Scholars Journal of Engineering and Technology (SJET)
Abbreviated Key Title: Sch. J. Eng. Tech.
ISSN 2347-9523 (Print)
ISSN 2321-435X (Online)

A Unit of Scholars Academic and Scientific Society, India
www.saspublisher.com

A Model to Measure the Risk after Applying BIM on Steel Projects

Mohamed Badawy[1*], Emam Soliman[2], Rasha Badr[3]
[1]Dr. of Construction management, Structural Engineering Department, Ain Shams University, Cairo, Egypt
[2]Professor of Steel structures, Structural Engineering Department, Ain Shams University, Cairo, Egypt
[3]Post graduate student, Structural Engineering Department, Ain Shams University, Cairo, Egypt

Original Research Article

***Corresponding author**
Mohamed Badawy

Article History
Received: 14.02.2018
Accepted: 24.02.2018
Published: 28.02.2018

DOI:
10.21276/sjet.2018.6.2.6

Abstract: There are copious amounts of research, conducting the issues within the construction sector. These issues led to increase in cost and time, and reduce the quality of the project. There is a gap in how BIM will affect the risk of construction special in steel projects. The goal of this paper is to study the effect of applying building information modeling through the whole project life cycle. A structured questionnaire for determining the probability and impact of the factors affecting on the steel projects before and after applying BIM techniques was suggested. Data were collected through interviews with the professional in the construction industry in Egypt. In total, 77 valid responses were received for analysis. The maximum reductions were in factor “Fabrication priority incompatible with the erection process” and the factor “Misunderstanding the building”. While the minimum reduction was happening in factor “Miss some of the obtained moments or forces on connections”. The paper provides deeper insights into the risk of factors affecting on steel projects and the effect of applying BIM on these projects. This paper estimates a model to estimate the risk after applying BIM techniques depending on the risk before applying BIM on steel projects.
Keywords: Building information modeling; construction; risk; steel projects; risk model.

INTRODUCTION

The low efficiency and high waste phenomenon are the main problem for the construction industry. The effective exchange of information and collaboration in construction processes is difficult.

Building Information Modeling (BIM) is considered the principal tool to do this is. Steel, by some margin, is the most popular framing material for multi-story buildings and it has a long track record of delivering high quality and cost-effective structures with proven sustainability benefits. The project risk management has very intensive processes in any construction project. Project manager identifying the risks with the help of other stakeholders based on their knowledge and available design information. Limited Information can be extracted from 2-D drawings, so 2-D drawings have not effectively support the risk identification process [1]. Building information modelling (BIM) provides information than 2-D drawings and in dynamic perspective. BIM has dependable in the risk identification and risk mitigation processes [2, 3]. More proactive procedures can be executed in risk and safety management in a BIM environment [4].

There are copious amounts of research, conducting the rank of risk factors within the construction sector. These factors led to increase in cost and time, and reduce the quality of the project. There is a gap in estimating a model for calculating the risk after applying BIM techniques depending on the risk without applying BIM, especially in steel projects. The main objective of the research is to determine the reduction ratio in risk of the issues due to applying BIM techniques and suggest a model for estimating the risk after applying BIM on steel projects.

LITERATURE REVIEW

Knowledge Management Research

The risk management processes were performed based on the knowledge and experiences of the project manager and his team. Each company has its own organizational processes, and the key of these assets is the knowledge [5]. Knowledge is considered as the base for economic development [6]. Thus, knowledge asset had become a decisive element in the competition of the organizations [7]. Knowledge was rated as a very high important factor [8]. Managing the knowledge flow within the organization is the important component on knowledge management [9, 10]. The knowledge-processing procedures can be enhanced to help the flow of knowledge of the organization by using the knowledge management technique [11, 12].

Risk Management in Construction Industry

The formalized risk management procedures will lead to better performance in construction projects [13]. A systematic way to quantify uncertainty in schedule in construction projects was suggested [14]. Due to the importance of risk management in the project performance, "A guide to the Project Management Body of Knowledge" had produced the processes for identifying and managing the risk [15].

