Valuation of 4D BIM to Influence Construction Project Performance

Written by: Robin G. Haller, SDG Construction Consulting

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Many construction projects are not supported by consistent time and cost management systems (Jrade and Lessard, 2015). This often leads to missed cost and schedule forecasts, which, in turn, results in lost time and wasted capital expenditures (Potts and Ankrah, 2014, pp. 1-11). Also, various authors say the industry needs to improve construction management practices by the use of the currently available technology as the future of capital projects becomes more digitized (Fuchs, Kroll and Nowicke, 2018). Furthermore, as automated progress tracking and visualization techniques continue to evolve, the modeling of progress tracking is one of the grand challenges in the construction industry (Leite et al., 2016). In other words, visualization technologies supporting decision making tasks in construction projects is becoming critical (Leite et al., 2016; WEF, 2017, p. 15).

Building Information Modeling (BIM) is not just an extension of 3D drafting, but models changed in one view to be reflected in other views (Baldwin and Bordoli, 2014, p. 193). 4D BIM as a visualization technique integrates 3D building models with project timelines and provides visualization of sequenced activities of components of a building (Mubarak, 2015, p. 397; Mills, 2016). Scheduling technology is contributed by 4D BIM in simulating as a virtual model of actual captured site data and provides reliable valuations to be carried out (Mubarak, 2015, p. 397).

BIM is designed to streamline processes and improve efficiencies within the construction industry. This is because scheduling processes are reported to be improved by the use of BIM (Jenkins et al., n.d.; Hardin and McCool, 2015, p. 211). It is reported that communication within architectural, engineering, and construction businesses is improved through the use of BIM with real-time visualization (Dave et al., 2018, p. 36). Moreover, other authors report that 4D BIM facilitates collaboration and is used by owners, engineers, designer, contractors, and subcontractors during planning and operation phases of construction (Day, 2014; Mubarak, 2015, p. 397). Also, 4D BIM is most often requested by clients for its visualization capacity for construction management services (Sadhu, 2015; Hardin and McCool, 2015, p. 213; Ghaffarianhoseini et al., 2017).

Another study reports that BIM provides ready design decisions and reduces waste and that this increases optimism in contractors about their ability to complete their projects on-time and on-budget.
Builders hope to improve efficiency by using 4D BIM to demonstrate the contract building to customers before the pouring of footings, and further wish to be able to create plan changes without losing money or squandering labor (Sadhu, 2016).

A study conducted by McGraw Hill Construction between 2007 and 2012, indicates the percentage of companies using BIM in the United States increased from 17% to 71% (America, 2019) and notes that 4D models offer more accuracy and influence shorter project construction phases (Sadhu, 2016). There is virtual interaction between BIM and reality capture technology such as the Internet of Things (IoT) to influence accuracy and real-time project updates (Blanco et al., 2018). The Internet of Things (IoT) supports the use of 4D BIM technology. According to a study conducted by Automated in Construction, there is potential synergy between the two platforms of BIM and IoT deployment (Dave et al., 2018, p. 36). These same authors also claim that research into the construction execution phase demonstrates that the BIM and IoT can be used in various sectors of the construction industry.

Stakeholders are reportedly given better performance visibility of job site activity with the use of this digital twin arrangement, and advanced twin and reality-catch arrangements enable stakeholders to make field corrections through continuous examination of the advancement of the construction work (Blanco et al., 2018).

Automation and satellite symbolism, along with 3D light detection and radar (LiDAR) scanning and photosphere based-arrangements, are key parts of numerous reality-catch endeavors, according to Blanco et al., (2018). The integration of these reality capture technologies with BIM systems can add value to project planning, allow for better data processing, provide support for making decisions and increment productivity, cost-effectiveness, and quality of a construction project (Turkan et al., 2012). The most effective uses of twin models are claimed to result from the consistent incorporation of 3D models produced by automation symbolism, which is enhanced utilizing IoT sensors (Blanco et al., 2018). This method makes a more accurate and computerized representation of the physical reality of the construction project (Turkan et al., 2012 citing Tang et al.). The quick, precise data representation makes it possible to centralize the information with 3D models for automated updates (Blanco et al., 2018). Doing so also makes it possible for clients to use mixed reality models which consolidate 3D models (Blanco et al., 2018). What is considered to be of a particular use of these applications is their capacity to reduce primary leadership cycles of a construction project to a routine. This is accomplished by automating the project’s scheduling and budget updates (Turkan et al., 2012 citing Tang et al.).

