Effects of Building Information Modeling on Construction Projects Delay: A Systematic Review

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Abstracts

Time is a critical factor or primary success metric in measuring the progress of construction projects since they are normally time-bound. The construction industry, on the other hand, seldomly completes projects on time due to its varied architecture - varying project styles, scopes, places, and sizes, as well as the participation of several stakeholders from different disciplines. Building Information Modeling (BIM) is expected to be a valuable tool in the construction industry, as it has the ability to mitigate construction project risks and complete projects successfully. As such, a systematic review on the effects of BIM on construction project delays become vital. Admittedly, systematic reviews provide a valuable opportunity for academics and practitioners to apply established expertise to further action, policy or study. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline, this study thus aims to conduct a systematic review on the effects of BIM on construction projects delay. This research approach yielded a positive effect of BIM on delay across multiple regions of the world with different construction project types. This systemic review, as an evidence-based methodology, will be crucial for the Architecture Engineering Construction (AEC) industry in enforcing the adoption of BIM for current and future projects in the sector globally. It is recommended that a comprehensive systematic review be conducted on other pertinent issues common to the construction industry.

Keywords: BIM, BIM Tools, PRISMA, Project Delay, Systematic Review.

1 INTRODUCTION

Time or schedule remains one of the critical factors or key performance indicator in determining the success of any construction project as they are typically timebound. Effective time management is vital for achieving project’s objectives, profitability and positive financial performance in the construction industry (Ankrah & Proverbs, 2005). Howbeit, the construction industry rarely completes projects in time due to its complex nature - vagaries of project type, scope, location and size and it often involves several stakeholders from multidisciplinary fields. For instance, Rivera, Le and Kapsikar (2017) found that seventy two percent of global construction projects experiences delay with a thirty eight percent increase in the original contract time. Furthermore, the percentage of delayed projects in Africa, Asia, Europe, Middle East and North America is seventy five, sixty eight, fifty three, seventy nine, and ninety eight respectively (PBSRG, 2016; Rivera et al., 2017).

Although several traditional methods or tools for example, the use of Importance Index (II) and Rank Correlation Coefficient (ρ) by Assaf and Al-Hejji (1995), Relative importance index (RII) by Odeh and Battaineh (2002), Relative Importance Weight (RIW) by Ramanathan, Narayanan and Idrus (2012) among many others, have been employed over decades to mitigate delay in construction projects, delay still strives as evident in its low profitability and capital investment (Egan, 2018; Rhodes, 2019). More so, the construction industry has been slow to adopt digital technologies and tools which have potentials capable of solving complex tasks or issues which have been widely adopted by other industries such as digital banking in banking and finance, virtual learning environment in education, self-driving vehicles in automobile, digital image recognition in health etc (Blanco et al., 2018; Marks, 2017).

Building Information Modeling (BIM) a digital technology or tool that is gaining traction around the world is believed to solve the majority of the construction industry's problems (Tahir Muhammad et al., 2019). The hypothesis of BIM was established in 1970 by Professor Charles Eastman at the Georgia Tech School of Architecture as building description systems (BDS) (Eastman *et al.*, 2008). Undeterred by its long-time existence, interest in BIM only took off few years ago. This present-day construction industry is predisposed by the wariness about BIM. Varying concerns around what exactly BIM is, whether BIM is only meant for large projects with complex geometries, how to change from the traditional design process to BIM etc. BIM is defined as structured model of data that represents building elements with its usage spanning beyond the pre-construction phase to the post-construction phase in Architecture, Engineering and Construction (AEC) industry (Ameziane, 2000). Also, BIM is perceived by facility managers as a tool used to improve building's performance and manage operations more efficiently throughout a building's life (Abbasnejad, 2013).

The practical adoption of BIM by the (AEC) industry for construction project started around the mid-2000s (Latiffi et al., 2013). It was first implemented by the United States of America (USA) with example BIM-based construction projects seen in Sutter Medical Centre, Castro Valley California USA (Davis, 2007). Presently, BIM-based construction projects have been implemented in several countries such as "Sydney Opera House", in Australia; "One Island East Office Tower", in Hong Kong; "Crussel Bridge", in Helsinki, Finland; "National Cancer Institute (NCI)", in Putrajaya, Malaysia; "Barking Riverside Extension and Rail Station", in London, UK etc (Eastman et al., 2008; Latiffi et al., 2013). The rate of adoption of BIM differs from country to another. For instance, according to a report by Bernstein (2010) 50% adoption rate amidst contractors was reached in North America compared to barely 24% of the counterparts in Western Europe meanwhile the Western Europe has more percentage of BIM user rate: 34% against North American BIM user rate: 18%.