The errors in steel structure

A high-quality steel structure that has been economically constructed can only be possible if all stages are successfully completed without errors. There is a need for a certain level of general knowledge and experience in the construction stages to attain this aim. The fabrication and assembly stages should be planned in the fastest and easiest way after the plans. The best methods for completing the maximum job in the minimum time should be studied [16]. There are many risks that may occur during the life cycle of steel projects. In the design stage; the constructability of the design, structural breakdown due to failure through erection, and non-designed members for transportation. During the fabrication stage the risks are incomplete or inaccurate shop drawings, members not clearly marked or recognizable, the breakdown of the structure due to element failure, incomplete fabrication, fabrication error, and welding failure due to poor quality or lack of a test. In the transport stages, the hazards are the steel members which fall during the loading or unloading, the steel falling due to instability of the vehicle load or becomes unstable during unloading, the vehicle becomes unstable, the vehicle collapses in the hole, no space, the shortage of the traffic management plan, access/ egress, the falling of the worker from the car during loading and unloading. In the erection phase, the risks were falling from height during counterfeiting, falling objects, collapse of the structure during construction, struck by equipment; plant connected to underground utilities, and hit objects such as steel members [17].

The effect of applying BIM in Construction Industry

McGraw Hill estimated that the reduction in issue due to applying BIM in construction was 52% [18]. Bryde said that; BIM assists in the management of construction projects. He gathered data from 35 projects that utilized BIM. He found that; the most positive benefit related to cost reduction, time saving and better control. Whereas, Negative benefits were focused on the use of BIM software which need for training and education [19]. The average return on investment for projects that applying building information modeling was 634%, which clearly describe its potential economic benefits. Teams that implementing BIM techniques should be very deliberate around the legal pitfalls, which include data ownership and associated proprietary issues and risk sharing. Such matters must be addressed up front in the contract documents [20]. The ways for construction can be changed if BIM techniques are applied. These changes include whole project life cycle. The applying of BIM will lead to improve in profitability, reduce in costs, and improve in customer-client relationships and better schedule management [21]. Design errors may have a great influence project performance and may lead to failures, accidents, or even loss of liveliness. The projects which using Building Information Modeling techniques have a cost for design errors less than those projects procured by traditional ways [22]. AECOM (2013) anticipated that this will continue to escalate with the BIM market expected to go up from $1.8 billion in 2012 to $6.5 billion by 2020. They also predict the market transformation in the near future. A precipitous increase in the number of BIM projects is expected after 18 months, constituting a significant market transformation well beyond achievements to date [23]. In 2014 McGraw Hill has been tracking the evolution and implementation of BIM in the worldwide construction industry since 2007 through an extensive global study. It was found that a significant change over that period and quite dramatic implementation increases over the past few years in particular. In North America their survey results showed that BIM adoption by contractors escalated from 28% in 2007 to 71% in 2012. There are many positive outcomes for project teams when they are applying BIM such as; the faster communications, more powerful and mobile computers, and a transformative shift toward integrated delivery processes [24]. Fan (2014) established that; applying BIM during construction the schedule savings of 5% to 10 %. A reduction in RFI's about 90% on BIM related projects. For rework; BIM is 60% quicker than by using 2-D clash detection [25].

Yunfeng Chen 2014 suggested a five-factor model that explained about 70% of the variation. The outcomes showed that all elements were significant in measuring BIM. The factors of the process and information were more important than the factors of technology and people [26]. Building information modeling becomes the latter technique used in different stages through all life cycle. BIM is used in construction, sustainability, energy [27], cost estimate, time management and risk management [28]. A study for comparing between the theoretical potential and practical application of BIM to reduce information asymmetry found that at that point was a large break between them. It also found that, although Building Information Modeling has the capability to reduce information asymmetry, it has not reached it yet actually to reduce the problem [29]. A research was done to examine the outcome of applying Building Information Modeling technology for building projects on reducing the different cases of construction claims through a questionnaire study. It found that, the applying of BIM technology in construction projects will get a very high effect on slimming the causes of some construction claims, especially in Mega projects [30]. This symbiotic integration of technologies with BIM enables a vibrant environment for design exploration and optimization to tackle construction waste [31]. Ding 2016, founds that the prototype system using BIM improved the risk management performance from the perspective of the knowledge management and reuse [32].

