

Challenges in the Building Information Modeling (BIM)/3D Trade Coordination Process

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Building information modeling (BIM) has been considered one of the most important recent developments in the architecture, engineering, and construction (AEC) industry, providing an innovative approach to managing the essential building design and project data in a digital format. If properly implemented, BIM can lead to a more integrated design and construction process, resulting in better quality buildings with lower project costs and shorter durations. This paper investigates the BIM/3D trade coordination process for challenges and problems through a case study approach and offers insights for continual improvement. The paper first reviews the background of three case study projects from a regional general contractor/construction management (GC/CM) firm. Document reviews and field observations from these three projects are presented and analyzed to assess the BIM/3D trade coordination process. The research found multiple challenges and issues (e.g., the lack of accountability of participants) faced during the coordination process, and made recommendations for continual improvement. The information presented in this paper will help contractors to further improve their BIM/3D trade coordination and BIM implementation, which benefits the entire AEC industry.

Key Words: Building Information Modeling (BIM), Trade, Coordination, Construction Industry

Introduction

Today's projects tend to be larger and more technically complex. Tighter schedule, new project delivery standards, regulatory restrictions, and reciprocal interdependencies between different stakeholders make the building projects even more complex and difficult to manage (Nuntasunti et al., 2006; Clough et al., 2008; Ghanem and Wilson, 2011). All these challenges require the architecture, engineering, and construction (AEC) industry to communicate and coordinate more frequently and collaborate more closely. Building information modeling (BIM), as a very promising recent development in the AEC industry, offers the greatest potential to facilitate communication, coordination and collaboration among project participants (Azhar, 2011).

BIM is a digital representation of comprehensive project information (including both graphic and non-graphic) throughout the entire building life cycle (Cerovsek, 2011). It provides a platform for multiple stakeholders (owners, designers, engineers, contractors, etc.) to communicate the related information in the 3-Dimensional (3D) virtual environment. BIM has been defined as "a set of interacting policies, processes, and technologies" that provides an approach to managing the essential building design and project data in a digital format (Succar, 2009). A building information model can be used for visualization, fabrication, code review, estimation, construction sequencing, clash detection, etc. (Azhar, 2011). If implemented properly, BIM could lead to a more integrated design and construction process, which would result in better quality buildings with lower project costs and shorter durations (Eastman et al., 2011).

Despite all the aforementioned benefits, the adoption of BIM still faces many key issues and challenges, which can be generally grouped into three categories (Gu and London, 2010; Azhar, 2011): 1) issues related to work practice and process, including data organization, version management, validation and data integrity, etc., 2) technical issues, including standards, registry of communication and information exchange, and security, and 3) roles, responsibilities, and training support. Therefore, more research will be needed to assess how BIM is implemented in practice, identify problems, and seek potential solutions or improvements. This paper first reviews previous studies that investigated BIM implementation, with a focus on evaluating the associated benefits, risks, and challenges. Then, field observations from three case study projects are presented and analyzed to assess the BIM/3D trade coordination process during project execution. The ultimate goal is to provide an in-depth assessment of the BIM/3D trade coordination process and to offer insights for continual improvement.

Background

Overview and Benefits of BIM

BIM is an emerging technological and procedural shift within the AEC industry (Succar, 2009). It helps project decision-making by sharing knowledge resource among the owner, Architects/Engineers (A/E), contractors, and other project stakeholders over the building project's life cycle (Goedert and Meadati, 2008; Cerovsek, 2011). BIM's main functions include, but are not limited to (Howell and Batcheler, 2005; Grilo and Jardim-Goncalves, 2010; Azhar, 2011; Bahar et al., 2013; Zhang et al., 2013):

- Generating 3D building renderings and shop drawings for various building systems;
- Helping fire departments and other officials review the building projects for code compliance;
- Detecting the conflicts, interference, and collisions among the trades work during the coordination;
- Enabling construction sequence and scheduling through BIM-based animation;
- Facilitating quantity take-offs and cost estimates;
- Visualizing safety measures to be implemented and helping identify potential safety hazards/risks;
- Providing data for wind, lighting, and/or energy simulation.