With reference to House et al. (2007) the major benefit of BIM is its accurate geometrical representation of building parts in an integrated data. Some research (Johansen, 2015; Jones, Young Jr. & Bernstein, 2008; Mohd & Latiffi n.d.; Siddiq, 2018) indicated that BIM is generally used during pre-construction, construction and post construction stages to produce better project design; aid in decision making process; improve collaboration and communication among stakeholders; centralize data administration in a common data environment; reduce changes during construction; reduce conflict during construction; minimize risks in execution period; visualize design solution in 3D; reduce project delay; improve overall project quality and achieve better cost control/predictability.

Although benefits of BIM with regards to construction projects have been enlisted, its application to the real world is seemingly limited to just 3D visualization and clash detection, thus there remains a large gap between its proposed application area and its current implementation (Jin, Tang & Fang, 2015; Charef *et al.*, 2019; Bouhmoud and Loudyi, 2020). Hence the need for a thorough investigation on effects of BIM on construction project delay. Consequently, this study aims to conduct a comprehensive systematic review on effects of BIM on construction projects delay. To accomplish this aim, the following objectives is used:

1. Identify and present BIM tools used to potentially mitigate delay from vast body of literature.
2. Establish the eligibility criteria for each project type identified with the respective effect of BIM tool identified in objective 1 on the project.

2 RESEARCH METHODS

This systematic review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). PRISMA is a protocol for conducting systematic reviews and meta-analyses that includes a 27-item checklist and a four-phase flow diagram. It was created by a consortium of 29 professors in the medical community with the aim of improving the clarity and consistency of literature reviews. PRISMA was therefore, chosen over other existing guidelines because of its comprehensiveness, its use in a variety of disciplines around the world outside of medicine, and its ability to improve accuracy through articles (Pahlevan et al., 2019).

In order to record the research process and inclusion criteria, a protocol was created in advance. A thorough literature search was conducted to find articles for this study. More precisely, only articles published until 1st of April 2021 in SCOPUS and American Society of Civil Engineers (ASCE) databases were used as its primary source of information for the search. These databases were chosen because the formal is the “largest abstract and citation database of peer-reviewed literature” (Cantú-Ortiz & Fangmeyer, 2017) while the latter is the “world’s largest publisher of civil engineering content” (ASCE, 2010). The abstract, title and keywords of publications in these databases were searched using the following search terms: (“BIM" OR "Building Information Model*" OR "Building Information Manage*" AND (“Delay*" OR "Schedule Overrun*" OR "Overtime")) with no date, language and article type restrictions.

A total of three hundred and eighty-eight articles were identified. The author’s name, author’s affiliation, articles title, articles abstract, authors keywords, publication year and source title were exported to a Comma-Separated Values (CSV) file. At first, two independent reviewers screened each title and abstract in the exported CSV file. Full text of articles from the file that fell within the eligibility criteria (mentioned above) were subsequently accessed and evaluated. Disagreements among the reviewers were explored and settled by consensus during this process. If no consensus could be found, the opinions of a third reviewer may have been considered.

The bibliographic information for the included articles, as well as the necessary elements from the PRISMA checklist (with a few changes), were added to the data management CSV file. Things relating to meta-analysis study findings (items 12–16 and 19–23) were excluded because they were related to meta-analyses only, hence outside the scope of this research. In order to optimize the extracted information and to code accordingly, a pilot test of fifteen randomly chosen included articles was carried out. Finally, all articles used were thoroughly examined for data extraction (research aim, project type, country/region, research method(s), tool(s), etc.) and coding by one author.