According to National BIM Report 2016; 63% believe BIM will help bring about a 33% reduction in the initial cost of construction and whole life cost of built assets. 57% believe BIM will help bring about a 50% reduction in the time from inception to completion for new-build and refurbished assets. 39% believe BIM will help bring about a 50% reduction in greenhouse gas emissions in the built environment. Less than a third believe that BIM will help produce a reduction in the trade gap between total exports and total imports for construction products. Many states specify a deadline for adoption projects with BIM technology. For instance, the UK government set a condition for adoption with a BIM approach for all companies which will work in the public sector from April 2016 [33].

A detailed analysis of BIM technology founds that using of the BIM approach achieves the green construction, improves the quality of the construction, and reduces construction costs. Establishing an integrated information management system with BIM technology achieves the construction project information management. For realization of BIM technology to the construction industry, it is necessary to establish a more mature application system of BIM research and development, formulate relevant policies and industry rules and regulations. The role of BIM technology must be through the joint endeavors of government and construction stakeholders [34].

What are the types of issues that can be eliminated or reduced if the team used BIM techniques on steel project? If the risk for any construction project that does not apply BIM technology was calculated, the main problem is what is the estimated risk if the team will apply BIM to construction project as general, and steel project as especial? That illustrated the need for a model to estimate the new risk after applying BIM techniques.

Questionnaire Design

Based on past studies; multiple ideas related to issues were generated and collected by using the brainstorming technique. By utilizing the Delphi technique; a selected group of experts to look back this questionnaire and provides feedback regarding the answers from each round until unanimity. Then, the final tilt of the issues which may be occurring in steel projects was developed. The questionnaire consisted of two parts. The first includes information about the company; its working field, profile, software used. The second part of the probability of issues before applying BIM and after BIM, and the impact of each issue on steel projects. The respondents were asked for determining the probability of issues before applying BIM and after applying it on a scale from 1 to 5, according to table (1). They also were asked to ascertain the impact of each issue on steel construction process according table (2). The scale runs from 1 which means very low, 2 means low, 3 means medium, 4 means high and 5 which means very high.

At the beginning, we distribute it on steel companies that work in design, fabrication and erection of steel structure around the globe by E-mail. Unfortunately, we did not receive any response from our several trials. That leads us to minimize the surveyed companies and make them limited to Egyptians and some Arabian ones. The questionnaire was distributed into 8 companies. The respondents are 77 engineers who have at least 10 years of experience. The working fields of 6 companies are Pre-engineering, Design, Fabrication and Erection of steel structure. The other 2 companies working fields are Pre-engineering and Design only.

The questionnaire studied the issues that could happen through the construction of steel structure in the following stages; Pre-engineering Stage, Pre-design and Detailing Stage, Fabrication Stage, Erection Stage.

The risk management plan

Definition of Probability and Impacts

Table-1: The Probability and Impacts Scale

Rate	Scale	Probability	Impact on cost
1	Very low	P < 0.1	I < 0.05
2	Low	0.1 < P < 0.3	0.05 < I < 0.1
3	Medium	0.3 < P < 0.5	0.1 < I < 0.2
4	High	0.5 < P < 0.7	0.2 < I < 0.4
5	Very high	0.7 < P < 0.9	0.4 < I < 0.8

Risk classification

The risk of each issue was estimated by multiplying the probability with the impact of the issue. The maximum risk is 25 and the minimum is 1. The author modifies Likert scale. The terminal points for each category can be calculated by computing the remainder between the uttermost, and the minimum, then separating the resultant on five. So, the risk classification could describe as shown in the table (2).

Table-2: The Risk Scale

Risk Scale	Risk
Very low	1 < R < 5.8
Low	5.8 < R < 10.6
Medium	10.6 < R < 15.4
High	15.4 < R < 20.2
Very high	20.2 < R < 25

RESULTS

The data were analyzed using the statistical program SPSS [35].

