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EFFECTIVE 5D BIM REQUIREMENTS FOR RISK MITIGATION DURING PRE-CONTRACT STAGE

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ABSTRACT

The implementation of building information modelling (BIM) can be challenging without proper processes, procedures and standards. As the development of BIM progresses, there are concerns related to the five-dimensional (5D) BIM procedures in producing deliverables from the cost aspects of the project that adopts BIM technology. While the concerns may expose to amount of risks that can influence the project cost, this paper is determined to investigate the technical risks of 5D BIM practice and explore risk mitigation strategies for the construction project that adopts 5D BIM technology. Three main groups of technical risks were identified and reviewed, namely modelling issues, poor execution procedures and design change issues. The population of this paper consists of quantity surveyors and the respondents come from consultancy firms, contractors and developers. This paper also found twelve critical issues and challenges of 5D BIM implementation that had been analysed with the relative importance index (RII) analysis. Risk mitigation strategies are proposed to make a positive impact on the 5D BIM implementation, which consist of regular checks and balances, improve skills and knowledge through training and acquire suitable 5D BIM applications. The use of a BIM execution plan (BEP) and BIM protocol are also being discussed in this paper.

Keywords: Digitalisation, Cost Management, BIM, Risk Mitigation

1. INTRODUCTION

The advantages of building information modelling (BIM) are widely recognised by people in the construction industry. It has become a well-known established collaborative process and a crucial area of development in the architecture, engineering and construction (AEC) industry (Diaz, 2016). Despite the adoption of BIM is getting popular, it is often seen that the cost of the construction project is overrun and results in significant design changes (Sattineni and Macdonald, 2014). This scenario contradicts the agenda of BIM adoption in a construction project.

As the use of BIM technology is started to grow globally, significant changes to the working processes, standards and procedures are needed (Borrmann, 2018). There are only a few Southeast Asia countries that mandated the use of BIM, such as Singapore and Hong Kong (Construction Industry Council, 2018; Borrmann et al., 2018). Therefore, there is still a big gap to improve and things that the local construction industry in the region can learn from the countries that are advanced in BIM adoption.

The letter "I", which stands for the "information", is one of the key success factors in implementing an effective BIM project (Juszczyk et al., 2016). Thus, it is important for all the construction industry professionals including quantity surveyors capable of managing it. Technical challenges in the construction industry have a slow pace of digitisation including the BIM adoption in a construction project (Agarwal et al., 2020). In the five-dimensional (5D) BIM, there are various technical issues and challenges as well. Project Management Institute (PMI) (2017) stated that risk mitigation is a risk response strategy whereby the project team acts to reduce the probability of occurrence or impact of a risk. The technical risks have to be mitigated to implement 5D BIM (Sattineni and Macdonald, 2014).

Therefore, this paper aims to investigate the technical risks of 5D BIM practice in Southeast Asia countries. This paper also intended to explore risk mitigation strategies for the construction project that adopts 5D BIM technology.

2. DIGITAL COST MANAGEMENT: DEFINITIONS AND TECHNICAL ISSUES

2.1Definition of 5D BIM

There are several dimensions in BIM, from 2D to nD. The nD modelling refers to the information model used for various analysis purposes such as for environmental or sustainability concerns (Kjartansdóttir et al., 2017). This paper will focus on the 5D, which enables the model to be used for the cost management in a construction project such as quantity extraction, cost estimate, cost updates, progress payment and many others (Kjartansdóttir et al., 2017).

Smith (2014) mentioned that the 5D BIM shall not be about the automation in measurement and instant generation of cost estimates, but shall also have the ability to simulate a range of design options with real-time cost advice and real-time cost updates throughout the design process, construction and when the asset is in operation. 5D BIM technology allows a quantity surveyor to efficiently develop the project cost with a 3D model as per the standard method of measurement, project requirements and collaboratively manage it with the project team.

2.2 Types of digital cost management

There are three main types of digital cost management, namely exporting quantities to the traditional software, bridging BIM design tool with cost management software and using 5D BIM-based cost management applications (Eastman et al., 2011; Wu et al., 2014; Lu, Lai and Tse, 2019).

Firstly, the first type, exporting quantities to the traditional software is the most used method in the organisation. For examples CAD Reader, DimensionX 2D, eTakeoff and many more. The advantage of this method is that the cost is not that expensive. Also, software applications such as Microsoft Excel, which is widely used in managing the cost in a construction project are not that difficult to be used. That means there is no cost of attending training will be incurred by the quantity surveyors in any organisation to manage the project cost.