Representing a building by accurate geographical information in an integrated data environment is the key benefit of BIM (CRC Construction Innovation, 2007). Other benefits include, but are not limited to 1) building/project information can be easily shared and reused; 2) visualization improves the understanding and coordination of the project; 3) whole-life costs and environmental effects can be evaluated and monitored; and 4) data output is flexible and enables automation (Azhar, 2011). Bryde et al. (2013) reviewed 35 cases with BIM applications over a 2-year period (2008-2010) based on a list of success criteria. They found that the effects of BIM on cost, time, communication, coordination, quality, risk and scope were all positive, showing that BIM should be considered an appropriate tool by project management profession to help manage construction projects. Based on the SmartMarket Report by McGraw-Hill Construction (2012), in 2012, industry-wide adoption of BIM is 71% in North America, and approximately 62% of all BIM users perceived that BIM had positive effects on return on investment.

Challenges and Risks in BIM Implementation

Azhar (2011) mainly discussed three risks in BIM implementation: 1) how to determine the ownership of the BIM data, 2) license issues related to designs, and 3) who will be responsible for updating BIM data and inaccuracies in the model(s). Bryde et al. (2013) revealed some negative effects of BIM on cost, time, scope management, communication, etc. and the potential causes. For example, extra time may be needed for the conversion between traditional CAD standards and a BIM platform. Also, the project team sometimes does not know how to better organize the team to take full advantage of BIM. Gu and London (2010) divided the BIM-related issues into three main categories as work practice and process related issues, technical issues, and other issues as mentioned above. Eastman et al. (2011) and Eisenmann and Park (2012) both mentioned that the team experience level was very important in maximizing benefits from BIM. Based on the results of two questionnaire surveys performed by Goucher and Thurairajah (2012), 75% of people having BIM experience did not agree with the statement that BIM training is an affordable option for all companies. The use of BIM was not required by some nongovernment clients. Therefore, some companies have been slow in spending money and time on BIM.

Methodology

The research has the following objectives: 1) to review the project documents and assess whether the coordination process and procedures are well defined, 2) to observe and assess the BIM/3D coordination process including an evaluation of the adequacy and interoperability of BIM software packages and technologies the project teams use, and 3) to observe and assess other project management activities that are related to BIM/3D coordination. This research adopts a case study approach. All the information was obtained by field observations on BIM/3D coordination meetings and weekly contractor coordination meetings, personal communication with project personnel from the surveyed general contractor/construction management (GC/CM) firm and subcontractors working for the firm's projects, and review of documents and website information of the GC/CM firm during the summer of 2016.

Case Study

The GC/CM firm involved in this case study is a Cincinnati-based contractor operating in four states with nine regional offices. Its 2015 annual revenue reached US$1.1 billion. The contractor specializes in managing, developing and performing complex commercial construction projects. The three projects selected for this case study are the three largest projects in this company's Columbus (Ohio) region. In the following, the basic background of these projects is introduced.

Hospital Campus Expansion and Modernization Project ($186 Million / to be completed in 2019)

This project is being delivered under the Construction Management at Risk model. As the Construction Manager, this GC/CM firm has been involved early in the design process for constructability review. Most of the specialty trades working on the BIM/3D coordination team were hired as design-assist contractors. The uniqueness of this project lies in the use of prefabricated utility rack system and bathroom pods. All the mechanical, electrical, and plumbing (MEP), fire protection, medical gas, technology, etc. have to be fitted into the very limited space above the ceiling, which requires intensive 3D coordination.