A study by Teizer et al., (2017) also discusses the concept of set availableness of current real execution informational collections through an IoT approach that joins condition and nearby information in a cloud-based BIM platform. These authors show that actual up to date performance data sets can be created by using an IoT approach and that this could be combined with a cloud-based
BIM platform that integrates environmental and localization data. These same authors also claim that the use of such a BIM/IoT method could lead to significant improvements in the construction industry to facilitate the coordination of projects and lead to more informed decision making. These authors also point out that the adaptation of innovative electronic technology is not new to the construction industry, and point to recent incorporation of Radio-Frequency Identification (RFID) as a prime example (Jones, 2014). However, they also say that an IoT approach to dealing with associate physical workplaces with advanced data anticipates a digital future. A future in which digital and physical objects (for example smartphones, machines, and instruments) can be linked to appropriate data and correspondence advancements in a way that streamlines and simplifies the administration of the project.

Further literature research touches on other technologies which can be used to support 4D BIM in the construction execution phase, such as unmanned aerial vehicles (UAVs) – Drones, Wearables, Artificial Intelligence (AI), Augmented Reality (AR), Reality Capture, and Robots to verify construction progress (Hedmond, 2018; Sullivan and Sullivan, 2014). These have been explored because various authors have reported that all of these technologies may be combined with the use of 4D BIM and that doing so can increase the effect of this approach (Son et al. 2017; Han, Cline and Golparvar-Fard, 2015; Zack and Pitaniello, 2016). According to Colin Guinn, Senior Vice President of Sales and Marketing at 3D Robotics, drones are efficient at obtaining accurate information of the precise type that architects, engineers, and constructors can use to do their jobs (Day, 2014). Drones which use the latest hardware and the most recent software programs can carry out numerous complex and practical functions (Brown, 2018). For instance, drones are being used to compare 3D models with as-built designs (Busta, 2016).

One specific innovation used in support of 4D BIM is wearable digital technologies with hardhat sensors (Brown, 2018). The use of such wearables is one of the methods that many builders believe can improve productivity (USG Corporation, 2018). This is particularly true since such wearable technologies can be integrated into a 4D BIM automated system (McIntyre, 2016).

Another innovation that is used in combination with 4D BIM is Artificial Intelligence (AI) and Augmented Reality (AR). Such tools can be linked to any 4D BIM system, and be used to process a vast amount of numerical data in a short amount of time (Zollmann et al., 2014). By doing so, such AI devices can be used to compare numerous possible scheduling scenarios and be quick to determine which particular pathway is most efficient (Brown, 2018).

Finally, several studies relate to reality-capture methods to visualize and automate construction progress measurement. One study by Blanco et al., (2018) mentions digital twin platforms and reality-capture solutions with the use of drones, satellite imagery, LiDAR scanning and photosphere solutions...
as key elements of many reality-capture endeavors. Another study by Turkan et al., (2012) mentions the use of 4D schedule with 3D sensing technologies with a Scan-vs-BIM framework (Turkan et al., 2012). A study by Son et al. (2017) proposes the feasibility of using local region-based, as-built point cloud data and comparing that data to an as-planned BIM model (Son, Kim and Kwon Cho, 2017). The research by Rebolj et al. (2017) presents the results of a more accurate application of using both point cloud and Scan-vs-BIM method for monitoring construction progress (Rebolj et al., 2017). The primary objective of research by Kim et al., (2013) develops a fully automated method of using 4D BIM with 3D data that was obtained with remote-sensing technology to measure construction progress (Kim et al., 2013). The study by Han, Cline and Golparvar-Fard (2015) goes into further detail and illustrates a classification mechanism augmenting 4D BIM with the level of detail from several 3D point clouds to enable visualization of construction progress assessment (Han, Cline and Golparvar-Fard, 2015). Another research study by Pučko, et al. 2018 proposes using small scanning devices to fit onto workers’ hard hats and applied machinery to provide a constant continuous updating process to the as-built 3D BIM model (Pučko, Šuman and Rebolj, 2018). Turkan et al., (2012) notes that laser scanning is the best adaptable reality-capture technology for accuracy and efficiency of sensing project status (Turkan et al., 2012). These innovative technologies are used in combination with the 4D BIM technology, and thus improve the ability of the system to measure progress on the job site during the construction execution phase of the project (Hardin and McCool, 2015, pp. 232-236).

