Emerging Managerial Risks from the Application of Building Information Modelling

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To cite this article: Almarri, K., Aljarman, M., & Boussabaine, H. (2021). Emerging managerial risks from the application of building information modelling. *Journal of Facilities Management*, *19*(2), 228-248. DOI: https://doi.org/10.1108/JFM-01-2020-0002

Abstract:
Purpose – Building Information Modelling (BIM) technology adoption is growing rapidly due to its perceived benefits. The purpose of this paper is to assess the perceptions of the users of BIM regarding the likelihood of managerial risks emergence that might influence the successful application of BIM, in order to facilitate the successful implementation of BIM in the construction industry.
Design/methodology/approach – Emerging managerial BIM risks were extracted from literature**.** The primary data were collected via a questionnaire survey. The analysis of the results was driven by univariate and inferential statistics (ANOVA) to assess the emergence of managerial risks.
Findings–The study confirmed the nine most likely managerial risks that might emerge from BIM adoption, which are lack of understanding of the expectations from BIM modelling, lack of experienced and skilled personnel, lack of clarity on integration of BIM with the current business practice, conflict due to dissimilar expectations from BIM, lack of collaborative work processes and standards, lack of understanding of BIM processes, lack of understanding modelling behaviours, lack of expertise within the project team, lack of expertise within the organizations, and lack of criteria for BIM project implementation.

Implications –The results will intensify the discussion about BIM risks, risk allocation and other aspects that are related to BIM methodology. The compiled list of managerial risks will help stakeholders in assessing financial implications that may result from BIM application. The list of risks could be used in pricing consultancy and construction services. More importantly, the list might be useful in developing an international standard for BIM risk management. The results showed that BIM success depends on the close collaboration, at the outset of the project, with contractors, consultants, designers and client.

Originality/value – Important managerial risks have been identified in the adoption of BIM. It renders a new understanding of the risks that might influence the successful application of BIM.

Keywords BIM technology, BIM adoption, Managerial risks, Construction management

Introduction:

Since the start of the use of Computer Aided Design (CAD), computer technology has played a very important role in the construction industry. Recently, BIM technology has become the main platform to exchange information and to communicate design with all parties. The history of BIM can be traced back to the 1970s in Georgia Institute of Technology, where the scholars developed the theory of Building Information Modelling. According to the National Institute of Standards and Technology (2004), BIM is "a shared digital representation founded on open standards for interoperability." However, Eastman (2008:8) defines BIM as "a modelling technology and associated set of processes to produce, communicate and analyse building models". A different definition is given by (Kymmell, 2008: 28) of BIM when he states that it is "project simulation consisting of the 3D models of the project components with links to all the required information connected with the projects' planning, construction or operation, and decommissioning". BIM purpose is to improve business processes (Giligan and Kunz, 2007). Vaciliou and Cormier (2010) indicate that BIM is a new way of working in the construction industry by using an innovative technology tool that can help in the identification of issues and uncover conflicts in the design of a project before it becomes too time-consuming and costly to fix (Almarri et al., 2019). Eastman et al. (2011: 544) argues that *"BIM represents a paradigm change that will have far-reaching benefits, not only for those in the building industry but for society at large, as better buildings are built that consume less energy and require less labour and capital resources"*. A multitude of research points a set of concerns that are attributed to legal, contractual, technical, supervisory, usage, and security concerns (Ashcraft, 2008; Chawla, 2012; Udom, 2012). However, the problem that the industry is currently facing is that there are no universally agreed standards and procedures. In addition, there are different concepts promoted by different stakeholders. For example, the lack of standards has been highlighted by Day (2011) who states that "Standards are a major industry issue". This problem is further illustrated by Migilinskasa et al. (2013) who anticipated that the use of BIM is "*constrained by existing contractual arrangements and traditional organization in the projects directed by stronger party with [an] atmosphere of fights for individual benefits instead of searching for better project delivery solutions and alternatives, which can make participation in the project delivery beneficial for all involved*". This uncertainty will lead to risk in the use of BIM as a collaborative working framework. This view is supported by Boyes (2014) who points out that "a number of new risks are inherent in the adoption of BIM". It is widely accepted that BIM represents a new risk frontier to the construction industry (Barra 2012). The author went on to point out that "*those desiring to use BIM should anticipate spending a little more in a legal effort to draft and negotiate the risk-shifting contract provisions that properly allocate risks to the party best able to manage them*". Boyes (2014) commented on the endeavour of the UK Government to promote the use of BIM as "*this is not without risk as the greater reliance on information technology has associated cyber security risks*". The author went on to emphasis that the "*integration of BIM information models and operational building systems presents a significant risk*".

Takashi and et al (2017) reported on the problems associated with implementation in Japan. The authors cited that the top-down processes of implementing BIM are not always encouraged. The authors went on to stress that in Japan the design risk is managed by transferring the task design and drawings to a general contractor. The authors didn't report on issues related legal aspects of BIM implementation.

In this paper, BIM risks are attributed to the uncertainty associated with the issues pertaining to who owns the application, library, data collaboration, BIM management, BIM content, frontier technologies and associated processes, etc.

A growing body of literature has highlighted that BIM technology can provide effective information management and communication, a simpler business process, high quality and efficiency in management throughout the project life cycle (Almarri et al., 2019; Arayici and Aouad, 2010). In contrast, it was argued that conventional techniques are unable to meet the required processes and improvements for large and complex construction projects (Yang et al., 2007). However, to realise these benefits, it is contended that BIM stakeholders need to undertake a comprehensive change management process (Arayici and Aouad, 2010). Organisational, managerial, and processes changes for adopting BIM practices carry considerable risk (Azhar et al., 2012; Ashcraft, 2008; Eastman et al., 2008). In this paper, BIM managerial risks are attributed the uncertainty associated coordination, user experience, quality of standards and cost.

Thus, this research aims to augment the BIM literature by identifying BIM managerial risks. This research is driven by the following question:

What are the managerial risks that influence the use of BIM technology in the project lifecycle?

The rest of the paper is structured as follows: first section presents the theoretical background and identify BIM managerial risks. Second section documents the research methodology. The third section presents the results from the flied study. The fourth part of the paper provides a discussion on the BIM managerial risks and reconcile between the views of the respondents and literature in project management. The article ends with conclusions and implications outlining recommendations for further research.