Secondly, bridging BIM design tools with cost management software is becoming popular. It is deemed by some organisations that a software application such as Autodesk Revit is 'one size fits all'. There are few plug-ins such as Tocoman iLink (Eastman et al., 2011) that supports this method. Currently, there are also few digital cost solutions that have the capability to use the BIM model from Revit or IFC file format to do cost estimation. For example, Cubicost TAS, Autodesk Takeoff and Vico Office.

Thirdly, 5D BIM-based cost management applications, which it manages and analyse the cost within the model itself. An example is the Cubicost by Glodon, which integrates the measurement applications that support various standard methods of measurement (SMM) with its own cost data management application that enables the user to have complete BIM 5D solutions. Lu, Lai and Tse (2019) mentioned that the advantages of this solution are that it supports manual and smart quantity take-off, cost report development, visualised cost information. It also supports the process of managing a project cost throughout the project cycle, which is from the inception phase to the closeout phase.

In digital cost management, there are three types of bidirectional mapping (Nassar, 2012; Lu, Lai and Tse, 2019). Firstly, one-to-one mapping, which maps one object to one cost database such as one number of lighting fixture equals to rate per unit of the lighting fixture. Secondly, many-to-one, which many objects map to one cost item such as a generator system that includes the generator, diesel tank, control panel, and any other related component. Lastly, one-to-many, where a beam maps to the cost of concrete, reinforcement and formwork as an example.

Some practices integrate the 3D software design tool with the application such as Dynamo and Microsoft Power BI, software applications that allows to mine data from the 3D model and help to provide more outputs than the application itself. It customises the mapping of the BIM objects with the cost database in the organisation. It has significant hardware, software licensing, and training costs associated with adopting 5D BIM (Sattineni and Macdonald, 2014; Fateh and Aziz, 2021).

The disadvantages are not just it increases the transactional cost of the organisation for the development, special training, but should the internal software engineer leaves the company without proper handover, the organisation would have difficulty maintaining the system and the application. Many companies also failed to develop their 5D BIM system (Koeleman et al., 2019). Therefore, this practice is not commonly being adopted especially for small and medium organisations.

2.3 Cost risk during BIM implementation

Cost risk is a technical risk that can cause the project expenditures more than the anticipated budget. Hopkin (2018) defined risk as to the ability to impact the project objectives including cost and core procedures such as cost management when the event occurs. Reddy (2015) explained technical risks as risks that are associated with the construction process, design and technology. Several technical risks can contribute to inaccurate and unreliable costing during BIM implementation from the BIM model.

Firstly, there are issues with the modelling. When there is an overlapping of the model, the report generated from the platform will have higher quantities (Lu, Lai and Tse, 2019). Also, when a wrong categorisation of a model happen, that automatically makes the quantity report generated by the applications also wrong and that creates confusion to the project teams.

Another case is issues related to tagging and legends, where the modeller only focus on the visual rather than the information. For example, if the wall type is being modified in the properties, the tag will not be updated. This often happened as the quantities required by the quantity surveyor are not available and inaccurate, which then requires to be measured by conventional method (Royal Institution of Chartered Surveyors (RICS), 2015).

Secondly, when the execution procedures are poor, there is a lack of model information for the cost management. Matipa et al. (2010) identified several challenges such as the difficulty of translating basic geometry information and lack of information. Enshassi, Hallaq and Tayeh (2019) found lack of information sharing and management to be among the significant limitation factors in the BIM model. These will make the cost estimation process becomes difficult for the quantity surveyor. Despite the lack of information due to the incompatibility and interoperability of the applications, it can also be due to the lack of standards and obligation issues (Mat Ya'acob et al., 2018).

Thirdly, there are design change issues, especially when there is a lack of involvement by the quantity surveyor in the construction project. Despite there are changes in the requirements, the modeller may not be updating the necessary part of the model, which results in outdated model information. Juszczyk et al. (2016) understand that the BIM model constitutes a shared database of information about the construction object. Therefore, if the model is outdated, the quantities and the cost generated through the automation process will then become invalid should the quantity surveyor not be aware of the change and carrying out any checks and balances.

