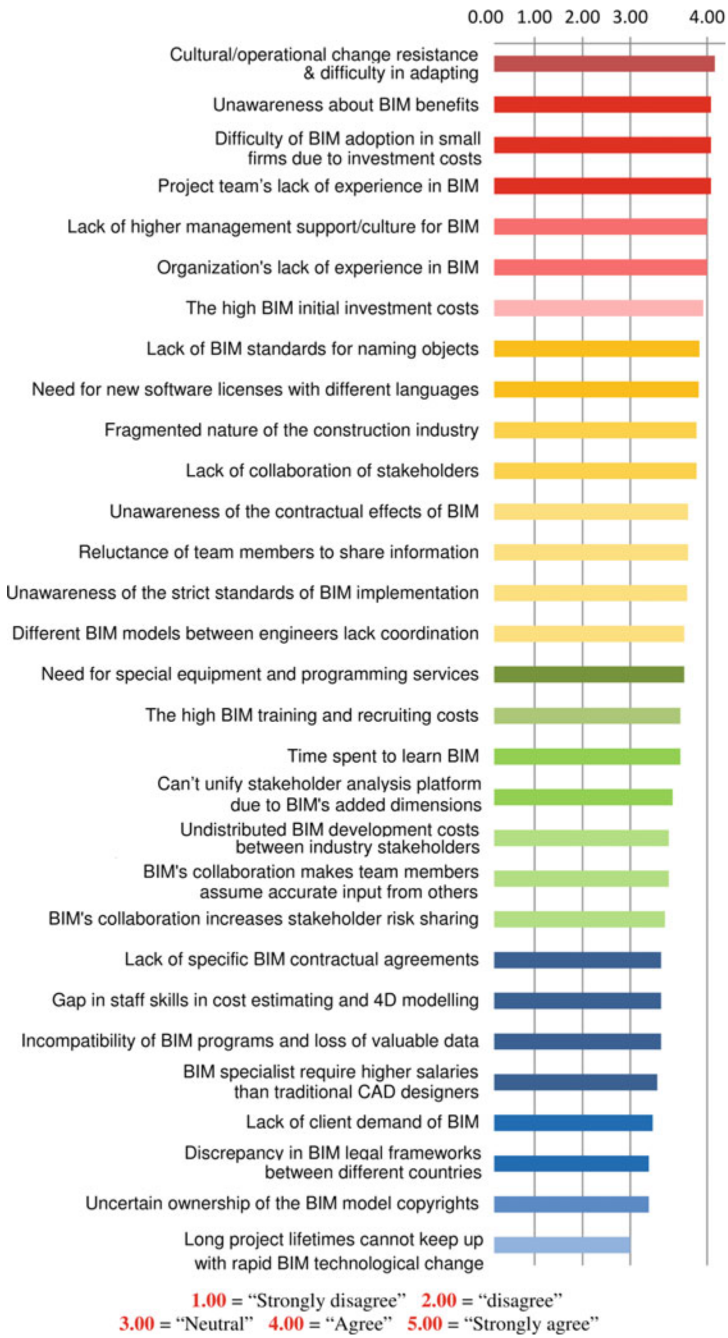

Fig. 4. Survey results of BIM organizational risks' significance. *Source* Researcher