Theoretical background

The phenom of adoption of technology and innovations has been studied for more than three decades. It is well understood in the literature that adoption is related to the decision to use an innovation or technology in term of both product and processes (Almarri et al., 2019). Similarly, in the construction industry is attributed to the decision made to use new systems to implement in projects and organisations (Almarri et al., 2019; Winch 1998 and Hosseini et al 2015, 2016). Hosseini et al (2015) pointed that BIM adoption is closely aligned with the innovation adoption process. Davies and Harty (2013) advanced the view that companies adopt BIM and implement it on their projects according to the innovation adoption process. Furthermore, BIM adoption in academic literature has been considered as technology innovation. More importantly, Murphy (2014) postulated that innovation adoption process is the most effective approach for the acceptance of BIM in construction companies. Thus, the innovation adoption definitions advanced by (Roger 2010, Hosseini 2015, 2016, and Winch 1998) is an appropriate approach for framing the emerging managerial risks from BIM adoption in the constructor sector.

The basis of UK BIM adoption is rooted back to the "Strategy Paper for the Government Construction Client Group" written by the BIM task working group (Almarri et al., 2019). The report key recommendations for legal, contracts and insurance includes, IP and copy transfer, right, standard contract amendments to comply with BIM protocols, standardisation of BIM Protocols, duties for consultants and contractors under BIM, data base right and risk transfer as model passes between different stakeholders (BIM Task Group 2011, 2012) . Although the report outlined a high level strategy and benefits for the use of BIM, it didn't not explicitly categorise BIM risks, or suggest statements (constructs) for measuring the occurrence such risks. Subsequently to the wound down of the BIM task group in 2015, UK national standard body BS, industry and academic organisations embarked on the development of several standards to facilitate BIM adoption. For example, BS 1192: 2014 and 2016, only establishes the methodology for managing the production, distribution and quality of construction information. Similarly, BS 8536 (2015) provided details or briefing for design and construction. Likewise, Publicly Available Specification (PAS 1192-2:2013) only describes the requirement for achieving BIM at level. Equally, PAS (1192-5:2015) only deals with security in utilizing digital technologies. The latest PAS (1192-6:2018) explains the requirements for sharing health and safety requirement. All these publications and others were about BIM adoption, motivation and benefit realisation, BIM standards, and high-level requirements for BIM implementation at different levels of adoption and life cycle of projects. Although some of these documentation (BS 8536 2015, PAS 1192-2:2013, PAS 1192-5:2015 and PAS 1192-6:2018) discussed the development of risk register format, it did not categorise BIM risks or list them in association with contractual issues, data issues, intellectual property rights and liability, and participants. The current literature although provided categories and respective risk associations, these categories did not explicitly address the managerial categories and their associated risks. This study discovered forty risks that are attributed to these six themes that are associated with BIM adoption. Thus, the study will enable the practitioners to identify the areas of vulnerabilities related to managerial risks in BIM adoption, and will also expands our understanding about BIM managerial risks which are relevant to all the levels of BIM adoption.

The process used to categorize risk follows Tah and Carry's (2001) methodology. The process starts with identifying BIM practices then moves on in identifying risks associated with BIM usage. Once the risks are identified from the literature, the common risk factors were categorized according to the source and influence of the risk factors. The reliability of our approach to identify and categorize risks is based on consistency (which means reliability). It is the degree to which an instrument will give similar results for the same experiment at different times. In this research, the extracted BIM risks and categories are reliable due to the fact that they have been reported in several sources.

Azhar (2011) categorised BIM into two groups legal (or contractual) and technical. The first group of risks deals with the lack of determination of ownership of the BIM data, whereas the second category is associated with interoperability, compatibility complexity of software. Ya'acob et al. (2018) classified BIM into further higher-level instances; financial, managerial, technical and legal. However, risk classification at a coarse level will not assist in accurate analysis of costing and managing BIM risks. Pruvost and Scherer (2017) categorized BIM risks into events than may influence BIM application. Kuo-Feng et al (2015) also identified 13 risk factors related to five BIM risk categories; technical, management, personnel, financial, and legal. Though, the authors did not specify and sub-classes BIM categories. Zhao et al (2017), extracted 16 BIM risks categorized into 9 groups from literature review. The authors didn't explicitly categorize managerial risks but they pointed to risks that are associated with managing BIM. In over-all there is sparse literature on risk management of BIM adoption. Risk associated with BIM adoption management is considered is essential for BIM implementation (Ya'acob et al. 2018).

The theoretical background review addresses managerial risks which might emerge from BIM adoption. The theoretical review is organized into four sections. The first section begins with a review on the managerial risks related to coordination issues, the extent of their complexity, their difficulty of use in the BIM approach and the consequences of concerns and questions among the users. The second section reviews the BIM managerial risks related to standards/efficiency issues and the emerging risks of the absence of such standards and lack of modelling competency among the parties involved. The third section reviews the emerging risks given by the users, team experiences, and the extent of commitment by the parties involved in sharing information by using BIM collaboratively. Finally, BIM managerial risks related to cost issues and the consequence of training costs associated with using BIM as well as costs of buying the software will be reviewed.

BIM coordination Risks

Lam et al (2017) provided framework conceptual framework to assist with the brokering of risks and rewards in adopting BIM. The authors suggested the framework will assist in taking informed decisions about BIM adoption. It has been suggested that, obtaining the maximum benefits from BIM technology is linked to the ability to maximize cooperation in the project regardless of who leads (Ya'acob et al 2018, Singapore BIM Guide1, 2012; Eastman et al., 2011). It is postulated that BIM coordination function allows project team members to make better decisions through using BIM tools. Furthermore, it is argued that owners and contractors can use the BIM model to facilitate management and a construction tool (scheduling, phasing, and construction cost estimating) (Autodesk, 2012). However, Schinler and Nelson (2008) stated that BIM coordination tools do not replace communication between project team members. In addition, their study found that there are obstacles relating to coordination and implementing BIM software (Zou et al 2019). It pointed out that the difficulties occur when transforming data between different packages. The authors went further to explain that there might be coordination difficulties by architects in determining ownership of elements, which were created by several different specialties (Zhang & Gao, 2013; Schinler and Nelson, 2008, Ganbat el al 2020). Furthermore, Gijezen et al. (2010) stated that BIM coordinators might face problems during the process of clash detection. The author exemplified his point with an anecdote related to BIM coordinators ability to perform clash detection tasks, especially when there might be large amounts of clashes. In addition, the author observed that when BIM coordinators perform clash detection tasks, it is not always immediately clear which participant is responsible for putting the elements into BIM visualisation platforms. The author posited that it is important to have clarity in the specialty of the participant responsible for any element, if this is not the case, it might result in an ineffective management of the design process (Goucher & Thurairajah, 2012; Gijezen et al., 2010). Also, the reluctance of stakeholders to fully engage such architects, engineers, and contractors in the BIM might have a negative outlook on BIM benefits realisation processes (Ku and Taiebat, 2011; Fox and Hietanen 2007). It was highlighted that the use of BIM significantly changes the relationships between parties in the project and blends their responsibilities and roles (Abanda et al., 2015; Ramaji & Memari 2015; Simonian, 2010). However, it was pointed out that the level of engagement interaction between participants varies depending on the level of BIM adoption (Miettinen and Paavola , 2015; Lowe and Muncey 2009, Ya'acob et al 2018).