Office and Parking Garage Project ($73 Million / to be completed in 2018)

This is a lump sum project using the traditional Design-Bid-Build delivery method with this GC/CM firm working as the General Contractor. Due to this arrangement, the firm had no involvement during the design stage and also had no impact on front end documents. The special features of this project include an air-supplied raised access floor system, a green roof, and a full rooftop mechanical penthouse. Before trade coordination begins, the Virtual Construction (VC) Manager of this GC/CM firm performed the pre-BIM coordination review on the architecture, structure and MEP 3D design-intent models for potential constructability issues. Then, these problems were reviewed by A/E and necessary adjustments were made. Despite this extra effort, this project is still facing great challenges during the BIM/3D trade coordination process due to the lack of commitment from participants.

Condominiums and Parking Garage Project ($40 Million / to be completed in 2017)

This is a Construction Management at Risk project with Design-Assist Contracting. This GC/CM firm works as the Construction Manager and has been involved early in the design process. This project features an outdoor swimming pool located on the roof, in which the coordination team has very little previous experience, as well as some customized condo units that add uncertainties into the BIM/3D trade coordination.

Results and Discussions

Observation of BIM/3D Trade Coordination

With the growing popularity of BIM, BIM/3D trade coordination becomes more common in today's industry practice, especially for the delivery of complex projects. Usually, the mechanical trade leads the BIM/3D trade coordination while the General Contractor or Construction Manager administers the MEP Spatial Coordination Team by creating the mutually agreed upon construction and BIM coordination schedules and ensuring the participation and performance of subcontractors in the coordination (BIMForum, 2009). However, this GC/CM firm handles this differently. For its projects, one of its VC team members or project engineers (instead of the mechanical engineer) leads the BIM/3D trade coordination process no matter which project delivery method is used. The purpose is to ensure the quality of coordination for the best interest of the project and all project participants as a whole.

To facilitate the BIM/3D trade coordination, this GC/CM firm developed detailed descriptions of the coordination process, standard procedures, and tools/forms to be used. A project specification portion directly related to the BIM/3D coordination was included in the project specification documents. The specification emphasizes the importance for mechanical trade contractors and Coordination Lead in the GC/CM firm to communicate more often outside the weekly meeting. It also recommended keeping in touch with subcontractors throughout the week and checking their progress. Fig. 1 shows the BIM/3D coordination meetings held in job site trailers of the GC/CM firm. Participants included the Coordination Lead and project team member(s) in this GC/CM firm, MEP contractors, fire protection, and some other trades dependent on the type of project (e.g., pneumatic tube, trash & linen, etc.). Based on the project complexity and construction schedule, the BIM/3D coordination team met either once or twice a week, and each meeting took about 3-4 hours. These meetings were held either face-to-face or through GotoMeeting.