The risk is higher especially for the countries that are not mandating the use of BIM in a construction project, which the project that adopts BIM perhaps lack proper guidelines and standards. As BIM adoption is meant to provide more benefits than the conventional process of construction project management, it is very crucial to analyse the risk that can cause the project cost inaccurate and even worse, overrun during the BIM implementation process. All these issues and challenges are the cost risks that need to be mitigated with effective strategies.

2.4 Importance of cost information during pre-contract stage

Typically, there are two stages in a construction project, which are the pre-contract stage and post-contract stage. According to the Royal Institution of Chartered Surveyors (RICS) (2011), pre-contract is the period before entering the contract of the project by the employer, which consists of inception phase, planning and design phase, and tendering and procurement phase. By following RIBA Plan of Work (2020) standards, the pre-contract stage includes strategic definition, preparation and briefing, concept design, spatial coordination and technical design.

A project that adopts BIM must conform to the required level of definition (LOD) at each plan of work stages to ensure the information being produced are clear, sufficient and efficient to transfer. This can be done during the development of a BIM execution plan (BEP) and BIM protocols, where the requirements are clearly specified. Therefore, when the levels of model detail are being determined for each plan of work stages, the quantity surveyor needs to be involved in ensuring the completeness of the information to develop and manage the project cost. Ji, Mbachu and Domingo (2014) highlighted that incompleteness and lack of analysis of project information during the pre-contract stage can lead to inaccurate cost estimates.

The LOD must not be used only to determine the detail of model from the design point of view as many architects have created their standards using the LOD language (BIM Forum, 2015). Rather, it shall take the considerations of any other deliverables or milestones including the cost management requirements. When there is no information of cost development requirements specified at each LOD stage, the modeller may overlook the information relevant to the quantity surveyors. Meanwhile, the quantity surveyor shall develop accurate and reliable cost estimation from the quantity takeoff process that follows certain standards of measurement.

The alignment of the LOD, plan of work and standard method of measurement is a critical issue to be solved for the 5D BIM practice in a construction project (Eynon, 2016). Without having these considerations, quantity surveyors working with a BIM model will have a problem outputting an accurate costing for the project as it forces the quantity surveyor to make various assumptions when issues of insufficient information occur. The pre-contract stage is crucial in a project because it is where the budget preparation will be carried out. It is the stage where the financial and cost planning process facing many obscurities (Minikevicius, 2017) but the budget has to be prepared as accurately as possible.

3. LIMITATION

The distribution of the questionnaire is confined to investigate the quantity surveyors involved in the development and control of project cost in a project that adopts BIM applications across Southeast Asia countries. This paper is also limited to the cost risk mitigation acts during the pre-contract stage of a building construction project that uses the BIM model for cost estimation and tendering purposes. This paper focuses on the effective strategies to acquire the information requirements for the quantity surveyors during the implementation of BIM in a building construction project.

4. METHODOLOGY

This paper was prepared through a thorough literature review and questionnaire survey followed by data collection, data analysis, and lastly, the conclusion of data. In this paper, the population consists of quantity surveyors from consultancy firms, contractors and developers. The questionnaire is designed by using secondary references related to 5D BIM, construction project risks and cost management. The questions in the survey were evaluated using validity tests to ensure their appropriateness and accuracy (Sekaran and Bougie, 2016). A total of 394 quantity surveyors are targeted as respondents. However, only 250 respondents are selected based on their involvement in a project that adopted BIM in the process.

This paper also aims to target a sample that involves in the cost management of construction projects. The respondents come from the Southeast Asia countries such as Malaysia, Singapore, Brunei, Hong Kong, Indonesia, Myanmar, Philippines, Vietnam and Thailand. The data were analysed using IBM SPSS Statistics 26.0 and Microsoft Excel with frequency analysis and relative importance index (RII) analysis.

5. RESULT AND DISCUSSION

5.1 Issues and challenges of 5D BIM implementation

The issues and challenges reviewed are ranked based on the RII in Table 1. Out of 14, this paper found 12 issues and challenges that are regarded as crucial for the quantity surveyors to make necessary response in the 5D BIM implementation. Therefore, it is relatively important to discuss these issues and challenges further, especially at the organisation level.