BIM shares similar characteristics to other digital collaborative environments. All digital environments are driven by a variety of software and hardware and there are often problems related to information or inconsistencies of programs. The literature is full of reports on failed and malfunctioning software. For example, in a study by Fischer et al. (2003) on the use of 3D and 4D on a major project, they pointed out that there are problems related to information, including lack of data related to scheduling and geometry or the link between the two. There were also inconsistencies in some instances in the 3D model, including too much data and too little detail, which "slows down computational processing of the 3D and 4D models". There is no doubt that this will affect information exchange, as well as the delay in model submission and approval. In the same vein, examples of BIM from practice suggest that there is a lack of tools to BIM support integration in project phases (Khemlani, 2012, Lam, et al 2017). In addition to that, it was claimed that information exchange and communication registry between the BIM users through different media is still ineffective and not captured in a BIM model (Masoud, Kharel & Naser, 2014; Kalny, 2007, Ganbat et al, 2020). These risks might limit the coordination processes (Pruvost and Scherer 2017). Therefore, the key risk issues which may emerge from this managerial aspect are summarized in Table 1. The first research hypothesis is posited as follows:

H1: There is no statistically significant difference between the respondents' rating of the emergence of BIM coordination risks"

Insert table 1 here

BIM standards efficiency risks

Researchers have argued that standards related to efficiency have played important roles in various business practices (Eastman et al., 201, Lam et al 2017). The use of BIM requires standards that provide guidance for multi-disciplinary perspectives for the efficient creation and sharing of information (Mutai, 2009 , Zou et al 2019).

Many organizations have developed guidelines for implementation of BIM on projects. However, these standards are still not yet defined and not widely adopted (Eastman et al., 2011). Tulenheimo

(2015) reports on the need for developing common BIM requirements in Finland. The author points out that there is growing need for standardization and common rules. Shelden (2015) reported on the emergence of several BIM standards. The lack of uniform BIM standards in industry means that most users are using the trial-and-error method (Mutai, 2009, Lam et al 2017). Thus, dissimilar expectations in the results lead to conflicts about the benefits of using BIM. Additionally, in the event that the business value is unclear and results unknown, of course, the risks will decrease the use of BIM (Mutai, 2009, Lam et al 2017, Zou et al 2019).

A greater barrier to up taking BIM is associated with model management and work processes for integrating multiple disciplines within the BIM model. This requires multiuser access by various disciplines (Eastman et al., 2011; Pruvost and Scherer 2017). Several studies have revealed that BIM methodology changes the relationship between contractors, consultants, sub-contractors, sub-consultants and other parties in the design and construction process. Thus, the administration needs to access information from various sources, given the changing requirements of the project by the owner that need to be carefully managed. However, there are no unified standards about how BIM projects will be managed, and how work processes will collaborate, in addition to the lack of modelling competency among parties involved (Negendahl, 2015; Gijezen et al., 2010). To realise the full benefits of BIM, it needs to be measured over the project lifecycle to ensure efficiency and continual improvement (Eadie et al., 2013, Ya’acob et al 2018, Zou et al 2019). Ashcraft (2009) noted that despite BIM’s advantages, there is still a "lack of immediate BIM benefits from projects delivered to date". In particular, there are benefits for the key adopters (the designers) such as the architects and engineers, while there are obvious benefits for the owner from the BIM through using a flexible model capable of producing an optimization design, more coordination, and fewer construction errors (Zhao et al 2017). In addition, the model can be used for facility management and operation by contractors for greater coordination and to decrease fabrication cost. However, economic benefits are often less apparent for the designers, as there are unequal rewards of the BIM model that form a significant obstacle for design professionals and create other risks affecting the competence (Ganbat el al 2020). BIM managerial risks related to standards efficiency become barriers limiting benefits of using BIM, are summarized in Table 2. The second research hypothesis is posited as follows:

H2: There is no statistically significant difference between the respondents' rating of the emergence of BIM standards efficiency risks "

Insert table 2 here

BIM user experience risks

Diffusion of technology and its success cannot be achieved without appropriate infrastructure of capabilities and skills that help in the adoption of the technology (Premkumar and Potter, 1995, Ya’acob et al 2018, Ganbat el al 2020). A firm that has a sufficient infrastructure, will be more willing to take risks to adopt innovative technologies (Premkumar & Potter, 1995).

Numerous case studies on BIM usage have reported the need for project team participants to have the requisite knowledge and ability to use BIM technology (Abanda et al., 2015; BIM Task Group, 2013; Zou et al 2019). The BIM methodology requires experienced staff who has the required knowledge and skills to drive the process (Eastman et al., 2008). According to an investigation on 'Understanding and facilitating BIM adoption in the AEC industry', participants raised concerns about the lack of adequate training and awareness for users on BIM applications (Gu and London, 2010, Ya'acob et al 2018, Lam et al 2017). For example, there were mistakes in the implementation of some intelligent approaches through models such as 'Virtual Project Development' for the first time in a project due to lack of sufficient experience which leads to expensive consulting or time consuming in searching activities (Darius et al., 2013).

It is further postulated that lack of experience in implementing BIM obscures business value to some user, resulting in unknown risks (Darius et al., 2013, Lam et al 2017). This leads to differing opinions about objectives and benefits of the project; hereafter, the conflicts about interests will arise, which could discourage the use of BIM. In the same context, Young Jr. et al. (2009), in a report about 'how BIM is solving real problems in actual projects', stated that the problem of measurement frequently faced digital technology implementations in identifying benefits or measurement of value. It is a tricky task, as obtaining data in order to conduct comparisons is difficult, in view of the uniqueness and variability of projects. Even in cases that obtained the data, big variations are reported (Azhar, 2011), which leads to the difference in determining the benefits from modelling practices for many of the users. Moreover, there is social and cultural resistance to the change of BIM adoption. It was postulated that designers are satisfied with their job through traditional methods (Yan & Damian, 2008, Zhao et al 2017). This resistance to BIM adoption might be due to a lack of sufficient experience to help on the use of technology optimally. Table 3 summarizes the risks reported in the literature. The third research hypothesis is posited as follows:

H3: There is no statistically significant difference between the respondents' rating of the emergence of BIM of user experience risks "

Insert table 3 here

BIM cost risks

Introducing an innovative technology in the construction process helps to manage information flows, coordinate, increase or decrease costs, and monitor and control projects. However, CAPEX and OPEX cost of the technology might affect their acquisition (Linderoth and Jacobsson, 2008, Lam et al 2017, Ganbat el al 2020). A previous study suggested that cost is a big barrier to the adoption of new technologies (Premkumar and Potter, 1995). Gustavsson et al. (2012) argued that IT tools in construction are rare and that this could be explained by lack of cost to acquire and use such tools (Gustavsson et al., 2012, Zou et al 2019, Lam et al 2017).