Technology is available today that offers the potential advantages of forward-looking project schedules that do not exhaust all available resources (Hardin and McCool, 2015, p. 281; Kerzner., 2009, p. 590; Mubarak, 2015, p. 397). Such technology draws information from the BIM model to give contractors and subcontractors an excellent comprehension of job progress, and this information, in turn, facilitates effective resource allocation, enhance efficiency, and improve on-time execution (Assemblesystems.com, 2017). Studies report that technology such as 3D models possesses the ability to reduce decision making cycle times from monthly to daily (Blanco et al., 2018; Shrestha and Schuetz, 2017; Holmberg, 2017). This can be accomplished by the full automation of project scheduling and budgeting updates for any construction project (Blanco et al., 2018). Furthermore, according to Jenkins et al., n.d., 4D scheduling shows the project from a different perspective in which the visualization tool provides the ability to obtain stakeholder buy-in of the schedule as it becomes more realistic (Jenkins et al., n.d.). Moreover, according to Jenkins et al., n.d., a 4D BIM integration tool helps those using the tool to drive crucial conversations, for stakeholders can examine not only the project but also examine its components (Jenkins et al., n.d.).

A detailed study by Teizer et al., (2017) theorize that proper construction project information management, including data generation knowledge accessibility and the sharing of crucial information,
is a primary key to the effective use of construction controlling techniques. However, in order to accomplish this, it is necessary to provide a consistent and reliable stream of data which can monitor the progress of the work, consider imperatives, and evaluate profitability continually. A proposed concept imagines encouraging higher task quality and on-time project delivery.

Also, Teizer et al., (2017) discuss using innovative IoT technology for the construction industry and present a method to track construction trades to quantify work progress in the existing framework by using interior finishing wall tasks of a building project as an example. These authors also state that information and communication technologies (ICT) are useful for enhancing stream of construction processes that can be eliminated if recognized to be non-value or risk adding activities. By using this approach, cycle times can be shortened, and the number of errors and rework reduced.

Challenges, Problems, and Construction Challenges to Implementation of 4D BIM and Visualization Technologies

One challenge pointed out by Shrestha and Schuetz, (2017) to the adoption of 4D BIM systems is that high-level project plans are alone used to pay contractors. Other authors report that such systems are most used to make presentations to appease owner interests, rather than for actual use in managing the project (Mao, Zook and Hunzeker, 2017). Along with appeasing client interests, the most substantial reasons that organizations are not readily adopting 4D BIM are absence of demand, price, issues of interoperability amongst technologies, time consuming, labor intensive and the lack of experienced professionals with the necessary skills (Ghaffarianhoseini et al., 2017; Lopez et al., 2016; Kim, Anderson et al., 2013). Another critical factor is the standardization of BIM as seen in the UK and Germany according to Shrestha and Schuetz, (2017). In the United States, there are increased use of International Finance Corporation (IFC) standards to gain the interoperability to facilitate more extensive use of 4D BIM (Baldwin and Bordoli, 2014, p. 193). Also, the National BIM Standard-United State standards are being utilized in the United States to help improve the competitiveness, efficiency, and effectiveness of the construction industry (Nationalbimstandard.org, 2019).

