Bibliographic analysis of BIM Success Factors and Other BIM Literatures using Vosviewer: A Theoretical Mapping and Discussion

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Abstract: Building Information Modelling (BIM) is a new technology in the construction industry to form a collaboration platform for effective communication and improve productivity and efficiency. Many researches have been published investigating BIM success adoption and implementation, challenges, risk, and barriers. However, there has been no systematic study analyzing the Bibliographic of these studies as a tool to explore a research gap in BIM implementation. This study is aimed to synthesize previously published papers on BIM and propose a new method for identifying success factors for effective BIM implementation by analyzing BIM-related journal articles published from 2009 to 2018. The main feature of this research methodology is the provision of a critical review of the literature and theoretical mapping for bibliometric analysis. As a result, limited articles have been dedicated to study the effective BIM implementation. This research paper has proposed a new useful method to be adopted for identifying success factors for effective BIM implementation.

Keywords: Building Information Modelling (BIM); Effective BIM Implementation; Success Factors; VOSviewer

1. Introduction

Building Information Modelling (BIM) is not just a tool or set of software that required some training to be successfully implemented. BIM is an n-D Modeling, Virtual Model, or Virtual Prototyping Technology [1], [2]. It encompasses all aspects of the design, construction, and operation of a building [1]. It manages building design and project data in a digital format and retains that data throughout the project life cycle [3], enabling stakeholders to insert, extract, update, or modify information during the BIM process [4], providing the exchange and interoperability of information among the stakeholders[3], and offering stakeholder collaboration at different stages of a building's lifecycle [4]. To achieve the comprehensive benefits of BIM technology, it is an important to understand the BIM technology process, how it is executed, the stakeholders’ relationships that must be considered in order to effectively balance stakeholder interest [2], [5], full configuration and alignment of BIM-based tools, project work processes, and the business models of the companies that work together on a project [6]. The government should play the main role to promote, regulate, and standardize the implementation [2]. According to Zakaria et al. (2013) [7], BIM technology implementation requires
the involvement of all parties, with the client having the main influence as the client can enforce other parties to use BIM.

BIM has a significant impact on current construction practices, and contractual policy. It is associated with several challenges and risks, as organizations faced some barriers to implement BIM effectively, and success factors are slowly obtained. This has led to low adoption of new technology among professionals and has caused low morale in the marketplace. This paper reviews the significant issues with BIM adoption and implementation. The aim of this review is to synthesize previously published papers on BIM and propose a new method for identifying success factors for effective BIM implementation. In addition, it provides a healthy knowledge and contributes to enhance the level of awareness of BIM implementation and its related challenges and success factors.

2. Research methodology

Based on the critical review and papers that have discussed underlying theories of BIM adoption and implementation, this paper review challenges, risk, barriers, and success of BIM adoption and implementation.

Many researchers have adopted the Scopus search engine as a comprehensive database that cover indexed publication Moreover, Scopus research engine was recommended as it covers most of the publication compare to others search engines such as Web of science (ISI indexed) and Google Scholar [8]. A total of 62 research papers were cited in this review which focused on BIM studies. Thirteen articles were extracted as research papers focused on BIM challenges, risk factors, influence factors and barriers to BIM adoption and implementation, and 8 articles were relevant to BIM CSF’s. However, the VOSviewer tools [9] were used to analyze the bibliometric of the selected relevant papers. Bibliometric analysis is used in previous research to map the occurrence of related topics in the research engines and areas that had received a low focus of research [5], [10].

The VOSviewer in this paper was employed to evaluate the network linkage among the selected articles. The network will visualize the linking between success factors and other BIM Literature that include BIM challenges, barriers, risks and influence factors. Further discussion of the network will be elaborated in section 6.

3. Current challenges, barriers, risks, and influence factors of BIM implementation

BIM implementation is highly influenced by conventional practices associated with organizations, applications, tools, project teams, processes, and business models [11]. Overall benefits of using BIM is not fully established because effective BIM implementation is still unclear for industry practitioners. Murphy (2014) [12] explained that “the mechanism problem exposed in BIM implementation was based on BIM currently being delivered as a project rather than an innovation”, and He et al., (2017) [5] described the problem as a “failure to address stakeholder competency in the key delivery agent of BIM”. As the matter of fact, the implementation of BIM has been always associated with a range of barriers, negative influence factors, and risks that have been categorized to technical [2], [4], [13], management [2], environmental, financial and legal factors [4], [13].