The training costs associated with using BIM are higher than the costs of buying the software. This could hinder the BIM benefits because many organizations are not excited about such investments unless they perceive the benefits of using BIM technology in the long-term (Eastman et al., 2008, Ya'acob et al 2018). Studies suggest BIM implementation requires more time spent for the user on inputting and reviewing data, these are additional costs in BIM projects (Fewings, 2013; Azhar, 2011, Lam et al 2017, Ganbat el al 2020.). It is highlighted that the change in the business processes related to the implementation of BIM require additional costs to provide the necessary infrastructure. Furthermore, there is a lack of clarity on the integration of BIM with the current business practice (Howard and Björk, 2008, Pruvost and Scherer 2017). Table 4 summarizes the risks reported in the literature. The fourth research hypothesis is posited as follows: *H4: There is no statistically significant difference between the respondents' rating of the emergence of BIM costs risks"*

Insert table 4 here

Method and Processes

It is commonly understood that survey methods tend to be a more favoured method for the collection of statistics and professional perspectives (Keil et al., 2008; Costa et al., 2007; Wallace at al., 2004). The BIM managerial risks were obtained from literature and then converted into statements of risk and questions. The list of risk statements or questions used in the questionnaire were validated by academic experts who have a working knowledge of BIM technology ensuring the statements had sufficient readability. Once the questions were developed, they were sent to experts to test their validity. Comments and suggestion from this process were used to modify the questions. Once the questionnaire was ethically approved by the university, the online survey was deployed. An online questionnaire survey was circulated electronically through emails to BIM experts in various government and private sectors in the UK, Europe, USA, Canada, Australia, India, China and Japan. The online format was selected for its many strengths, out of which are greater coverage of respondents, flexibility, speed and timeliness, ease of data entry and analysis, and access to large sample (Evans and Mathur, 2018). While the number of experts who are knowledgeable about BIM technology could be very high, it was difficult to determine this population, as the BIM experts who are knowledgeable about emerging risks from BIM application could be very small indeed. This guess is based on the lack of literature that exists in this area. Therefore, one could assume that only a few experts may know about risks in BIM. Thus a moderate estimate that the emerging risks from BIM application will be known to only 5% of the professionals ($p= 0.05$), to achieve the target of a sampling error within 5% ($SE= 0.05$) at a confidence level of 95% [$(1-\alpha) = 0.95$; $Z\alpha/2 = 1.96$], the minimum sample size (s) would be 73 (McClave et al., 2010).

The questionnaire was divided into two major professional parts. The first one dealt with collecting general information about the respondents, questions in this section relate to the duties they had to execute with BIM technology, whereas the second part pertains to emerging possible BIM managerial risks. A five-point Likert scale was adopted for measuring the likely occurrence of BIM risks. A five-point Likert scale is deemed to be provide a good reliability over the normal range of the measures, it is a widely used scale for measuring the attitudes and opinions of respondents in BIM studies such as Monko et al., 2017 and Chien et al., 2014.

The total number of respondents was 426 spread over various roles, such as an architect, engineer, constructor, consultants, cost consultants, and other professionals. 105 responses were recorded (35% response rate). This response rate is higher than the average response rate of similar studies, which is around 27% as reported by Monko et al. (2018).

The respondents were: 29 (28%) Architects, 24 (23%) Engineers, 15 (14%) Constructors and Consultants (Cost and Miscellaneous), leaving 37 (35%) as miscellaneous professions. 33 (31%) were private, 9 (8%) were public, and 64 (60%) from educational backgrounds. Findings state the lowest records 20 respondents (19%) having no BIM use, 27 (25%) that used BIM up to three years, 21 (20%) used BIM between three and five years, and 38 respondents (36%) used BIM for 5 years and more making it dominant.

The univariate and severity index were used to pre-analyse and rank responses. Inferential Statistics (ANOVA) was performed to determine if there were any significant differences between the views of respondents on rating the likely emergence of BIM managerial risks. The ANOVA technique uses one categorical independent predictor and tests the differences in the centroid (vector) of means of the multiple interval dependents for various categories (Keller & Warrack, 2003). An ANOVA analysis was conducted in order to justify the groups' statistical differences. ANOVA was used to identify the similarities and differences among the opinions of respondents on the risk factors identified in this study based on the experiences of respondents. Tukey tests were used as one of the HSD post-hoc multiple comparison tests by identifying that the mean difference is significant at the 0.05 levels.

The coefficient variation has been used in this study, which is a standardized measure of dispersion of a probability distribution or frequency distribution. in addition, the severity index was used, which provides standardized criteria to ensure inter-rater uniformity in assigning severity. The Kendall's W Test was used, which is used to attribute agreement analysis among participants in the various professions, and overall ranking was used to establish the respondent's ranking on each of the factors according to their importance and impact on usage of BIM (McClave et al., 2010).

Using the SPSS software and with a significance level of 0.05, the hypothesis test was computed using alpha=0.05, while observing the F-statistic and the p-value. The details of the analysis are explained in the following sections.

Results: analysis of the responses

BIM managerial risk were clustered as coordination, standards efficiency, user experience, and costs. This research has investigated 33 risks related to BIM managerial matters. The respondents were asked to rate the likelihood of emergence of these risks.

BIM Coordination risks

The rating of BIM Coordination risks is shown in figure 1. The results indicate that "Ineffective BIM contracting procedure" and "Ineffective BIM team selection procedure" risks are mostly to occur. In contrast, the less likely to emerge were risks “Slow information exchange” and “Ineffective measurement and coordinate systems”.

Insert figure 1 here

The ANOVA results showed that there were significant differences between respondents’ perceptions in the likely emergence of risk (High BIM ownership costs), the result showed that F = 2.948 with p-value = 0.039, and with regard to risk "Infective modelling content and reference information", the result showed that F = 3.259 with p-value = 0.027. A follow up with Tukey’s HSD post- hoc test was performed to find the significance of the difference between the respondents' perceptions about these factors based on different specialties. The post hoc test showed that the ratings for “Delay in model submission and approval” are not significantly different between Architect, Engineers and Other groups; however, there is a difference with Consultants groups. The post hoc test showed for "Infective modelling content and reference information” risk, there is a significant difference between Architect and Consultants, while other groups have the homogeneity of opinion on this risk. In general, in this part with the null hypothesis, there is no statistically significant difference between the respondents' perceptions on "all BIM risk factors related to Managerial issues" is accepted, apart from “Delay in model submission and approval”.