Table 1: 5D BIM issues and challenges

Item	Issues and Challenges	RII	Rank
SP	Standards of Practice		
SP1	Absence or lack of information requirements	0.842	5
SP2	Poor standards of procedures for BIM project	0.828	7

Item	Issues and Challenges	RII	Rank
SP3	Lack of cost management guidelines for BIM project	0.844	4
TC	Technical Challenges		
TC1	Lack of skills in handling cost for BIM project	0.854	1
TC2	Poor support from the solution provider	0.809	9
TC3	Lack of training	0.851	2
OC	Organisational Challenges		
OC1	Poor leadership in the company	0.810	8
OC2	Loss aversion/bias in BIM opportunities	0.802	12
EC	Economic and Financial Challenges		
EC1	Poor financial plan	0.838	6
EC2	Lack of investment in technology	0.850	3
EC3	Poor incentive by the government	0.798	13
CI	Cultural Issues		
CI1	Lack of national driven agenda	0.804	11
CI2	Reluctant to change	0.806	10
CI3	Lack of trust in technology	0.792	14

According to the relative importance index (RII) analysis, the highest ranking is TC1-Lack of skills in handling cost for BIM project (RII = 0.54). Due to this, there is correlation to the higher salary demand and consultancy fees (Fateh and Aziz, 2021). It will be deemed as the most critical factor in the 5D BIM implementation. Secondly, TC3-Lack of training (RII = 0.851). Thirdly, EC2-Lack of investment in technology (RII = 0.850). Fourthly, SP3-Lack of cost management guidelines for BIM project (RII = 4). Fifthly, SP1-Absence or lack of information requirements (RII = 0.842). From these five categories, the technical challenges are ranked the highest compared to the other categories.

After that, another issue especially for the organisation is EC1-Poor financial plan (RII = 0.838) in sixth place. Next, SP2-Poor standards of procedures for BIM project (RII = 0.828) in seventh place. The highest in the organisational challenges category is OC1-Poor leadership in the company (RII = 0.810), which positions at number eight. At number nine position is TC2-Poor support from the solution provider (RII = 0.809). Then, C12-Reluctant to change (RII = 0.806) positions at number ten. Other than that, C11-Lack of national driven agenda (RII = 0.804) and OC2-Loss aversion or bias in BIM opportunities (RII = 0.802) at eleventh and twelfth spot respectively.

Overall, most of the issues and challenges are not for the acknowledgement of BIM practitioners, but also the considerations for the strategic management level to take necessary and prompt action in overcoming the issues and challenges. National construction bodies such as Construction Industry Development Board (CIDB) in Malaysia, Building and Construction Authority (BCA) in Singapore, Construction Industry Council (CIC) in Hong Kong, and more also play important role to support the development of BIM implementation and growth in the country, especially on the critical factors.

5.2 Standards development for cost management

As these two documents are important for the quantity surveyors to acquire information in a project that adopts BIM, this paper investigated the involvement of quantity surveyors in the development of a BIM execution plan (BEP) and/or BIM protocol in a construction project. This is also to understand before the requirements of the quantity surveyor are being complied, are these requirements are first being specified in the documents.

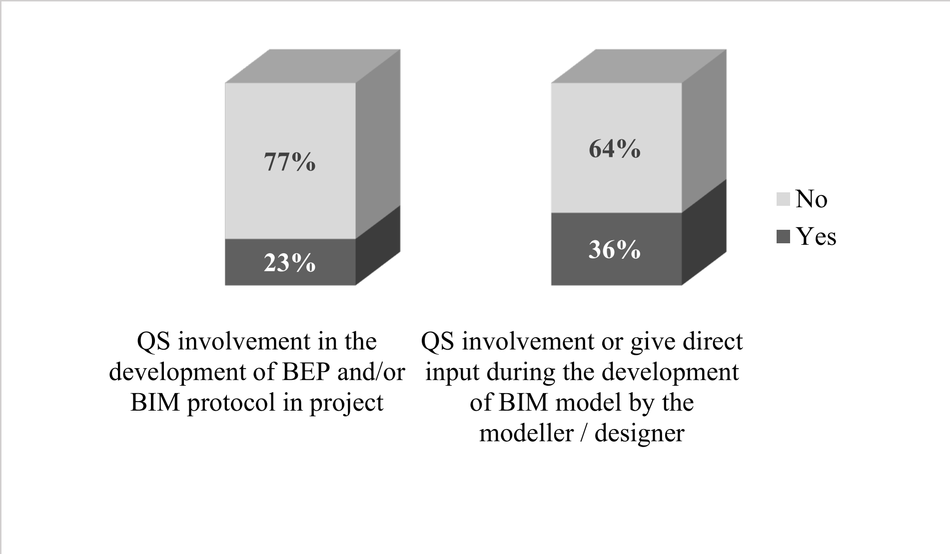

Figure 1: QS involvement in the standards and information development of BIM project

Results in Figure 1 show that the QS involvement in the development of BEP and/or BIM protocol in a construction project are quite low with only 23 per cent chose yes, while 77 per cent of the respondents chose no. Next, the results for the QS involvement or give direct input during the development of BIM model by the modeller or designer seen only 36 per cent of respondents chose yes and 64 per cent chose no. Based on the results, this can be said that quantity surveyors involvement is still quite insignificant in the standards and information development of a construction project that adopts BIM technology.