A drawback stated by Teizer et al., (2017) was that the construction industry is in a state of constant challenge regarding digital transformation for the measurement of work progress. Teizer et al., (2017) has determined that most construction enterprises are committed to business practices that are removed from integrating BIM and IoT. The small number of visionary construction companies that are using the IoT are few and far between, and could be best described as “digital islands.” These
same authors say that, in general, there is no digital connection of a construction company during the project execution phase (Teizer et al., 2017).

**Barriers to Implementation of 4D BIM**

According to Jenkins et al., n.d., one significant barrier to full implementation of 4D BIM within the construction industry is that in most contracts, 4D BIM is not a contractual requirement at the construction execution phase (Mao, Zook and Hunzeker, 2017). Further, in the United States, federal regulation on BIM is absent, which has meant that BIM refinement has progressed in small stages driven by local governments, and individual agencies (ibid. 2017). In contrast, the Los Angeles Community College District (LACCD) in 2018 mandated that it’s $9.5 billion renovations and construction program would adopt BIM standards (Engineering.com, 2019). Because of this mandate, LACCD sets the pace in encouraging United States projects to use mature BIM technologies (ibid. 2019).

Another barrier to implementing 4D BIM as pointed out by Shrestha and Schuetz, (2017) is an issue of “big data” not being applied in the construction industry. According to them, most of these reasons come down to “Velocity vs. Variety.” The term “velocity” as used here, refers to the pace that data is generated, and the term “variety,” refers to the ability to arrange incoming data in different categories (Whishworks.com, 2019). Examples of “velocity” are data from schedules, documents, point clouds, BIM models, sensors, and drone images. On the other hand, examples of velocity are construction site size, type, location, contractors, contract type, materials, and union vs. non-union. As reasoned by the authors, the vast amount of data and the speed of which it is processed is a barrier to applying 4D BIM at the construction execution phase (Shrestha and Schuetz, 2017).

Dave et al., (2018, p. 36) indicates that, within the domain of BIM and IoT integration, open data and open communication standard problems have not been addressed. Currently, there are “250 reported IoT platforms available on the market”, most of which are not compatible and constitute a barrier to 4D BIM and IoT implementation on construction sites” (Dave et al., (2018, p. 44). The research concludes that it is possible to integrate IoT devices with building information data through Open Messaging interfaces (Dave et al., 2018, p. 44).

**Solutions for Implementation of 4D BIM and Digital Technologies**

Research has shown there are various technologies available to integrate 4D scheduling, such as a team member can access a system and see the key indicators from their iPad and iPhones (Jenkins et al., n.d.). These tools provide a visual map of the planning process and thus provide an improved understanding of what is planned and what is being executed (Assemblesystems.com, 2017). Facilitating and proactive problem resolution can lead to gains in productivity by the improved understanding of the execution of the work (Blanco et al., 2018). The dynamic view of the project that
integrates digital twin platforms and reality capture solutions can permit a real-time comparison of the work progress (Blanco et al., 2018).

**Summary**

The literature review discusses the existing 4D BIM scheduling, IoT, RFID, Drones, Robotics, Reality Capture, and other field capture technologies relevant to the study. Several previous researchers have concluded that the construction industry has been slow to embrace the current technologies described in this chapter, but there are signs that this is changing (woetzel, n.d.). The use of 4D BIM technology can help construction companies’ complete projects on schedule and improve the efficiency of onsite construction operations (Zack and Piniello, 2016; Gledson and Greenwood, 2017).

However, during a recent AUTODESK 2017 conference in Las Vegas, Nevada, 3 panelists representing prominent general contractors in California acknowledged that they were “not doing 4D BIM as a rule” and on the occasions when they did use this technology, they used it only for bidding on projects (Mao, Zook and Hunzeker, 2017).

The literature research concludes that successful construction project management must appreciate and utilize cutting edge digital technological innovations ((Lexology.com, 2019; WEF, 2017). The most recent technological innovations can enable a builder to move from being reactive to being proactive (Assemblesystems.com, 2017).