Respondents' evaluations BIM standards efficiency risks

The results of rating the emergence of efficiency risks of BIM are shown in figure 2. The results showed that, the highly rated two risks were “Conflict due to dissimilar expectations from BIM” and "Lack of collaborative work processes and standards". Likewise, risks ‘Lack of criteria for BIM project implementation” and “Lack of modelling competency among clients” are likely to induce impacts on BIM utilization. The risk that less likely to was “Lack of coping with the disturbances caused by the BIM from a social context perspective”.

Insert figure 2 here

The results revealed that there were some significant differences in the means of respondents’ opinions on managerial risk related to standards/efficiency in factors "Lack of benchmark for model accuracy and tolerances" and "Lack of coping with the disturbances caused by the BIM from a social context perspective” where the result of risk ME2 showed that F = 5.428 with p-value= 0.002. With regard to risk MCo10 "Infective modelling content and reference information", the result showed that F = 4.674 with p-value = 0.005. Tukey's HSD post- hoc test result indicates that the mean scores for the engineers and Consultants group were significantly higher than that of all the other groups for "Lack of benchmark for model accuracy and tolerances". Similarly, in risk "Lack of coping with the disturbances caused by the BIM from a social context perspective" the engineers group again was significantly higher than that of all the other groups

Respondents' evaluations of BIM of user experience risks

The findings from BIM user experiences risks are shown in figure 3. The highly likely to emerge risks were "Lack of understanding of the expectations from BIM modelling"; "Lack of understanding of BIM processes"; "Lack of experienced and skilled personnel"; "Lack of understanding modelling behaviours"; "Lack of expertise within the project team"; and "Lack of expertise within the organizations". The less likely risk to emerge was "Differing project objectives/benefits lead to participants' conflicts of interest. In particular, risk "there are low levels of effort and interaction between participants" (Lowe & Muncey, 2009) that may arise from lack of experienced and skilled personnel in BIM projects.

Insert figure 3 here

The results revealed that there were some significant differences in the means of respondents' opinions on risks "Lack of understanding of the expectations from BIM modelling" indicate that F-statistic = 4.243 with p-value = 0.008, and risk "Cultural resistance to BIM application" the result showed that F = 2.863 with p-value = 0.043. The results of Tukey's HSD post-hoc tests on risk "Lack of understanding of the expectations from BIM modelling" indicated that the mean scores for the engineers group were significantly higher than that of all the other groups. Similarly, in risk "Cultural resistance to BIM application" the engineers group was also significantly higher than that of all the other groups

Respondents' evaluations of BIM costs risks

The findings from BIM costs risks are shown in figure 4. The surveyed respondents indicated that the most likely risk to emerge was "Lack of clarity on integration of BIM with the current business practice". The results showed that the factor that followed in likelihood of occurrence "Poor BIM data quality due to cost and time constraints". Likewise, "Lack of additional project finance to support BIM" is marginally rated rate lower than other risks.

Insert figure 4 here

The results indicate that there were significant differences in the mean scores for respondents' perceptions on risk "Poor BIM data quality due to cost and time constraints", where the result of this factor showed that F = 3.664 with p-value = 0.016, as well as risk "Lack of additional project finance to support BIM" where the result indicated that F = 2.762 with p-value = 0.049 which is below 0.05.

The result of Tukey's test for risk "Poor BIM data quality due to cost and time constraints" indicates that there was a difference between the "Other" group and Architect, Engineers, and Consultants see that there are risks of "Poor BIM data quality due to cost and time constraints" and that this may affect the use of BIM in the project life cycle. For risk "Lack of additional project finance to support BIM", the result indicates that there is a large agreement between "Architects, Consultants, and Other" groups on the impact of this factor on the uses of BIM. This is due to both groups using the model in the initial stages of the project and the design phase, while Engineers see this factor as having no effect on the use of the program.

Discussion

The summary of the variance analysis is shown in Table 5. Literature review showed that nine BIM coordination risks. Among these risks is "Inefficient design coordination", where majority of the respondents strongly acknowledged that the risk is likely to emerge. This risk might stem from the weakness of cooperation and participation by some of the participants Ganbat el al 2020, Ya'acob et al 2018). This is further could well be due risks "Ineffective BIM contracting procedure" and "Ineffective BIM team selection procedure". Generally, the majority of respondent showed that there were no significant differences regarding the likelihood of the occurrence of BIM coordination risks. This implies that most of risks in this group might have a material influence on BIM adoption. However, the ANOVA showed that there was a difference in views on risks, Ineffective modelling content and reference information" and "Delay in model submission and approval". This is consistent with the findings of Fischer et al. (2003) who pointed out that there are "inconsistencies in some instances in the 3D model, [such as] too much data and too little detail, which slows down computational processing of the 3D and 4D models". This is in line with the findings from Zou et al (2017) study. The results indicate that there is a statistically significant difference between the Architect group and Consultants group, while the rest of the other groups have the same opinion on its likely of occurrence. They see that this risk is significant likely to emerge. This finding is consistent with the result of Gijezen et al. (2010), who pointed out that during the clash detection process, substantial amounts of clashes occur, but it is not always immediately clear who was responsible for the inclusion of elements in 3D. These may hinder BIM coordinators in managing the design change after identifying relevant clashes. This is also consistent with the results of Schinler and Nelson (2008) and Ganbat el al (2020) who stated that BIM coordination tools do not replace communication between the design team. Quite the contrary, the team needs to identify the necessary level of detail required for achieving its use, particularly in determining ownership of elements by architects, which is usually added from several different specialties.

Insert table 5 here

All respondents agree on the importance of BIM standards efficiency risks. This shows that BIM experts are with a view that efficiency achievement of using BIM is impossible without the presence of uniform standards. This is consistent with the findings of Eastman et al. (2011) and Lam et al (2017) who pointed out that there are efforts from several organizations to homogenise BIM practices. However, these standards are still not yet defined and are not widely adopted. Despite this effort to harmonize the standards, software owners are not very enthusiastic to incorporate these standards in their platforms. Tulenheimo (2015) claims that "*still and inconveniently, some international companies are trying to push their own BIM standards forward*". This is contrary to the view of benefits that are attributed to BIM. According to NBS (2014), "all team members should be working to the same standards as one another". There is also the issue of inconsistency between some BIM practices and standard contracts procedures. It was suggested this illustration demonstrates that synchronization between contract terms and BIM standards needs to be considered carefully to avoid unanticipated legal or contractual risk issues (Looi, 2015, Lam et al 2017 and Ganbat el al 2020).