Reliability

Cronbach's Alpha for probability of issues before using BIM equal 0.869. Cronbach's Alpha for probability of issues after using BIM equal 0.820. Cronbach's Alpha for impact of issues equal 0.893. Which implied that there is a good internal consistency in this questionnaire.

Table-3: The Risk of the factors

I.D.	Factor	Before	After	Improve ment ratio
B01	Determine the location of the construction area imprecisely.	9.57	3.69	61.47%
B02	Misunderstanding the building.	12.66	4.18	66.97%
B03	Column spans are not economic.	7.32	3.17	56.74%
B04	Column spans are not functional and not statically feasible.	8.29	3.00	63.79%
B05	Supports & joints are incompatible with the fabrication conditions.	8.60	3.40	60.42%
B06	Supports & joints are incompatible with the assembly conditions.	10.45	3.75	64.10%
B07	Over budget costs.	10.19	3.58	64.84%
B08	Change in requirements according to the owner.	13.01	4.62	64.47%
B09	Change in requirements according to soil conditions.	7.55	3.17	58.00%
B10	Supports & joints are incompatible with the determined conditions.	7.26	2.87	60.47%
B11	Missing some moments or forces on connections.	7.42	3.90	47.46%
B12	Design hard transfer members.	8.08	3.55	56.11%
B13	Design members are hard to assembly.	10.69	4.03	62.33%
B14	Miss to include or duplicate some members in fabrication list.	11.37	4.33	61.93%
B15	Wrong dimensions for steel members.	12.60	4.77	62.14%
B16	Shifted bolt hole.	9.19	3.56	61.30%
B17	Welding thickness requirements of the project not conformed.	7.40	3.40	54.03%
B18	Fabrication priority incompatible with the erection process.	10.88	3.50	67.84%
B19	Wrong position or level of column bases.	8.69	3.75	56.86%
B20	Member in wrong place.	9.40	4.08	56.65%
B21	Bolt in wrong connection.	6.44	2.81	56.42%
B22	Bolts are not tightened enough.	7.04	3.31	53.01%

Models for Estimation the Risk after Applying BIM Technology

Estimating overall risk model

First, we will use Null Hypotheses (H0); No relation that is statistically significant at the 95% level of trust between overall risk after using BIM and overall risk before using BIM. Second, Alternative Hypotheses for this study (HA); there is a relation that is statistically significant at the 95% level of trust between overall risk after using BIM and overall risk before using BIM. Least Squares Method was applied in the analyses of linear regression. The dependent variable is an overall risk after using BIM. The independent variable is an overall risk before using BIM.

It was found that; the coefficient of Correlation R between the independent variable overall risk before using BIM and the dependent variable overall risk after using BIM 0.586. The accuracy in determining the dependent variable (R Square) is 34.4%. The linear regression for the data; the summation of regression squares is 14.58 and residual squares is 27.83. Where the total number of squares is 42.41. Degree of freedom for regression is 1 and for residual are 75. Mean Square for regression is 14.58 and mean Square for residual is 0.37. The value of ANOVA test is 39.28. The significant 0.000 less than Null Hypotheses assumption 0.05, so we refuse it and the linear regression appropriate with the data.

The model will be OA = a + b OB; Where (a) is the intersection with Y axis and it equals 2.374. The slope of the regression line is (b) and it equals 0.139. OB is the independent variable (overall risk before applying BIM). OA is the dependent variable (overall risk after applying BIM). By analyzing the significant for T-test we found that the significance of Pre-engineering is 0.000 which is less than Null Hypotheses assumed 0.005 so we refuse it and there is a relation between overall risk before and after applying BIM. The equation of the line will be;

$$OA = 2.374 + 0.139\ OB \quad \text{eqn. (1)}$$

Estimating pre-engineering risk model

The coefficient of Correlation R between the independent variable EA and the dependent variable EB equal to 0.75. Where EB is the risk at a Pre-Engineering stage before using BIM and EA is the risk at a pre-engineering stage after using BIM. The accuracy in estimated the dependent variable (R Square) is 56.3%. It was shown that, the significance of T-test is 0.000 which is less than Null Hypotheses assumption 0.005 so we refuse it and there is a relation between Pre-engineering before and after applying of BIM techniques. The equation of the risk was;

$$EA = 1.625 + 0.205\ EB \quad \text{eqn. (2)}$$

Estimating pre-design risk model

The coefficient of Correlation R between the independent variable DA and the dependent variable DB is 0.68. Where" DB" is the risk at a Pre-design stage before using BIM and "DA" is the risk at a pre-design stage after using BIM. The accuracy in determining the dependent variable (R Square) is 47.2%. It was shown that, the significance of the T-test is 0.000 which is less than Null