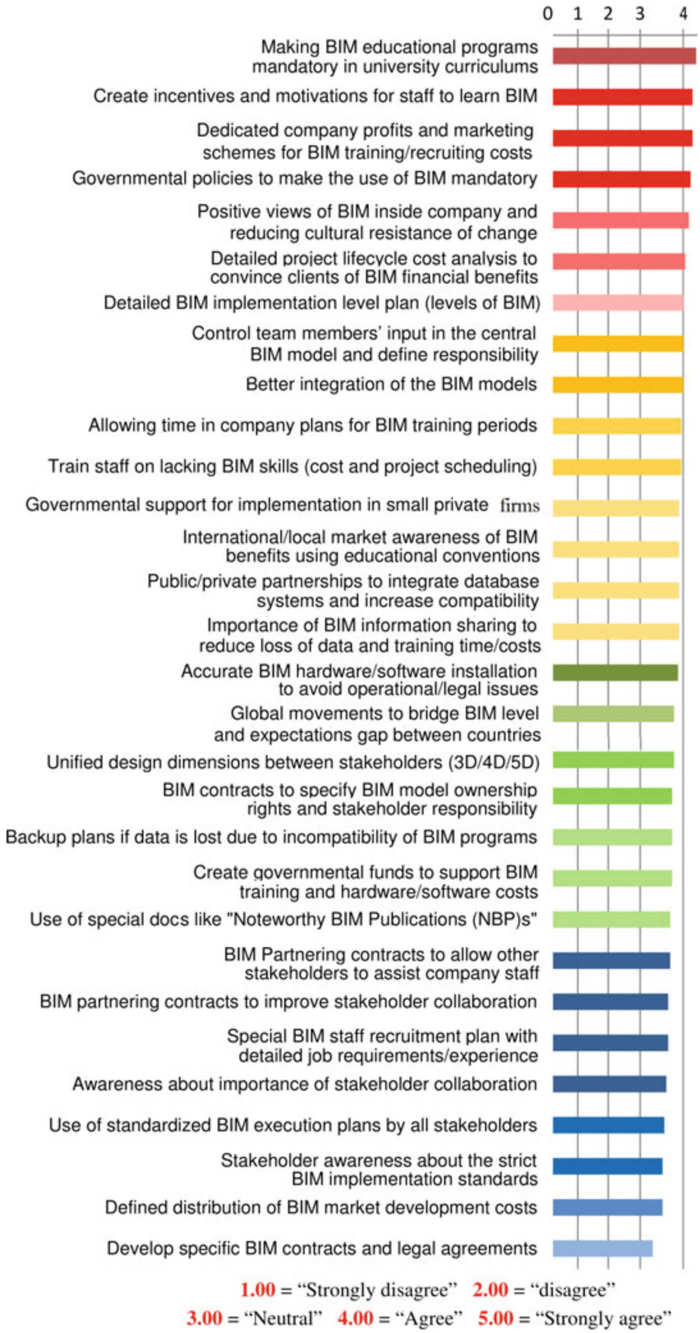

Fig. 5. Survey results of BIM organizational risk mitigation strategy significance. *Source* Researcher

3.4 SPSS Analysis of Survey

The previous findings of the survey were analyzed using the SPSS software, after finding the means and standard deviations of the risk factors; the reliability and correlation of the BIM risk factors are examined, then regression test is conducted based on the guidelines in the course slides (when examining risk factors and both dependent and independent variables are categorical (ordinal); a regression test is valid for analysis).

Standard Deviation: This type of test examines how closely related the survey questions (factors) are to one another. First, the different variables were added in SPSS where respondents were the first type of variable (to enter different respondent answers) and the BIM risk factors (survey weights) were the second type of variable with an ordinal (categorical) scale of 1–5, the factors were labelled with their original numbering (1.1, 2.2, … etc.) with the addition of a letter in the beginning to identify their types (S = Strategic, C = Contractual, M = Managerial, R = Resources) and because SPSS requires an alphabetical letter to start with. After defining the variables, the risk survey weights were added in the data view based on the 18 different respondents' answers (complete results).

Table 2 shows that the average variance between factor weights is 1.025 which is equal to 20.5% (scale 1–5). The average overall mean of the factor weights is 3.717 (range from 3.17 to 4.22), the factor with the lowest weight mean (3.17) and highest standard deviation (1.38) from the overall mean is 1.6 "*Long project lifetime*." while the factor with the highest weight mean (4.22) is 1.2 "*Unawareness about BIM Benefits*", finally the factor closest to the overall mean (with 0.71 deviation) is 2.5 "*Unawareness of the BIM Contractual effects*".

Table 2. Summary of survey means and variances

Summary item statistics							
	Mean	Minimum	Maximum	Range	Minimum/Maximum	Variance	No. of items
Item means	3.717	3.167	4.222	1.056	1.333	0.067	30
Item variances	1.025	0.500	1.912	1.412	3.824	0.118	30

Reliability Test: The reliability of the risk factors is examined using the values of the "Cronbach's Alpha if item deleted", which indicates the internal consistency between the items, according to the course slides a Cronbach's alpha value greater than 0.7 means that the item is highly reliable. Fortunately, all of the surveyed factors had a Cronbach's alpha higher than 0.7 which indicates their consistency and reliability; therefore no factors were eliminated.

Factor Analysis: This test aims at reducing the different variables that were studied (respondent feedback) as well as proving or rejecting any previous hypotheses that categorized or grouped the variables. The test uses the Rotated Component Matrix for the risk factors where 5 components were extracted (out of 18 results), then risk factors were grouped based on common component values (greater than 0.5), these values indicate the interrelatedness between the BIM risks and their significance (high component values), 4.2 "*BIM's collaboration makes project members assume accurate input from others*" has the highest rotated component (0.942) while 4.4 "*Reluctance of team members to share information*" has the lowest (0.425).

The matrix grouping of the risk factors shows that component-1 mainly included high-level risks (market/stakeholder level) as well as a few resource risks, the second group was mainly associated with organization and project team risks, the third included issues of BIM unawareness and team member attitudes, the fourth group consisted of 4 components each representing one of the four levels of the mitigation strategies and finally, the fifth component matrix group incorporated most technical/software risks.

Correlation Test: The goal of this test is to detect factor correlations (inner relationships); it begins by identifying all the bivariate (two-way) relationships between factors with a "Sig. (2-tailed)" value between 0.01 (99%) and 0.05 (95%), then it eliminates repeated relationships and finally, it finds more significant correlations by only highlighting (yellow) Sig. (2-tailed) values of smaller than 0.025. The findings of this analysis show that the lack of client demand of BIM increases risk sharing between stakeholders; they also demonstrate that the absence of specific BIM contracts is affected by the fragmented nature of the construction industry as well as the high initial investment costs of BIM. Another observation shows that the unawareness of the contractual implications of BIM is caused by organizations' lack of BIM experience.