The most likely user experience risks to emerge from the standpoint of respondents are "Lack of understanding of the expectations from BIM modelling" and "Lack of experienced and skilled personnel". The respondents also believed that "Lack of experienced and skilled personnel" would lead to "Lack of understanding of the expectations from BIM modelling" by users, which leads to conflicts because of the unexpected f results from model, caused by poor user experience. This is consistent with the finding of Darius et al. (2013) who pointed out that 'Lack of experience in implementation of BIM' leads to business values being unclear and having different expectations of results, which in turn lead to risks of conflicts over users' interests. Similarly, other studies have indicated that there is a "lack of experienced and skilled personnel in this aspect" (Ku & Taiebat, 2011; Ya'acob et al 2018; Ganbat el al, 2020). Lack of information or misunderstanding of the BIM onsite data will lead to time wasting and probably to tasks been carried out not according to construction detail's intentions. This view is supported by Miskimmin's (2014) statements: "Nor can they (clients) risk mistakes due to inaccurate, incomplete, out-of-date, or just incorrect information that leads to rework, getting rid of the old materials and the carbon overhead". Thus, as has been pointed out, the success of BIM producing high quality offsite manufacturing information will "depend on the ability to capture all relevant data in the BIM model and to successfully exchange data between different project participants" (Nawari, 2012).

The literature review indicated that there are four BIM cost risks. These are "High modelling costs"; "Poor BIM data quality due to cost and time constraints"; "Lack of additional project finance to support BIM" and "Lack of clarity on integration of BIM with the current business practice". The views of the respondents showed that the most likely risks to occur is "Lack of clarity on integration of BIM with the current business practice". This means that with the rapid changes in prices, especially in an emerging market, this may affect the implementation of BIM in business processes (Ya'acob et al 2018, Ganbat el al 2020). This is consistent with the findings of

Howard and Björk (2008), where they pointed out that lack of integration of BIM with the current business practice is serving as a new risk of using BIM in the project lifecycle (Pruvost and Scherer 2017).

The risk that is followed in likelihood of occurrence is “Poor BIM data quality due to cost and time constraints”. This risk is due to the substantial number of objects used in the model which lead to a weakness of download in the model, which is confirmed by Tommelein and Gholami (2012). In addition, implementation of BIM requires more time spent by users for inputting and reviewing data in the model, and this serves as new additional costs in BIM projects. This is also stressed by Azhar (2011), Lam et al (2017) and Ganbat el al (2020) .

Similarly, "Lack of additional project finance to support BIM" and "High modelling costs", are risks that followed in likelihood of occurrence from the standpoint of respondents. There is no doubt that implementation of innovative technology such as BIM needs to be used in conjunction with adequate training for the participants, and this requires additional support and costs. However, as Eastman et al. (2008) pointed out, training costs are higher than the costs of buying BIM software, and this could hinder the use of BIM in some organizations, especially small businesses. This similar to the view expressed by Lam et al (2017).

It is conjectured that BIM technology can provide effective information management and communication throughout the project life cycle. This will largely depend on how BIM stakeholders are willing to change their business processes (Lam et al 2017). The conjecture is based on the fact that BIM digital collaborative environments through the exchange of information will render the coordination of project information more effective. But one needs to understand that BIM coordination tools do not replace communication between the project team members. It is also found that change in business processes related to the implementation of BIM is still simple and there is a lack of clarity on the integration of BIM with the current business practice (Lam et al, 2017 and Pruvost and Scherer, 2017). However, implementation guidelines and policies are starting to emerge, but their maturity and effectiveness has yet to be assessed.

There is overwhelming evidence in the literature to suggest that BIM will reduce tangible risks, for example physical clashes and coordination. However, it also indirectly creates new intangible risks through usability problems and possible disputes between BIM users. There is the fear that over-reliance on BIM technology will lead to increased construction risk due to make mistakes, miscalculations, and errors of judgment, which in turn leads to rework and possible liability

Conclusion

The objective of this study was to identify the Managerial risk factors influencing the use of BIM technology in the project lifecycle. The research has successfully investigated and documented the managerial risks that influence BIM application. This was based on the classification of risk factors in the literature of this research. Managerial risk factors included 33 risk factors divided into four categories; technical, standards/efficiency, user, and costs. The results showed that 9 most likely risks to emerge "Lack of understanding of the expectations from BIM modelling"; "Lack of experienced and skilled personnel"; "Lack of clarity on integration of BIM with the current business practice"; "Conflict due to dissimilar expectations from BIM"; "Lack of collaborative work processes and standards"; "Lack of understanding of BIM processes"; "Lack of understanding modelling behaviours"; "Lack of expertise within the project team"; "Lack of expertise within the organizations"; and "Lack of criteria for BIM project implementation". The results indicate that there is a concern among the respondents about the managerial aspects of BIM implementation. These results may also suggest that BIM implementation is strongly related to managerial aspects. From these results one can presume that without good management processes in place, the potential benefits from BIM cannot be realised.

From a practical point of view, this study has contributed to the support for the application of BIM in the industry. The extracted managerial risks' classification is expected to be used within entities such as clients, contractors and consultants to assess their risks. The results will certainly intensify the discussion about BIM risks, risk allocation and all aspects that are related to BIM managerial issues. Also, the complied list of managerial risks will help stakeholders in assessing financial implications that may result from BIM application. The list of risks could be used in pricing consultancy and construction services. More importantly, the list might be useful in developing an international standard for BIM risk management. The risk classification developed in this study will provide a unique opportunity to advance the research capability in this emerging field. The results will help to increase the maturity and importance of BIM risk assessment.

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Table 1 : BIM Coordination risks

R.F Code	BIM Managerial Risk Factors Related to Coordination issues	References
MCo1	Slow information exchange	Giligan and Kunz (2007); Gijezen et al. (2010); Schinler and Nelson (2008); Fischer et al. (2003); Khemlani and Holzer (2007); Kalny (2007); Miettinen and Paavola, (2014); Abanda et al. (2015) Masoud, Kharel & Naser (2014) Ramaji & Memari (2015) Goucher & Thurairajah (2012) Zhang & Gao (2013) Zhao et al (2017) Ya'acob et al (2018) Zou et al (2019) Ganbat el al (2020)
MCo2	Inefficient design coordination	
MCo3	Ineffective schedule of information exchange	
MCo4	Delay in model submission and approval	
MCo5	Delay in information submission and approval	
MCo6	Ineffective measurement and coordinate systems	
MCo7	Ineffective BIM team selection procedure	
MCo8	Ineffective BIM contracting procedure	
MCo9	Ineffective modelling content and reference information	

Table 2: BIM Standards Efficiency risks

R.F Code	BIM Managerial Risk Factors Related to Standards of Efficiency issues	References
ME1	Conflict due to dissimilar expectations from BIM	Eastman et al. (2011); Mutai (2009); Gijezen et al. (2010); Ashcraft (2009); Abanda et al. (2015); Negendahl, (2015) Zhao et al (2017) Ya'acob et al (2018)
ME2	Lack of benchmark for model accuracy and tolerances	
ME3	Lack of criteria for BIM project implementation	
ME4	Lack of collaborative work processes and standards	
ME5	Lack of immediate BIM benefits from projects delivered to date	
ME6	Lack of benchmark for model accuracy and tolerances	
ME7	Lack of modelling competency among designers	
ME8	Lack of modelling competency among contractors	
ME9	Lack of modelling competency among clients	