Hypotheses assumed 0.005 so we refuse it and there is a relation between Pre-design before and after applying of BIM techniques. The equation of the risk was;

$$DA = 2.063 + 0.182\ DB \quad (3)$$

Estimating fabrication risk model

The coefficient of Correlation R between the independent variable FA and the dependent variable FB is 0.385. Where FB is the risk at a fabrication stage before using BIM and FA is the risk at a fabrication stage after using BIM. The accuracy in determining the dependent variable (R Square) is 14.8%. It was shown that, the significance of the T-test is 0.000 which is less than Null Hypotheses assumed 0.005 so we refuse it and there is a relation between fabrication before and after applying of BIM techniques. The equation of the risk was;

$$FA = 2.925 + 0.096\ FB \quad \text{eqn. (4)}$$

Estimating erection risk model

The coefficient of Correlation R between the independent variable EA and the dependent variable EB is 0.21. Where EA is the risk at an erection stage after applying BIM and EB is the risk at an erection stage before using BIM. The accuracy in determining the dependent variable (R Square) is 4.4%. By using an ANOVA test, the significant was 0.134 which is more than Null Hypotheses assumption 0.05, so we accept it and the linear regression is not appropriate to the data.

DISCUSSION

In an effort to elucidate the risk after applying BIM technology to help the company to make a decision, whatever it should change from the traditional methodology to BIM or not. A questionnaire was made out in identifying the probability and impact of the critical factors affecting the risk on steel projects with and without applying BIM technology. Submissions were received from 77 respondents. The questionnaires are distributed only on in Egypt. Seven of eight companies are Egyptian companies. AIC is an Arabian company working in Egypt and we have received 17 responses from it. The risks for each factor were calculated by multiplying the probability with the impact.

The risks of all factors reduced after applying BIM technology for steel projects as expected from past studies. Great risk reductions were happening in Factor

B18 "Fabrication priority incompatible with the erection process" which was reduced by 68% and the factor B02 "Misunderstanding the building" which was had a reduction of 67%. While the minimum reduction was happening in factor B11 "Miss some of the obtained moments or forces on connections" which had a reduction of 47%.

Pre-engineering Stage

Generally, the risk of issues in Pre-engineering stage without using BIM was 9.74. After applying BIM techniques, the risk of issues was 3.62. Which means that the risk at this stage was reduced from low to very low due to applying of BIM techniques. The improvement ratio in this stage is 63%.

Due to applying of BIM techniques, the issue "Misunderstanding the building" was reduced from 12.66 "Medium" to 4.18 "very low", that means the improvement ratio is 67%. The issue "Change in requirements according to the owner" also was reduced from 13.01 "Medium" to 4.62 "very low" with an improved ratio of 64%.

Pre-Design and Detailing Stage

By using building information modeling on steel projects; it was found that the risk in pre-design stage was reduced from 8.36 "low" to 3.58 "very low". The improvement ratio in pre-design stage was 57%. The risk "Design members hard to assemble" was reduced due to using of BIM techniques from 10.69 "Medium" to 4.03 "very low" with an improved ratio of 62%.

Fabrication Stage

In this stage without using BIM techniques; it was found that the risk was 10.29 "low". After applying building information modeling it was 3.91 "very low". So, the improvement ratio was 62%. Before applying BIM; the risks "Miss to include or duplicate some members in the fabrication list" was 11.37 "medium and after BIM it was 4.33 "very low" with an improved ratio of 62%. The risk "Wrong dimensions for steel members" was 12.06 "medium" before applying BIM and it was 4.77 after applying BIM techniques with an improved ratio of 60%.