3 MAIN DISCUSSION

Performing the search terms on the electronic databases yielded a total of three hundred and eighty-eight articles. Only eighty-eight of them remained after screening the title and abstract of these articles as others (For example, Yan *et al.*, (2008); Studebaker, (2014); Surendhra *et al.*, (2018); Moselhi *et al.*, (2020) etc) were not relevant to the effect of BIM on construction projects delay. Furthermore, each reviewer read the full-length of the remaining articles carefully to ensure that they were relevant. Thirty-eight of these were further discarded because they did not satisfy the eligibility criteria. Consequently, a total of fifty articles – thirty-one journals, seventeen conference proceedings, and two books remained and were used for this research as summarized in figure 1:

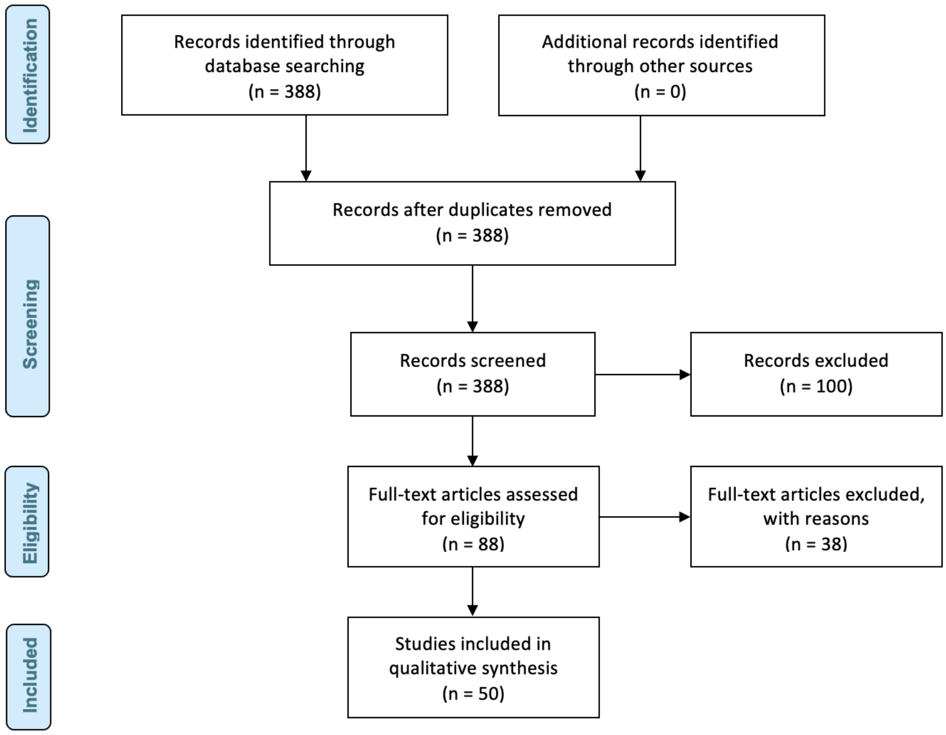

***Figure 1: Flow diagram of research selection process*.**

By observation (see table 1), it appears that the global construction industry has only paid more attention on the effect of BIM to its project delay in the continent of Asia (in terms of number of publications by researchers and practitioners used in this study) when compared to other continents of the world. This can further suggest the possible increase in the rate of adoption of BIM and a lesser number of delayed projects in that region as was evidently demonstrated in the construction of a 1,000-bed Huoshenshan and 1500-beds Leishenshan Hospitals for COVID-19 patients in Wuhan, China between the 23rd of January and 2nd of February 2020.

Table 1
List of research articles used and their respective countries/continents.

SN	Continent	Countries (# of Research Articles)	Total Countries	Total Articles
1	Africa	Zambia (1), Egypt (2),	2	3
2	North America	Canada (2), USA (2),	2	4
	South America	Peru (1),	1	1
3	Asia	India (3), Malaysia (7), Korea (4), China (5), Thailand (1), Taiwan (2), Jordan (1), Singapore (1), Slovenia (1), Indonesia (1), Hong Kong (1)	11	27
4	Europe	Italy (2), Spain (1), Germany (1)	3	4
5	Oceania	Australia (1)	1	1
6	Multicontinental	Multinational (10)	n/a	10

Table 2 summarizes the extracted variables and information as the main characteristics of all the reviewed articles towards the discovery of effects of BIM on construction projects delay. Various attempts at mapping and synthesising the current body of information have emerged in the literature since BIM in AEC (as an area of inquiry) has increasingly grown and supposedly reached intellectual and analytical sophistication in decades. Systematic analyses have emerged as one of the key methods for assessing the effect of BIM on construction projects delay among the various forms of research undertaken by scholars (Alaka et al., 2018). One of the most evident findings of our analysis concerns the variety of different BIM tools used in different construction projects and their unanimous effect on project delay. More specifically, while only one of the studies was neutral on the effect of BIM on delay, others concluded BIM's positive effect on construction projects delay even though they implemented BIM differently on different construction projects across different regions of the world (see table 2). This is highly incredible as the novel BIM is said to have the potential to be regarded as a disruptive technology by the AEC across the globe which this study's analyses is further confirming.