		Zou et al (2019) Ganbat el al (2020)

Table 3: BIM user Experience risks

R.F Code	BIM Managerial Risk Factors Related to Experiences	References
MX1	Low levels and degrees of effort and interaction of participants	Lowe and Muncey (2009); Ku and Taiebat (2011); Gu and London (2010); Darius et al. (2013); Azhar (2011); Yan and Damian (2008); BIM Task Group, (2013); Abanda et al., 92015) Zhao et al (2017) Ya'acob et al (2018) Zou et al (2019) Ganbat el al (2020)
MX2	Differing project objectives/benefits lead to participants'' conflict of interests	
MX3	Lack of coordination of the modelling effort	
MX4	Lack of experienced and skilled personnel	
MX5	Lack of understanding of the expectations from BIM modelling	
MX6	Lack of understanding modelling behaviours	
MX7	Lack of understanding of BIM processes	
MX8	Lack of expertise within the project team	
MX9	Lack of expertise within the organizations	
MX10	Cultural resistance to BIM application	

Table 4: BIM managerial risks related to costs issues

R.F Code	BIM Managerial Risk Factors Related to Costs issues	References
MC1	High modelling costs	Eastman et al. (2008); Azhar (2011); Linderoth and Jacobsson (2008); Howard and Björk (2008); Fewings, (2013);
MC2	Poor BIM data quality due to cost and time constraints	
MC3	Lack of additional project finance to support BIM	
MC4	Lack of clarity on integration BIM with the current business practice	

		Lu et al. (2014) Zhao et al (2017) Ya'acob et al (2018) Zou et al (2019) Ganbat el al (2020)