Erection Stage

The mean for risk of issues at this stage before applying BIM was 7.89 (low), and after applying BIM was 3.49 (very low). This implied the improvement ratio at this stage equal to 56%. The risk for issue "Member in wrong place" before using BIM techniques is 9.4 (low) and after using BIM was 4.08 (very low). This means that, the improved ratio was 57%

Overall Stage

The results indicate that the risk of issues before using BIM had an overall mean of 9.05 (low). After using BIM; the overall average risk was 3.63 (very low). Therefore, the improvement ratio after applying BIM techniques was 60%.

Comparison with Past studies

McGraw Hill (2010) estimated the decrease of issues due to applying BIM in construction by 52%. Which is close to the ratio estimated from the results (60%). McGraw results enhance the output from this research. Models for each stage was estimated depending on the results of the questionnaire before and after applying BIM technology for steel projects. By using these models, the company can estimate the new risk depending on its own risk before applying BIM. For future research, the models for estimating the risk after applying BIM on steel projects need for revaluation in other countries.

CONCLUCION

Many issues were appearing in steel projects. The probability of these issues can be reduced by applying BIM techniques. The risks of all factors reduce after applying BIM technology for steel projects as expected from past studies. After applying BIM, the factor B18 "Fabrication priority incompatible with the erection process" was reduced by 68% and the factor B02 "Misunderstanding the building" was reduced by 67%. While the minimum reduction was happening to factor B11 "Miss some of the obtained moments or focus on associations" which received a decrease of 47%.

The risk in pre-engineering stage without applying BIM was 9.74 and after applying BIM techniques, the risk of issues was 3.62. So, the improvement ratio in this stage is 63%. The risk in pre-design stage was reduced from 8.36 to 3.58 when the company applies BIM. The improvement ratio in pre-design stage was 57%. In fabrication stage the risk without using BIM techniques was 10.29 and after applying building information modeling it was 3.91. So, the improvement ratio was 62%. The results for risk of issues at the erection stage before applying BIM are 7.89 and after applying BIM were 3.49. The improvement ratio at this stage equal to 56%. The overall risk of issues before using BIM was 9.05, and after using BIM the overall average risk was 3.63. So, the improvement ratio due to applying BIM techniques was 60%. The equation which describes the relation between overall risk before and after applying BIM will be; OA = 2.374 + 0.139 OB. Where OB is the overall risk before applying BIM and OA is the overall risk after applying BIM.

REFERENCES

1. Li J, Hua Z. An object library approach for managing construction safety components based on BIM. Gerontechnology. 2012 Jun 27;11(2):416.
2. Smith DK, Tardif M. Building information modeling: a strategic implementation guide for