**Potential Benefits of 4D BIM**

Table 4 summarizes the responses of the 56 respondents regarding the potential benefits of 4D BIM. The top three highest frequencies of responses were construction execution (49; 87.5%), communication with owner/client (43; 76.8%), and pursuit/bid development (35; 62.5%). These responses demonstrated the most consensus on potential benefits of 4D BIM according to the 56 respondents. More than half of the 56 respondents also chose communication with site staff (33; 58.9%), stakeholder engagement (32; 57.1%), communication with senior executives (29; 51.8%), and planning temporary work (29; 51.8%) as potential benefits of 4D BIM.
<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pursuits / bid development</td>
<td>35</td>
<td>62.5</td>
</tr>
<tr>
<td>Stakeholder engagement</td>
<td>32</td>
<td>57.1</td>
</tr>
<tr>
<td>Communication with owner / client</td>
<td>43</td>
<td>76.8</td>
</tr>
<tr>
<td>Communication with senior executives</td>
<td>29</td>
<td>51.8</td>
</tr>
<tr>
<td>Communication with site staff</td>
<td>33</td>
<td>58.9</td>
</tr>
<tr>
<td>Construction execution</td>
<td>49</td>
<td>87.5</td>
</tr>
<tr>
<td>Planning temporary work</td>
<td>29</td>
<td>51.8</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
<td>23.2</td>
</tr>
</tbody>
</table>

**Table 4**

*Frequency and Percentage Summaries of Responses on Potential Benefits of 4D BIM*

**Utilization of 4D BIM Planning**

Table 5 summarizes the responses of the 56 respondents regarding the utilization of 4D BIM planning. More than half (36; 64.3%) of the 56 respondents responded that 4D BIM is utilized at the construction execution phase. More than half (32; 57.1%) of the 56 respondents reported that 4D BIM allowed all project stakeholders to visualize all scheduled activities ahead of time when in progress. More than half (32; 57.1%) of the 56 respondents said that 4D BIM enabled and helped superintendents, foremen, and craft labor to visualize the design and construction plan in advance of the actual construction and helped them see what it is they are to build, in what order, and enable them to trust the plan. Almost half (27; 48.2%) of the 56 respondents stated that 4D BIM allowed stakeholders to anticipate and maintain a strategic distance from issues. More than half (34; 60.7%) of the 56 respondents responded that 4D BIM approach gives stakeholders a clear visual understanding of step-by-step construction development. Less than half (22; 39.3%) of the 56 respondents reported that their company has been able to see some significant efficiency gains for using 4D BIM. Less than half (21; 37.5%) of the 56 respondents stated that 4D BIM construction execution schedule is usually in place before the start of construction. Less than half (20; 35.7%) of the 56 respondents stated that 4D BIM construction execution schedule is customarily updated monthly. Only 7 (12.5%) out of the 56 respondents reported that 4D BIM construction execution schedule is customarily updated every week. Only 6 (10.7%) out of the 56 respondents reported that 4D BIM construction execution schedule is customarily updated daily. Only 10 (17.9%) out of the 56 respondents observed that there is increased use of the National BIM Standard-United States® (NBIMS-US™) (Nationalbimstandard.org, 2019) to gain interoperability to facilitate the use of 4D BIM. Less than half (20; 35.7%) of the 56 respondents clarified that their organization is exploring solutions to decrease human intervention and have a more real-time analysis of the project at the construction execution phase in order to improve 4D BIM applications. As a summary, the mean total number of yes responses in all 12 questions
regarding the utilization of 4D BIM planning was 4.77 ($SD = 3.55$). The total number of yes responses is used as the composite measure of the utilization of 4D BIM planning in the logistic regression.