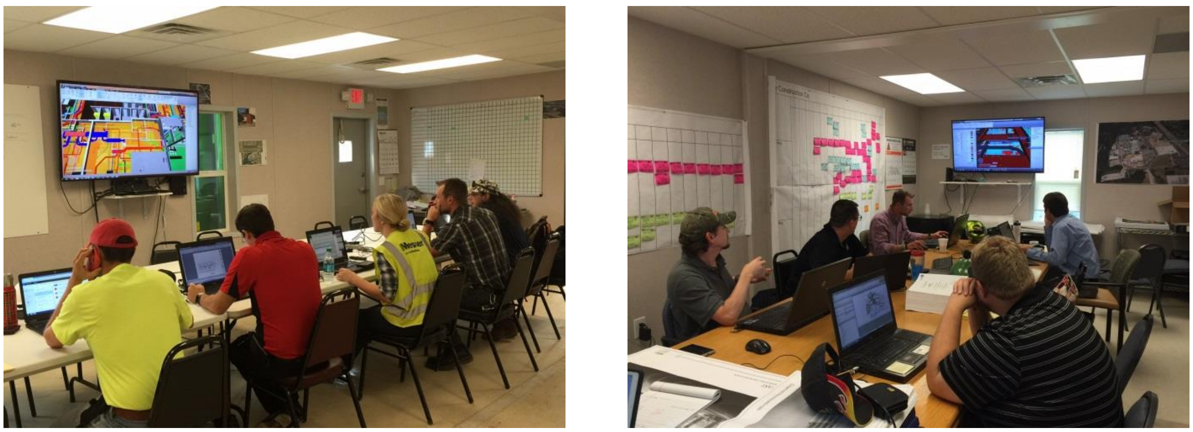

Figure 1: BIM/3D coordination meetings in job site trailers

The current BIM/3D coordination schedule was determined based on the project schedule using the Reversed Phase Scheduling (RPS) method. For the Hospital Campus Expansion and Modernization project, around one-month time was planned for completing the coordination for each building level. Then 65 days was left for submission of drawings for A/E review and approval, fabrication, and delivery. Once all the parties agreed that the identified conflicts in a level were resolved during the coordination process, they were required to sign the sign-off sheets in person as well as sign-off on each other's drawings.

Challenges Observed During the BIM/3D Coordination

It was found that the detailed descriptions about the BIM/3D coordination process and standard procedures, tools/forms to be used, as well as the BIM related specification are all available on the internal website of the GC/CM firm. It seems that all the information has been regularly updated for accuracy and completeness. In general, the BIM coordination meetings were performed in a way that is in line with the project specification. The level of development for the submitted and coordinated models is appropriate and also complies with the specification requirements. However, issues and challenges were still observed during the BIM/3D coordination process, which are listed below:

- *Participants coming in without adequate preparation or unprepared*: For example, the promised revisions/updates were not done yet, leaving previous comments unaddressed; updated models/drawings were not uploaded ahead of time (ideally to be 24 hours before coordination occurs); subcontractors failed to check and resolve some basic clashes, e.g., those between their system components and architectural and structural models or some cross-trade clashes that can be easily resolved.
- *Trade contractors not involved*: It was not uncommon to see when discussions were centered on one trade

contractor's work other participants in the coordination process were just waiting. The discussion could be lengthy in some cases. There is a great need to shorten the duration of each coordination meeting and improve its efficiency and effectiveness. This saves time for all the participants.

- *Information sharing and model posting*: Models/drawings were not posted on time. Or it was unclear what had been posted by a contractor, how this version was different from the last version, and what information a particular trade would need from others, so other participants in the coordination process could not prepare themselves in advance.
- *Delays due to unanswered requests for information (RFIs):* For example, those related to design intentions including ceiling height, space availability, etc. Although it is extremely helpful for the design team to be part of the coordination so some problems can be resolved right away, this may not be feasible in the current project delivery environment. Managing the RFI workflows efficiently is still a more viable solution under most circumstances.
- *Non-decision maker participants:* The person attending the coordination meeting was not able to make decisions and had to go back to find solutions to identified problems. This may happen when the main responsible person is not available and someone is sent on that person's behalf. Or a trade contractor was absent from a coordination meeting due to vacation or other reasons.
- *Participant(s) not engaged:* This happened more often when the second-tier subcontractors were involved in the coordination process. Due to the increasing trend for outsourcing in the construction industry, this situation becomes more common. It could be worse when outsourcing involves foreign companies, which result in problems including time difference, language/cultural barrier, different design practice and code requirements, etc.
- *Which format to choose—GoToMeeting vs. face-to-face*: At the current stage, these two meeting formats co-existed for most of the time; i.e., some subcontractors came to the field trailer for coordination while some others joined through GoToMeeting due to their remote locations or other causes. Physical presence was usually required when sign-offs were expected. At present, both of these formats had pros and cons as summarized in Table 1. The Coordination Lead will need to evaluate the real-world situation (e.g., physical constraints, coordination progress and performance, etc.) to determine what format to use.