architects, engineers, constructors, and real estate asset managers. John Wiley & Sons; 2009 Apr 13.
3. Kiviniemi M, Sulankivi K, Kähkönen K, Mäkelä T, Merivirta ML. BIM-based safety management and communication for building construction. VTT research notes. 2011; 2597.
4. Ku K, Mills T. Research needs for building information modeling for construction safety. InInternational Proceedings of Associated Schools of Construction 45nd Annual Conference, Boston, MA 2010.
5. Drucker PF. Post-capitalist society. Routledge; 1994.
6. Macinko J, Starfield B, Shi L. The contribution of primary care systems to health outcomes within Organization for Economic Cooperation and Development (OECD) countries, 1970–1998. Health services research. 2003 Jun 1; 38(3):831-65.
7. Hadikusumo BH, Rowlinson S. Capturing safety knowledge using design-for-safety-process tool. Journal of construction engineering and management. 2004 Apr; 130(2):281-9.
8. Carrillo P, Chinowsky P. Exploiting knowledge management: The engineering and construction perspective. Journal of Management in Engineering. 2006 Jan; 22(1):2-10.
9. Davenport TH, Prusak L. Working knowledge: How organizations manage what they know. Harvard Business Press; 1998.
10. Nonaka I, Konno N. The concept of "ba": Building a foundation for knowledge creation. California management review. 1998 Apr;40(3):40-54.
11. Tan HC, Carrillo PM, Anumba CJ, Bouchlaghem N, Kamara JM, Udeaja CE. Development of a methodology for live capture and reuse of project knowledge in construction. Journal of management in engineering. 2007 Jan;23(1):18-26.
12. McElroy MW. The new knowledge management: Complexity, learning, and sustainable innovation. Routledge; 2003.
13. Tah JH, Carr V. Knowledge-based approach to construction project risk management. Journal of computing in civil engineering. 2001 Jul;15(3):170-7.
14. Mulholland B, Christian J. Risk assessment in construction schedules. Journal of construction engineering and management. 1999 Jan;125(1):8-15.
15. Snyder CS. A guide to the project management body of knowledge: PMBOK (®) guide. Project Management Institute: Newtown Square, PA, USA. 2014.
16. Smical IR, Muntean AD, Bud IO, Arad VI. Research on the influence of the local mining activities on the sediments quality of Băiţa Valley in Maramureş County, România. InRecent Advances in Civil and Mining Engineering, Proceedings of the 4th European Conference of Civil Engineering (ECCIE '13), Proceedings of the 1st European Conference of Mining Engineering,(MINENG '13) Antalya, Turkey 2013 Oct 8 (pp. 278-284).
17. Behm M. Linking construction fatalities to the design for construction safety concept. Safety science. 2005 Oct 1;43(8):589-611.
18. Bernstein HM, Russo MA, Jones SA, editors. Green BIM: How building information modeling is contributing to green design and construction. McGraw-Hill Construction; 2010.
19. Bryde D, Broquetas M, Volm JM. The project benefits of building information modelling (BIM). International journal of project management. 2013 Oct 1;31(7):971-80.
20. Azhar S. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and management in engineering. 2011 Jun 15;11(3):241-52.
21. Azhar S, Khalfan M, Maqsood T. Building information modelling (BIM): now and beyond. Construction Economics and Building. 2015 Oct 15;12(4):15-28.
22. Lopez R, Love PE. Design error costs in construction projects. Journal of construction engineering and management. 2011 Jul 30;138(5):585-93.
23. Langdon D. Blue Book 2013–Collaboration: Making Cities Better. AECOM Australia, available from www. aecom. com. 2013.
24. Construction MH. The Business Value of BIM For Construction in Major Global Markets: how contractors around the world are driving innovation with building information modeling. Smart MarketReport. 2014.
25. Fan SL, Skibniewski MJ, Hung TW. Effects of building information modeling during construction. 淡江理工學刊. 2014 Jun 1;17(2):157-66.
26. Chen Y, Dib H, F. Cox R. A measurement model of building information modelling maturity. Construction Innovation. 2014 Apr 1;14(2):186-209.
27. Abanda FH, Byers L. An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). Energy. 2016 Feb 15;97:517-27.
28. Musa AM, Abanda H, Oti H. Assessment of BIM for managing scheduling risks in construction project management. InCIB W78 conference, 27-29 October, 2015, Eindhoven, The Netherlands 2015 Oct.
29. Forsythe P, Sankaran S, Biesenthal C. How far can BIM reduce information asymmetry in the Australian construction context?. Project Management Journal. 2015 Jun 1;46(3):75-87.
30. El Hawary AN, Nassar AH. The Effect Of Building Information Modeling (BIM) On Construction Claims. International Journal of Scientific & Technology Research. 2015 Jan 1;4(8):25-33.

31. Bilal M, Oyedele LO, Akinade OO, Ajayi SO, Alaka HA, Owolabi HA, Qadir J, Pasha M, Bello SA. Big data architecture for construction waste analytics (CWA): A conceptual framework. Journal of Building Engineering. 2016 Jun 1;6:144-56.
32. Ding LY, Zhong BT, Wu S, Luo HB. Construction risk knowledge management in BIM using ontology and semantic web technology. Safety science. 2016 Aug 1;87:202-13.
33. Greed C, editor. Social town planning. Routledge; 2002 Jan 4.
34. Xu J. Research on Application of BIM 5D Technology in Central Grand Project. Procedia engineering. 2017 Jan 1;174:600-10.
35. George D, Mallery M. Using SPSS for Windows step by step: a simple guide and reference.3003.