Prior to the enhancement of the usage of BEP and BIM protocol, the standards such as the LOD requirements of the quantity surveyor need to be established. The establishment is to ensure the development of the BIM model is sufficient and clear for cost management purposes.

There are few elements to analyse for the development of the information requirements. Firstly, the requirements must align with the plan of work stages. Secondly, the requirements also need to align with the LOD of the model detail and model information. This is to ensure that LOD use is sufficient to produce cost budgeting for the project owner. At the same time, the LOD must be standardised with the language as the information of design management. Thirdly, it is crucial for the quantity surveyor to output the quantities according to the specific standard method of measurement. For example, in Malaysia, we have a new standard, namely the Malaysian Standard Method of Measurement for Building (MYSMM). This is to produce accurate quantity results and reliable cost estimation.

Then, once the information requirements are established at the organisation level. It is important for the document to be included in the BEP. The inclusion of the document in the BEP can satisfy the need for 5D BIM for the construction project as one of the project deliverables required. After that, it can also be used as supplementary guidance in the BIM protocol, particularly for the information particulars. As cost is one of the important elements for the success of the construction project, with BIM protocol, which sets in place specific liabilities, obligations for information production and associated limitations on the use of the model.

5.3 Mitigation strategies

Nickols (2016) defined strategy as thoughts, ideas, insights, goals, perceptions and expectations that provide general guidance for specific actions in pursuit of particular ends. In this paper, strategy refers to ideas, perceptions and insights that generally will help in dealing with the technical risks that can negatively influence the project cost. There are several mitigation strategies to counter risk in the 5D BIM implementation.

Firstly, regular checks and balances on the information produced must be carried out. A quantity surveyor involves in a BIM project needs to be aware of any lack or loss of information as stipulated by the contract that can influence the project cost. Besides the visual checking on the model, the descriptions and categories must also be carried out as these will reflect on the quantity report generated. The scope of works also must be determined carefully by the quantity surveyor for the purpose of tendering, procurement, cost analysis and many others.

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Secondly, in dealing with the BIM applications, quantity surveyor needs to be equipped with specific skills and knowledge, which can be carried out through relevant training. The technology of BIM applications develops rapidly to suit the practice in the industry. That means a quantity surveyor need to attend the training periodically to make sure that the skills and knowledge acquired are up to date.

Finally, the 5D BIM application must be suitable for the organisational and project needs. The BIM shall enhance the process to be more efficient. Therefore, the adoption of 5D BIM must not negatively disrupt the existing working practice. For example, as a quantity surveyor, the measurement must be carried out according to the standard method of measurement. Thus, that fundamental practice shall not be ignored when using any BIM application.

6.CONCLUSION

This paper has accomplished its aims to investigate the technical risks of 5D BIM practice in Southeast Asia countries. The risk mitigation strategies for the construction project that adopts 5D BIM technology are also being proposed as a guideline for a quantity surveyor to effectively manage the process of 5D BIM in a construction project. Lastly, this paper is hoped to transpire better strategies and give guidelines to quantity surveyors or any professionals involve in the cost management process of a construction project particularly those that adopts BIM technology.

BIM technology has transformed the way construction projects or assets being managed. It is recommended for future studies to see the information requirements for cost management of an asset when it is in the operational stage. This gives a full representation of the life cycle costing of the asset and can influence the way business is being strategised and formulated.

This paper aligns with the Construction Industry Transformation Programme (CITP) in promoting BIM technology and Malaysia’s agenda in the need to embrace Industry 4.0 as a critical cornerstone of sustainable competitiveness. At the global level, this paper supports the 2030 agenda for sustainable development in building resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.