**Use of 4D BIM on Construction Projects**

Table 6 summarizes the responses of the 56 respondents regarding 4D BIM use on construction projects. The majority of the 56 respondents either strongly agree or agree with the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>4D BIM allows option analysis</td>
<td>44</td>
<td>78.5%</td>
</tr>
<tr>
<td>Alternative proposals are provided to the client with 4D BIM</td>
<td>39</td>
<td>69.6%</td>
</tr>
<tr>
<td>Logistical challenges are successfully resolved on site with 4D BIM</td>
<td>45</td>
<td>80.4%</td>
</tr>
<tr>
<td>Vast amount of data and the speed of which it’s processed has been a barrier to applying 4D BIM at the construction execution phase</td>
<td>35</td>
<td>62.5%</td>
</tr>
</tbody>
</table>

More than half or half of the 56 respondents either strongly agree or agree with the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>4D BIM reduces project duration</td>
<td>28</td>
<td>50%</td>
</tr>
<tr>
<td>Reactive decision making in the field has reduced with 4D BIM</td>
<td>33</td>
<td>58.9%</td>
</tr>
<tr>
<td>The use of 4D BIM has decreased delays due to scheduling interferences and conflicts</td>
<td>28</td>
<td>50%</td>
</tr>
<tr>
<td>Increased use of 4D BIM planning / scheduling could decrease the intensity of monthly autonomous schedule updates that take time and manual work</td>
<td>29</td>
<td>51.8%</td>
</tr>
<tr>
<td>Shorter planning and tighter feedback/update cycles lead to increased and better project performance and that 4D BIM allows this</td>
<td>31</td>
<td>55.4%</td>
</tr>
<tr>
<td>4D BIM has increased project performance</td>
<td>32</td>
<td>57.1%</td>
</tr>
<tr>
<td>4D BIM has increased productivity in the field</td>
<td>27</td>
<td>48.2%</td>
</tr>
</tbody>
</table>
Table 8 summarizes the responses of the 56 respondents regarding the rank adaptability of field data capturing. For those respondents who reported their organization using any of the listed associated technologies, there were greater frequencies that rated the following technologies as having the best or good adaptability of the field data capture technology for accuracy and efficiency used in combination with 4D BIM to improve the ability to measure progress at the construction execution phase:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser scanning</td>
<td>34; 60.8%</td>
<td></td>
</tr>
<tr>
<td>Global Positioning System (GPS)</td>
<td>31; 55.4%</td>
<td></td>
</tr>
<tr>
<td>Light detection and radar scanning (LiDAR)</td>
<td>30; 53.6%</td>
<td></td>
</tr>
<tr>
<td>UAVs – Drones</td>
<td>28; 50%</td>
<td></td>
</tr>
<tr>
<td>Radio-Frequency Identification (RFID)</td>
<td>24; 42.9%</td>
<td></td>
</tr>
<tr>
<td>Point Clouds</td>
<td>23; 41%</td>
<td></td>
</tr>
<tr>
<td>Internet of Things (IoT)</td>
<td>20; 35.7%</td>
<td></td>
</tr>
<tr>
<td>Satellite Imagery</td>
<td>18; 32.1%</td>
<td></td>
</tr>
<tr>
<td>Photosphere-based solutions</td>
<td>17; 30.3%</td>
<td></td>
</tr>
<tr>
<td>Ultra-Wideband (UWB)</td>
<td>14; 25%</td>
<td></td>
</tr>
</tbody>
</table>

Table 8

**Uses and Application of 4D BIM**

Even though most of the participants in the study indicated that 4D BIM is utilized in their organizations, only a few were utilizing 4D BIM frequently. This is indicative of many construction companies having used this innovation at least once in their project development, but not on a regular basis. It appears that many construction leaders and managers have not fully integrated 4D BIM use in their organizational practices despite the availability and self-observed benefits of this innovation. Hence, it appears that 4D BIM use is a case to case basis depending on the decision of those who are involved in construction projects.

The findings show that the utilization of 4D BIM planning was applied primarily in the construction execution phase, allowing all project stakeholders to visualize all scheduled activities ahead of time when in progress. The use of 4D BIM also enabled superintendents, foremen, and craft labor to visualize the design and construction plan in advance of the actual construction, helped
them see what it is they are to build, in what order, and enabled them to trust the plan. All these uses are in alignment with the literature indicating its benefit in the construction industry (Jenkins et al., n.d.; Hardin and McCool, 2015). The contribution of this study is that it affirms what is previously known regarding why 4D BIM is utilized in construction companies.