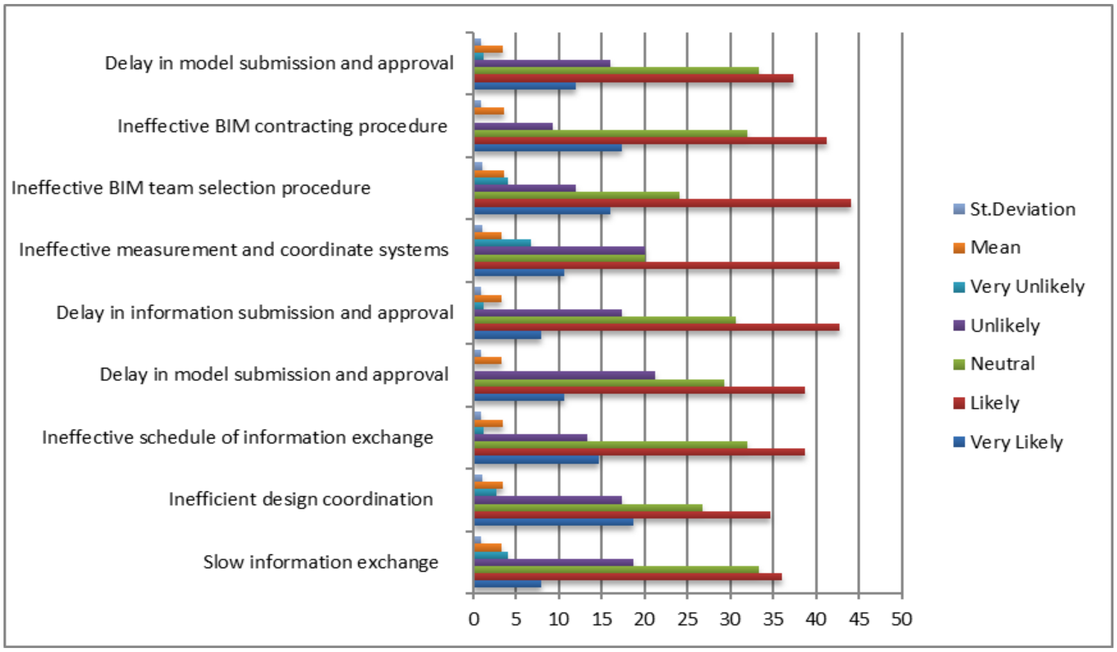

Figure 1 Respondents' evaluations coordination risks

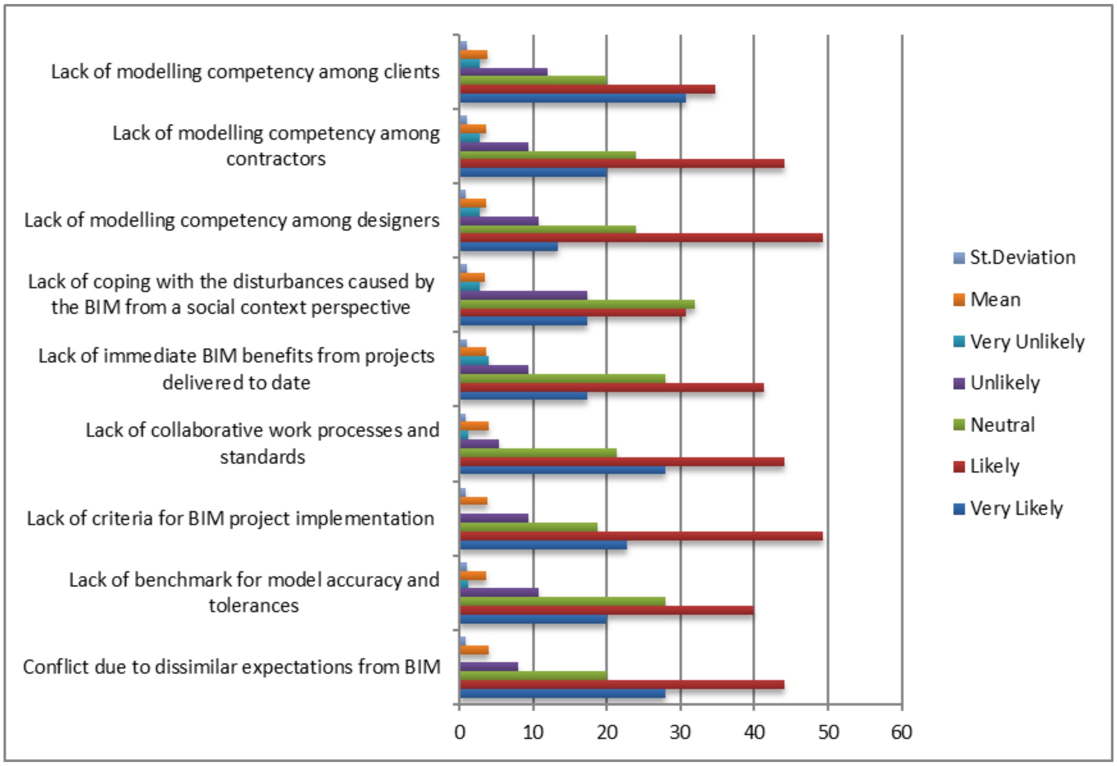

Figure 2 Respondents' evaluations BIM standards efficiency risks

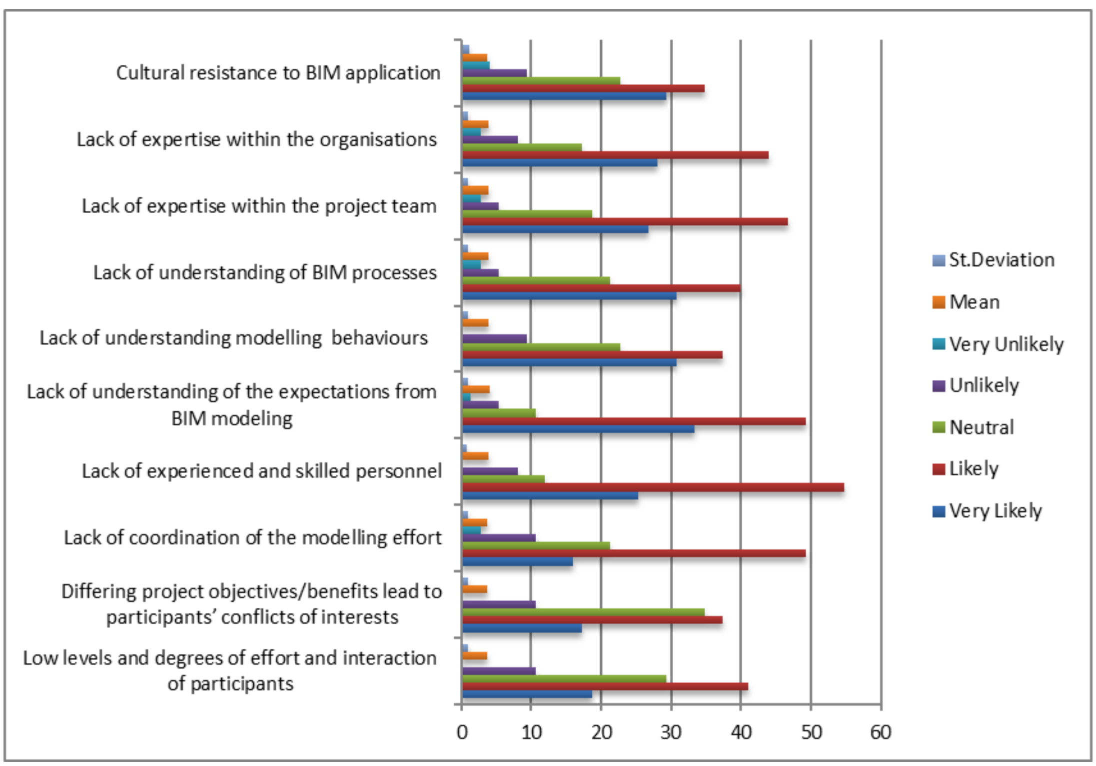

Figure 3 Respondents' evaluations of BIM of user experience risks

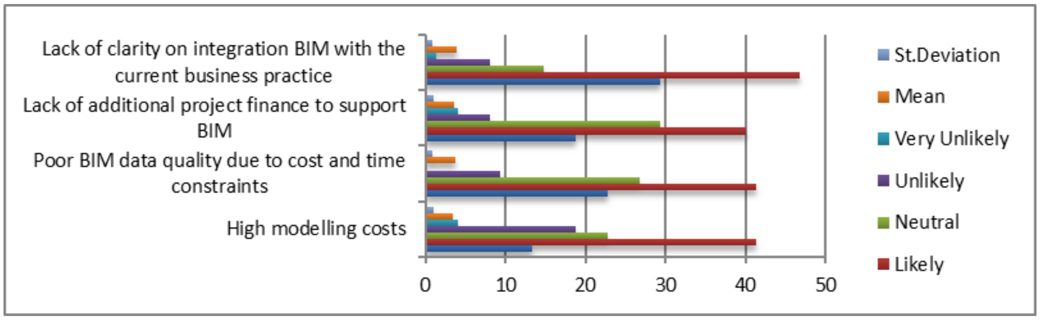

Figure 4 Respondents' evaluations of BIM costs risks

Table 5: Summary of the variance analysis

Research Question	Is there a statistically significant difference between the respondents' perceptions in rating emerging BIM Managerial risk?
Hypothesis	*H1: There is no statistically significant difference between the respondents' rating of the emergence of BIM coordination risks"* *H2: There is no statistically significant difference between the respondents' rating of the emergence of BIM standards efficiency risks "* *H3: There is no statistically significant difference between the respondents' rating of the emergence of BIM of user experience risks "* *H4: There is no statistically significant difference between the respondents' rating of the emergence of BIM costs risks"*
Results	The ANOVA results indicate that there were significant differences between the respondents on the likely of emergence or risks, Delay in model submission and approval, Ineffective modelling content and reference information, Lack of benchmark for model accuracy and tolerances, Lack of benchmark for model accuracy and tolerances, Lack of understanding of the expectations from BIM modelling, Cultural resistance to BIM application, Poor BIM data quality due to cost and time constraints and Lack of additional project finance to support BIM
Researcher Observation	• **Delay in model submission and approval.** There is not significantly different between the Architects, Engineers and academics, there is only a difference with Consultants group. • **Ineffective modelling content and reference information.** The results indicate that there is a statistically significant difference between the Architect group and Consultants group, while the rest of the other groups have the same opinion about the occurrence of this risk.

	• **Lack of benchmark for model accuracy and tolerances.** Engineers and consultants ratings are significantly higher than that of all the other groups about this factor. ME6" Engineers group see the likely emergence of this risk more than other groups • **Lack of understanding of the expectations from BIM modelling and Cultural resistance to BIM application.** Engineer group rated the likely emergence of these risks more than other groups. • **Poor BIM data quality due to cost and time constraints.** The difference stems from Architects, Engineers, and Consultants who rated this risk to be likely to occur. • **Lack of additional project finance to support BIM**. The result indicates that there is a strong agreement between Architects and Consultants on the occurrence of this risk, while academic disagree.
Conclusion	The null hypotheses Ha_0 $(p<0.05)$ was rejected for these factors Delay in model submission and approval and Ineffective modelling content and reference information, Lack of benchmark for model accuracy and tolerances, Lack of benchmark for model accuracy and tolerances, Lack of understanding of the expectations from BIM modelling, Cultural resistance to BIM application, Poor BIM data quality due to cost and time constraints and Lack of additional project finance to support BIM.