Table 2
The summary of study characteristics: summary of effects of BIM on construction projects delay.

SN	Study	Source Type	Country	Project Type	Research Method	BIM Tool Used	Effects
1	Narlawar, Chaphalkar and Sandbhor, (2019)	Journal	India	Residential Building	Quantitative	Autodesk Revit, and Autodesk Navisworks Manage	Positive
2	Narlawar G.S., Chaphalkar N.B., (2017)	Journal	Malaysia	General construction	Mixed methods (semi-structured interview and Questionnaire)	None	Positive
3	Ryu *et al.*, (2015)	Journal	Korea	Tunnel	Quantitative	Simulated Annealing (SA) and BIM	Positive
4	Nawi *et al.*, (2014)	Journal	Malaysia	Industrialised Building System (IBS) Construction Projects	Qualitative	Integrated Project Delivery and BIM	Positive
5	Li *et al.*, (2017)	Journal	Hong Kong	General construction	Qualitative and Experimental	RFID-enabled BIM	Positive
6	Subramani and Ammai, (2018)	Journal	Multinational	General construction	Qualitative	Primavera	Positive
7	Amany, Taghizade and Noorzai, (2020)	Journal	Multinational	General construction	Quantitative	Last Planner System (LPS) technique with Revit BIM	Positive
8	Husin, (2019)	Journal	Indonesia	high-rise building	Quantitative	None	Positive
9	Abdelbary, Edkins and Dorra, (2020)	Journal	Egypt	General construction	Quantitative	None	Positive
10	Shin, Lee and (Kim, 2018)	Journal	South Korea	Railway Site	Mixed methods	None	Positive
11	Park and Lee, (2017)	Journal	Korea	hospital building	Quantitative	2D drawings and BIM	Positive
12	Park *et al.*, (2017)	Journal	Multinational	General construction	Experimental	Web and Database-Based 4D BIM	Positive
13	Sepasgozar *et al.*, (2019)	Journal	Generic	General construction	Qualitative, Quantitative and Experimental	None	Positive

14	Chiponde *et al.*, (2017)	Journal	Zambia	General construction	Mixed methods	None	Positive
15	Sami Ur Rehman *et al.*, (2020)	Journal	Multinational	General construction	Mixed methods	None	Positive
16	Giel and Issa, (2013)	Journal	Multinational	General construction	Qualitative	None	Positive
17	Jang and Lee, (2018)	Journal	Korea	General construction	Quantitative	None	Positive
18	Chen and Tang, (2019)	Journal	China	Buildings	Quantitative	None	Positive
19	Ern, Ooi and Al-Ashmori, (2020)	Journal	Malaysia	General construction	Quantitative	None	Positive
20	Elhusseiny, Nosair and Ezeldin, (2021)	Journal	Egypt	General construction	Quantitative	None	Positive
21	Malacarne *et al.*, (2018)	Journal	Italy	General construction	Qualitative	None	Positive
22	Handayani, Likhitruangsilp and Yabuki, (2019)	Journal	Thailand	Story Building	Qualitative	Autodesk Revit	Positive
23	Wong, Zhou and Chan, (2018)	Journal	China		Quantitative	3D/4D BIM	Positive
24	Tserng, Ho and Jan, (2014)	Journal	Taiwan	General construction	Experimental	Construction BIM-assisted Schedule management (ConBIM-SM)	Positive
25	Liu *et al.*, (2020)	Journal	China	Buildings	Experimental	None	Positive
26	Vilventhan, Razin and Rajadurai, (2020)	Journal	India	infrastructure construction project	Qualitative and Experimental	Geographic Information System (GIS)	Positive
27	Delgado *et al.*, (2015)	Journal	Spain	Building	Experimental	Web3D visualizer and BIM	Positive
28	Hossain *et al.*, (2018)	Journal	Singapore	Story Building	Experimental	None	Positive
29	Stegnar and Cerovšek, (2019)	Journal	Slovenia	office buildings.	Quantitative	None	Positive
30	Khalesi *et al.*, (2020)	Journal	Multinational	Residential Building Construction	Quantitative	None	Positive
31	Tahir *et al.*, (2018)	Journal	Multinational	General construction	Qualitative	None	Positive
32	Vahdatikhaki and Mawlana, (2017)	Conference	Canada	Experimental	Experimental	None	Positive
33	Tahir Muhammad *et al.*, (2019)	Conference	Malaysia	General construction	Quantitative	None	Positive