Previous investigation was carried out to evaluate the significant challenges, barriers, influence factors [13], [14] which provide a clear understanding of BIM technology and identified the challenges and risks of BIM in building industry. For example, Zahrizan et al., (2014) [15] conducted an empirical study to evaluate barriers and factors driving BIM implementation in Malaysian construction industry, while Gardezi et al., (2014) [16] evaluated the challenges. There is a consensus of potential legal issues encountered with BIM implementation that hinder and slow the adoption and implementation. These issues were categorized by Arensman and Ozbek, (2017) [17] into model ownership, right to rely, shifting of risk, standard of care, BIM compensation. On the other side, Alreshidi (2017) [4] evaluated BIM adoption barriers and collaboration issues, then developed a BIM governance framework (G-BIM), identifying effectiveness factors that guarantee successful collaboration.
However, the challenges for effective BIM implementation remain unclear, and literature shows non-exhaustive challenges that are found to be significantly influencing the effectiveness of BIM implementation. Replacing current construction practices required support and motivation from industry and organization. A consensus agreement based on the reviewed literature that policy outcomes significantly enhanced the level of BIM implementation.

4. Success factors of BIM adoption and implementation
CSF’s or key success factors was first discussed by Daniel in the early 1960s [18]. It is defined as “those characteristics, conditions, or variables that when properly sustained, maintained, or managed can have a significant impact on the success of a firm competing in a particular industry.” [18]. Ismyrlis & Moschidis (2013) [19] highlighted that objectives associated with the identified success factors should be achieved, otherwise the organization will fail with serious negative consequences in its objectives.

According to Antwi-afari et al., (2018) [8] “CSFs for BIM implementation can be defined as a set of key areas and measuring outcomes that drive all key practitioners to change from traditional project delivery using object-oriented computer-aided design (CAD) to successfully implementing BIM collaboratively from early design stage to the facility management stage”. Studies conducted to define the CSF for BIM adoption for successful implementation are limited. In general, previous research categorized CSF’s to: organizations, software tools, people, processes, business models, policy, resources, and projects factors. The difference between them was that some focused on the assessment and success of BIM adoption [20]–[22], enhancing BIM implementation [23], and some consider the success BIM implementation [24], the later however gives attention to these key CSFs of long-run build of a sustainable BIM implementation in Malaysia.

Antwi-afari et al., (2018) [8] illustrates that some developed countries established their CSF’s for measuring successful BIM implementation. Some CSF’s differed but major CSF’s are shared among these countries.

However, the review concludes that policy, technology, and processing are considered the main construct of BIM implementation. Each construct can then be categorized into two, three or more group factors. For effective BIM implementation, it is recommended that future study be focused on BIM processing success factors investigating the influence of policy and technology development to assess decision makers understanding the relationship between the main construct and BIM implementation.

5. Bibliographic Analysis
Bibliographic analysis considers the author’s research areas, the citation network and the paper content among other things [25]. In this paper, selected articles were analyzed according to the author keywords [10], articles source and co-author country. Finally, the map of the selected papers were analyzed based on title and abstract to visualize the most co-occurred terms and connections between them. Visualization provides a clear overview of topics discussed, strength, and lack of author terms discussion.

5.1. Co-Occurrence (Author keywords)
VOSviewer is used to develop a network of keyword co-occurrence based on the 21 studies of success factors, challenges, risk, influence, and barrier in BIM implementation. This network is useful to provide a clear understanding of the associated content of the selected articles. As recommended by Oraee, Hosseini and Papadonikolaki, (2017) [10], “author keywords show the core of the study and the focal point of an investigation which are carefully selected by the authors”. Nodes in the network represent individual keywords used to generalize the essence of each article. He et al., (2017) [5] described that the overall network of the keywords developed overtime and shows the important outline of the subject study.

Six clusters were generated based on the strength links between keywords as illustrated in Figure 1.
(Cluster #1) Critical Success Factor of construction industry: referred to studies about critical success factors for BIM. This cluster involves human-related factors, project success, implementation, and adoption assessment in the construction industry.

(Cluster #2) Critical Success Factor for BIM services: this cluster referred to studies about critical success factors for BIM services, which consisted of organizational strategy, information technology, BIM service, BIM-assisted project, BIM software application.

(Cluster #3) BIM legal issues: referred to BIM studies on legal issues, challenges, standard of care, negative and positive factors.