In terms of 4D BIM use in construction projects, most of the respondents agreed that it could be used for options analysis, provision of alternative proposals to clients, and successful resolution of logistical challenges on site. All these benefits underscore the versatility of the benefits that can be gained from using 4D BIM. However, as suggested above, these projected benefits do not necessarily translate to the regular adoption of 4D BIM in many construction projects.

Regarding the use of field data capturing technology adaptability to 4D BIM by their organization on the construction site, some of the uses identified in the study included light detection and radar scanning and UAVs-Drones on the construction site in combination with 4D BIM. These are benefits that can significantly enhance the efficiency of the construction phase of project developments. These projected benefits, however, do not necessarily translate to the regular adoption of 4D BIM in many construction projects. This lack of proactive efforts to adopt 4D BIM is consistent with the observations and arguments of Teizer et al. (2017) that many organizations continue to be behind in terms of utilizing technological advancements that can significantly enhance performance and efficiency.

Challenges and Barriers

The challenges and barriers of using 4D BIM noted in this article included skilled resource availability, lack of experienced professionals with the necessary skills, the absence of demand, and the vast amount of data and speed necessary for processing at the construction execution phase. The barriers identified in previous studies indicated a lack of contractual requirements (Mao et al., 2017) and issues pertaining to “big data” not being applied in the construction industry (Shrestha and Schuetz, 2017). These barriers are indicative of the lack of individuals who have the actual skills to use 4D BIM, preventing construction companies from using this innovation. This article extends the findings from previous research studies by also identifying the absence of demand for 4D BIM as a barrier, probably influencing the lack of proactive efforts to increase the usage of this construction innovation.

All these past and current findings regarding the barriers in 4D BIM use in construction suggest a complex web of individual and institutional factors that may affect the consistent use of 4D BIM. However, there is still no explicit empirical support that these barriers predict 4D BIM use in the construction phase of project development. More specifically, these barriers have not been
empirically established as the reasons why there appears to be less frequent usage of 4D BIM in construction companies. There is a possibility that these identified barriers are not necessarily the only factors that determine why 4D BIM remains insufficiently adopted in construction companies.

Benefits and Opportunities

Based on the findings generated from the analysis, the opportunities that can be gained by using 4D BIM include construction execution, communication with owner/client, and pursuit/bid development. Based on these benefits, enhanced efficiency and the improved relationships with clients are likely to be the results of adopting 4D BIM.

Other possible benefits of using 4D BIM included reduction of project duration, reduced in the field reactive decision making, decreased delays due to scheduling conflicts and interferences, decreased intensity of monthly autonomous schedule updates, shorter planning, and tighter feedback/update cycles leading to increased and better project performance.

Recommendations for Practice

Based on the findings reported in this article, the most essential recommendation still involves widespread 4D BIM adoption in the United States construction industry given that many construction leaders are still not using this innovation at a frequent basis. As discussed earlier, remarkable performance and efficiency benefits are not being utilized because of the lack of consistent use of 4D BIM in construction companies. More efforts from the leaders of construction companies are needed to increase the usage of 4D BIM at a more frequent rate since according to the findings, it can provide efficiencies.

One of the more interesting findings was that lack of demand for the use of 4D BIM could be a barrier in the adoption of this innovation in construction companies. In other words, construction companies may not see the need/benefits of 4D BIM since it is not currently in demand by clients/owners. This suggests that clients may be not aware of the benefits of 4D BIM or that construction leaders are not trying to educate their clients. One suggestion for the improvement of practice is to have more proactive efforts on the part of the leaders to inform their client about the potential benefits of using 4D BIM. During the discussion of projects, construction project leaders could initiate a conversation about the benefits of utilizing 4D BIM.

Based on the results of the data analysis in this article, another possible recommendation is to focus the efforts of leaders and managers towards the enhanced adoption of 4D BIM in construction in areas such as construction execution, communication with owner/client, and pursuit/bid
development. The results of the article indicate that these three main areas provide opportunities that can be beneficial in the adoption of 4D BIM. Hence, leaders may use these three specific areas to encourage project leaders to enhance their use of this innovation.

1. References