34	Btoush and Harun, (2017)	Conference	Jordan	General construction	Qualitative	3D/4D BIM	Positive
35	Dallasega *et al.*, (2019)	Conference	Italy	hospital construction project	Experimental	3D/4D BIM	Positive
36	Diaz *et al.*, (2019)	Conference	Peru	Road projects	Experimental	Civil 3D, Revit and IfraWorks 360	Positive
37	Ansah *et al.*, (2016)	Conference	Malaysia	General construction	Qualitative	3D/4D BIM	Positive
38	Chou and Chen, (2017)	Conference	Taiwan	General construction	Quantitative	3D/4D BIM	Positive
39	Wang *et al.*, (2015)	Conference	Australia	Liquefied Natural Gas Construction	Quantitative	Laser Scanning, Mobile Computing and RFID	Positive
40	Kermanshahi *et al.*, (2020)	Conference	Malaysia	Police Headquarter Building	Quantitative	Autodesk Revit and Autodesk Navisworks	Positive
41	Couto and Ericson, (2017)	Conference	USA	Airport Building	Experimental	3D/4D BIM and Laser Scanner	Positive
42	Vacanas *et al.*, (2015)	Conference	Multinational	infrastructure construction project	Qualitative	3D/4D BIM and Unmanned Aerial Vehicle (UAV)	Positive
43	Suermann and Issa, (2009)	Conference	USA	Air Force Building	Experimental	3D/4D BIM	Neither Positive nor Negative
44	Liu and Liu, (2020)	Conference	China	Substation Construction	Qualitative and Experimental	Glodon 5D BIM	Positive
45	Ibrahim, Hashim and Ahmad Jamal, (2019)	Conference	Malaysia	General construction	Quantitative	Traditional 3D/4D BIM	Positive
46	Zhang and Liu, (2021)	Conference	Multinational	General construction	Qualitative	3D/4D BIM	Positive
47	Ocheoha and (Moselhi, 2013)	Conference	Canada	General construction	Quantitative	3D/4D BIM	Positive
48	Sigalov and König, (2018)	Conference	Multinational	General construction	Experimental	3D/4D BIM	Positive
49	Teng *et al.*, (2013)	Book	China	General construction	Qualitative	Integrated Project Delivery and BIM	Positive
50	Srao, Rai and Mann, (2018)	Book	India	General construction	Qualitative	3D/4D BIM	Positive

4 CONCLUSIONS AND RECOMMENDATIONS

Since construction projects are usually time-bound, time remains a crucial factor or primary performance measure in assessing their progress. However, owing to its diverse design - varying project types, scopes, locations, and sizes, as well as the involvement of many players from various disciplines - the construction industry seldom finishes projects on schedule. BIM is speculated to be a useful tool in the construction industry, as it has potentials to aid its users in reducing uncertainties and achieving good project completion. As a result, a systematic review on the effect of BIM on construction project delays became vital. Admittedly, systematic reviews provide a valuable opportunity for academics and practitioners to apply established expertise to further action, policy or study. Using the PRISMA guideline we conducted a systematic review on the effects of BIM on construction project delay. Our results and analyses indicated a positive effect of BIM on delay across multiple regions of the world with different construction project types. This is extremely crucial for the AEC industry as the rate of adoption of BIM for current and future projects in the sector will be adhere to more seriously. Also, the BIM mandate required from contractors/consultant by policy makers or government agencies across regions will be released there by reducing conflicts or law orders between project stakeholders as construction projects achieves timely completion of its projects. Systemic review, as an evidence-based methodology, should essentially be able to assist business policymakers in a number of areas, such as decision-making. However, due to a number of other unusual issues such as reworks, cost overruns, and so on, it's unclear to what extent this new review will benefit the industry. It is recommended that a comprehensive systematic review be conducted on other pertinent issues common to the construction industry.

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