(Cluster #4) BIM in the AEC industry: this cluster referred to BIM in the AEC industry as it is referenced to the AEC industry, BIM performance assessment, and technology adoption.

(Cluster #5) Collaboration: referred to collaboration, information technology, virtual design and construction, and integrated project delivery.

(Cluster #6) Practical implementation: this cluster referred to BIM practical implementation which involves product lifecycle management and virtual project development.

Figure 1. Co-occurrence network of author keywords

It is important to highlight that there is no link between cluster 1 and 2, in which both clusters focus on CSFs of BIM from different perspectives. Similarly, cluster 3 and 4 focus on BIM technology but differ in the scope, wherein cluster 3 addresses legal issues, challenges, and influence factors while cluster 4 focused on the BIM assessment of the AEC industry. The linkage between clusters is weak especially on the focus of CSFs. Related studies did not show any link between the CSFs and cluster 5 (collaboration) and cluster 6 (practical implementation). There is also a lack of integration between cluster 1 and cluster 2. Therefore, the identified list of success factors extracted from these related papers would have a significant impact to include these clusters and link them theoretically. Furthermore, empirical investigation is recommended to identify the significance in different region.

5.2. Source

Relative articles were extracted from 16 journals as shown in Table 1. At least one paper has been published in these journals that fir the criteria of this research. The relative articles are categorized as 10 articles from International Scientific Indexing (ISI) extracted from Web of Science from 6 sources, 9 journal articles are indexed in Scopus, and two conference and proceeding articles indexed in Scopus as well. Only 11 articles show the largest set of connected items as shown in Figure 2. The range of the linked journal was from 2012 to 2017.

Table 1: Source of relative articles

| ID | Source                              | Documents | Citations | Total link strength | Web of Science | Scimago Journal ranking | SJR |
|----|-------------------------------------|-----------|-----------|--------------------|----------------|-------------------------|-----|
| 1  | Applied mechanics and materials     | 1         | 7         | 1                  | -              | -                       | Q4  |
Architectural engineering and design management  |  2  |  41  |  1  |  -  |  -  |  Q2  
Asian journal of civil engineering  |  3  |  1  |  0  |  0  |  -  |  -  |  Q3  
Automation in construction  |  4  |  371  |  4  |  Q1  |  3.432  |  Q1  
Computing in civil and building engineering - proceedings of the 2014 international conference on computing in civil and building engineering  |  5  |  1  |  3  |  1  |  -  |  -  |  Q2  
Construction management and economics  |  6  |  1  |  21  |  0  |  -  |  -  |  Q1  
International journal of construction education and research  |  7  |  1  |  13  |  1  |  -  |  -  |  Q2  
International review of management and marketing  |  8  |  1  |  0  |  1  |  -  |  -  |  Q3  
Journal of building engineering  |  9  |  1  |  3  |  1  |  -  |  -  |  Q2  
Journal of civil engineering and management  |  10  |  1  |  0  |  1  |  Q2  |  1.546  |  Q2  
Journal of construction engineering and management-ASCE  |  11  |  1  |  38  |  1  |  Q1  |  1.735  |  Q1  
Journal of management in engineering Chinese institute of engineers, transactions of the Chinese institute of engineers, series a/chung-kuo kung ch'eng hsuch k'an  |  12  |  1  |  7  |  1  |  Q2  |  2.011  |  Q1  
Leadership and management in engineering  |  13  |  2  |  16  |  1  |  Q4  |  0.345  |  Q2  
Procedia engineering  |  14  |  1  |  331  |  8  |  -  |  -  |  Q4  
Renewable and sustainable energy reviews  |  15  |  1  |  42  |  0  |  -  |  -  |  Q1  
Renewable and sustainable energy reviews  |  16  |  1  |  12  |  2  |  Q1  |  8.05  |  Q1  

Figure 2: Network and connection among the largest set of connected sources of related articles