The correlation test indicates that the difficulty in unifying analysis platforms between stakeholders is caused by the undistributed costs of developing the BIM technology. The test also shows a relationship between the strict BIM implementation standards and its adoption in small companies. Another suggested outcome is the lack of coordination between project team members that use BIM is because of their missing experience in the new system.

The outcomes of the test also suggest that the absence of higher management support of BIM adoption and the gaps in staff skills in the new BIM dimensions are concurrent with the high training/recruiting costs of BIM. Finally, it is argued that the incompatibility of the BIM programs might have an effect on team communication and information sharing as well as stakeholder risk sharing due to loss of valuable project data.

Ordinal Regression: This analysis was generated in order to examine the relationship between the suggested significance of the BIM organizational risks based on their literature citation and the established importance of these risks through the feedback of the respondents in the questionnaire. The proposed scale of the risks from research citation is an ordinal measurement (1–2 citations = less significant, 3–4 citations = significant, 5–6 citations = more significant) while the scale of the survey factor significance was based on the average weight of the respondent agreement (average weights ranged from 3 to 4.10 out of 5 which was converted to three categories similar to the first scale; 3.00–3.35 = less significant, 3.40–3.70 = significant, 3.75–4.10 = more significant) (Fig. 6). The resulting data view of the analysis is shown in Fig. 7.

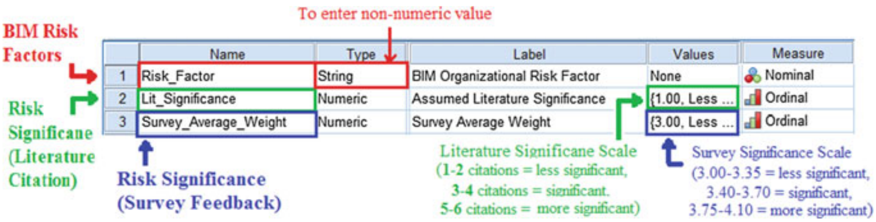

Fig. 6. Variable view of regression analysis *Source* Researcher

	Risk_Factor	Literature Significance	Survey_Average_Weight
1	S_1.1	3.00	3.29
2	S_1.2	3.00	4.05
7	C_2.1	6.00	3.24
8	C_2.2	4.00	3.86
14	M_3.1	4.00	4.00
15	M_3.2	5.00	4.10
20	R_4.1	6.00	4.05
21	R_4.2	1.00	3.50

Fig. 7. Data view of regression analysis *Source* Researcher

The null hypothesis in the regression test indicates that the risk factor significance of both the literature citations and the survey feedbacks are consistent and that the slope coefficients in the model are the same across both variables. In order to prove or reject the null hypothesis, we must look at the chi-square significance value of the regression analysis (if chi-square significance is greater than 0.05 then the null hypothesis is valid). The chi-square sig. value in both the Goodness-of-Fit test and the Test of Parallel Lines is greater than 0.05, this means that we can approve the suggested null hypothesis and therefore the significance of the BIM risk factors is consistent with the achieved significance from the survey results.

4 Conclusion

In reviewing what has been discussed in this paper, the main aim of the study was to present the subject of the Building Information Modelling (BIM) technology and its primary improvements to the project delivery process in the AEC industry. It investigated the major organizational challenges in the BIM implementation process such as risks of international strategies concerning the execution of BIM, liability and stakeholder risks, process, culture and change, system specifications impacting organizational processes and finally human, physical and informational resources involved in the BIM process. After that, the operational risks of BIM were summarized and ordered based on their citation by different researchers, then a conceptual model on how to prevent those risks was given on four levels: strategic, market/stakeholder, organizational and project team levels. The framework incorporated risk mitigation strategies that were suggested by authors or implemented in different locations, some of those strategies included increasing global awareness of the benefits of BIM, public/private partnerships, creating more BIM specific contracts and execution plans to reduce model ownership issues, detailed project lifecycle cost assessments of BIM projects and staff training on added BIM aspects (cost and project scheduling).

The final part of this paper was a quantitative analysis of the findings in the literature where the feedbacks of industry professional on the proposed risks and their prevention approaches were examined. The top 3 important risks of BIM according to the survey were "Cultural change resistance", "Unawareness of BIM benefits" and "Difficulty of BIM adoption in small firms due to investment costs" while the top 3 important mitigation strategies were "Mandating BIM programs in university curriculums", "Create incentives for staff to learn BIM" and "Dedicating company profits and marketing schemes for BIM training/recruiting costs".

The survey results were furthered studied by examining the standard deviation and reliability to determine the internal consistency of the results, no factors were eliminated as a result of the reliability test and then a factor analysis was conducted to find internal relationships between the factors where the grouping was similar to the initial grouping of the risks (Strategic, Contractual, Managerial, Resources). After that a correlation test helped further in finding other internal relations and finally regression analysis was used by studying the significance of the risks in the survey against their theoretical significance from the literature, the results approve the null hypothesis that suggest the consistency of the survey results with the literature review.

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