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8. REFERENCES

Agarwal, R., Chandrasekaran, S., & Sridhar, M. (2020). Imagining Construction’s Digital Future. McKinsey & Company. https://www.mckinsey.com/business-functions/operations/our-insights/imagining-constructions-digital-future

BIM Forum. (2015). Level of Development Specification (October 2015). https://bim-international.com/wp-content/uploads/2016/03/LOD-Specification-2015.pdf

Construction Industry Council. (2018). Production of BIM Object Guide - General Requirements (June 2018). https://www.bim.cic.hk/en/resources/publications_detail/6?order=asc&sorting=all&back=%2Fen%2Fresources%2Fpublications%3Forder%3Dasc%26sorting%3Dall

Diaz, P. (2016). Analysis of Benefits, Advantages and Challenges of Building Information Modelling in Construction Industry. Journal of Advances in Civil Engineering, 2(2), 1–11. https://doi.org/10.18831/djcivil.org/2016021001

Fateh, M. A. M. & Aziz, A. A. A. (2021). The Cost Profile of Building Information Modelling Implementation in Malaysia. Malaysia Construction Research Journal, 14(3), 109–124. https://www.cream.my/my/publication/download-malaysian-construction-research-journal/mcrj-special-issue-volume-14-no-3-2021

Eynon, J. (2016). Construction Manager's BIM Handbook. Wiley-Blackwell.

Hopkin, P. (2018). Fundamentals of Risk Management: Understanding, Evaluating and Implementing Effective Risk Management (5th ed.). Kogan Page.

Juszczyk, M., Tomana, A., & Bartoszek, M. (2016). Current Issues of BIM-based Design Change Management, Analysis and Visualization. Procedia Engineering, 164, 518–525. https://doi.org/10.1016/j.proeng.2016.11.653

Kjartansdóttir, I. B., Mordue, S., Nowak, P., Philp, D., Snæbjörnsson, J. T., & Politechnika Warszawska. Wydział Inżynierii Lądowej. (2017). Building Information Modelling - BIM. Amsterdam University Press.

Koeleman, J., Ribeirinho, M. J., Rockhill, D., Sjödin, E., & Strube, G. (2019, August 20). Decoding Digital Transformation in Construction. McKinsey & Company. https://www.mckinsey.com/business-functions/operations/our-insights/decoding-digital-transformation-in-construction

Lu, W., Lai, C. C., & Tse, T. (2021). BIM and Big Data for Construction Cost Management (1st ed.). Routledge.

Mat Ya'acob, I. A., Mohd Rahim, F. A., & Zainon, N. (2018). Risk in Implementing Building Information Modelling (BIM) in Malaysia Construction Industry: A Review. E3S Web of Conferences, 65, 03002. https://doi.org/10.1051/e3sconf/20186503002

Minikevicius, S. (2017). Pre-planning in Construction: Differences in 'Design-Bid-Build' and 'Design-Build' Approaches (Master's thesis). https://projekter.aau.dk/projekter/files/250422918/Simonas_Thesis.pdf

Nassar, K. (2012). Assessing Building Information Modeling Estimating Techniques Using Data from the Classroom. Journal of Professional Issues in Engineering Education and Practice, 138(3), 171–180. https://doi.org/10.1061/(asce)ei.1943-5541.0000101

Nickols, F. (2016). Strategy. Retrieved from http://www.nickols.us/

Project Management Institute. (2017). A Guide to the Project Management Body of Knowledge (PMBOK® Guide)– Sixth Edition (Sixth Edition, Sixth Edition). Project Management Institute.

Reddy, A. S. (2010). Risk Management in Construction Industry – A Case Study. India; International Journal of Innovative Research in Science, Engineering and Technology.

Royal Institution of Chartered Surveyors (2011). Contract Administration 1st Edition, Guidance Note. https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/building-surveying/contract-administration-1st-edition-rics.pdf

Royal Institution of Chartered Surveyors (2015). BIM for Cost Managers: Requirements from the BIM Model 1st Edition (August 2015). https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/construction/bim-for-cost-managers-1st-edition-rics.pdf

Sattineni, A. & Macdonald, J. A. (2014). 5D BIM: A Case Study of an Implementation Strategy in the Construction Industry. Proceedings of the 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC). Published. https://doi.org/10.22260/isarc2014/0048

Sekaran, U. & Bougie, R (2016). Research Methods for Business: A Skill Building Approach (7th ed.). Wiley.

Smith, P. (2014). BIM & the 5D Project Cost Manager. Procedia - Social and Behavioral Sciences, 119, 475–484. https://doi.org/10.1016/j.sbspro.2014.03.053