5.3. Co-authors (country)
According to Miettinen & Paavola (2014) [26], local experimentation and continuous learning play a central role in the implementation of BIM. Table 2 presents 15 co-author analysis based on country name, number of related articles, number of citations, and total link strength. Total link strength is described as standard weight attributes which indicate the total strength of the links of an item with other items [9]. To illustrate that, items are not connected to each other. The largest set of connected items consist of 5 items as shown in Figure 3. United States has the largest total link strength with four countries, South Korea, New Zealand, Canada, and Malaysia.
Table 2: Co-author analysis based on country name, number of related articles, number of citations, and total link strength

| ID | Country     | Documents | Citations | Total Link Strength |
|----|-------------|-----------|-----------|---------------------|
| 1  | Australia   | 1         | 55        | 0                   |
| 2  | Canada      | 1         | 12        | 3                   |
| 3  | German      | 2         | 316       | 0                   |
| 4  | Hong Kong   | 1         | 0         | 1                   |
| 5  | India       | 1         | 0         | 0                   |
| 6  | Lithuania   | 1         | 42        | 0                   |
| 7  | Malaysia    | 4         | 40        | 3                   |
| 8  | New Zealand | 1         | 12        | 3                   |
| 9  | Saudi Arabia| 1         | 3         | 1                   |
| 10 | Singapore   | 1         | 0         | 0                   |
| 11 | South Korea | 1         | 38        | 1                   |
| 12 | Taiwan      | 2         | 16        | 0                   |
| 13 | Turkey      | 1         | 7         | 0                   |
| 14 | United      | 3         | 38        | 2                   |
| 15 | United States| 5      | 72        | 4                   |

Figure 3: Network and connection among the largest set of connected co-authors (country)

5.4. Map the articles

Figure 4. Most co-occurred terms in BIM (title and abstract relative articles)
VOSviewer has the ability to provide an insightful view of the text-mining, and it was utilized to create a co-occurrence network for collaboration in BIM [10]. VOSviewer uses the sentence detection algorithm provided by the Apache OpenNLP library [9]. This function is applied to the title and abstract of the relative studies. “Binary counting” method was recommended by Eck and Waltman, (2018) [9] to be applied. This was suggested so that the number of times a noun phrase occurs in the title and abstract does not play any role [9]. Out of the 599 terms identified, 118 terms met the threshold of the minimum number of co-occurrence above 2. As the default configuration of VOSviewer, 60% of these terms with the highest relevance were chosen to create the network. This resulted in the selection of 53 terms as shown in the co-occurrence network in Figure 4.

6. Method proposed to identify success factors for effective BIM implementation.
Success factors are measure value, attitude, item, process, or personal characteristic that is required a proper management to perform the job and improve performance of specific role [27]. CSFs will support the company’s success factors, business unit, and the overall organization [28].

![Figure 5. Methodology identifying Success factors for effective BIM implementation.](image)

The identification of success factors was almost uniform in previous research. Literature review was the main source of all researchers to define the success factors [21], [22], [29]–[31]. Mom, Tsai and Hsieh, (2014) [21] also synthesize influence factors from the literature and domain experts to developed CSF for assessment of BIM technology adoption, and Ozorhon and Karahan, (2017) [22] highlighted that synthesizing of barriers, critical risk factors, and motivation factors all are various factors that affect the success of BIM. Won et al., (2013) [20] these research studies evaluate variables for CSFs by considering those factors.

Based on the above literature, BIM challenges, barriers, and risk factors identified from literature are recommended to be analyzed as challenges. Those challenges if effectively managed to be overcome, will enhance BIM implementation. From the other side, BIM influence factors impact BIM implementation either positively by motivating the organization to BIM base technology or negatively which consider as a challenge to top management to have a clear decision on adopting BIM. Figure 5 illustrates an effective approached that comprehended methods from previous studies to identify success factors and summarized a method for identifying success factors for effective BIM implementation.

7. Conclusion
BIM technology has proven its ability to enhance productivity and efficiency. BIM also has proven intelligent ability to visualize building component and maintain information throughout the project lifecycle. It performs a collaborative platform that allows new integrated working approach. However,
these advantages were difficult to achieve unless challenges, risks, and barriers are effectively managed to maintain a successful BIM implementation.

Adoption of BIM is low because of the existence of significant negative influence factors, challenges, risks, and barriers that constrain the implementation among construction practitioners.

Evaluating the success factors is recommended as a solid start for organizations to enhance awareness, prioritize their needs, and improve their work performance towards BIM projects. Therefore, for future work, the researcher intended to evaluate a wide range of success factors explored through the proposed method from literature and to empirically investigate its significant to achieve an effective BIM implementation in Malaysia.

This paper also synthesizes previously published papers and analyze them according to the author, article source, and co-author country based on title and abstract to visualize the most co-occurred terms and connection between them. The visualization provides a clear overview of topics discussed, strength, and lack of author terms discussion.

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