Table 1

The Pros and Cons of Two Meeting Formats (Face-to-Face and GoToMeeting)

	Pros	Cons
Fact-to-face	Easier face-to-face discussion; Clear and effective communication; More dedicated and accountable participants; Can sign-off models; A team working environment	Taking more time (commuting plus meeting time); For trades who have to wait for others to discuss their problems, they are not able to utilize their time efficiently; Potential accessibility problem to drawings or models on their servers (internet connection and hardware constraints); Lack of other resources
GoToMeeting	Good for shorter meetings; Productive when they can access more resources in their home office	Does not work for sign-off; Unsure whether they actually make changes to their models; Unsure whether they are dedicated to the coordination process on the other end of the phone; Creating distance in a team environment

- *Promises not kept after the coordination*: There were times subcontractors did not make the promised revision on their models following the coordination meeting. It was also not rare that subcontractors did not provide the promised sleeve drawings and Submittals on time. This could negatively impact field operations of the GC/CM firm (e.g., setting up sleeves and pouring decks), other subcontractors' work (applying fireproofing on structural steel), as well as subcontractors' own fabrication and installation.

- *Incomplete/poor quality architectural/structural models or missing items from special trade(s):* This was case by case, e.g., the reflected ceiling plan (RCP) and roof pool in the Condominiums and Parking Garage project, fountain piping drawing from a landscape design consultant for the Office and Parking Garage project, miscellaneous steel supports in the Hospital Campus Expansion and Modernization project, etc. Currently, the Coordination Lead in the GC/CM firm and a modeler had to spend extra time during or outside the coordination meeting to correct issues or add some of these items into the model.
- *Design errors or changes*: There were design errors identified late in the process, so the virtual coordination had to be performed again to resolve new clashes. Sometimes, the coordination got harder since some trade work had already been put into place or space availability was very limited. A trade contractor could also initiate the change due to various reasons (e.g., cost savings to that contractor). As a result, re-coordination is required.
- *Inherent challenges from the project delivery method used*: It was perceived by the VC Manager in the GC/CM firm that the BIM/3D trade coordination faced greater challenges when the project used the traditional Design-Bid-Build delivery method. It was harder to build a high efficient, cooperative, and committed team for the coordination process. Working with the design team could also be challenging.

Although the BIM/3D coordination process led to high-quality construction documents, which were observed for all three projects, the process itself did not achieve satisfactory efficiency with noticeable wastes—very lengthy coordination meetings and the substantial amount of time spent to resolve conflicts for each building level. Among all the challenges presented above, how to hold trade contractors involved in the coordination process accountable is the most critical issue.

Insights for Continual Improvement

From the perspective of lean, any process improvement has to be coupled with flow improvement to increase the overall efficiency. In this study, the coordination meeting can be viewed as the main process, and other related activities (model revisions, obtaining needed information, etc.) can be viewed as supporting information or work flows. Some recommendations towards how to hold participants on the BIM/3D coordination team more accountable for their coordination responsibilities are shown below:

- Send participants' meeting minutes or a wrap-up summary to specify 1) what they promised to do or need to accomplish with the expected timeframe, and 2) what will be performed in the next coordination meeting and to what degree they need to be prepared. This works as a checklist for trade contractors. Putting it in writing also helps ensure proper attentions to be paid and actions to be taken by the involved parties.
- When facing longer intervals between two coordination meetings, (e.g., three or more days), the Coordination Lead needs to keep in touch with them; e.g., automatic reminders are sent to the involved parties to keep them engaged in their tasks or re-engage them if they are working on other projects.
- Measure or rate the coordination progress/performance, so the team (or individual parties) can receive feedback for correction or improvement while still maintaining good team relationships and a collaborative working environment. From the lean point of view, participants of the coordination team have promised to make things ready for the next meeting and other trades' work. How many times are they able to keep their promises? For how long are items still overdue? The measurement needs to be simple, direct, but effective to keep things tracked.
- There are information or work flows associated with the BIM coordination, e.g., model revision following the coordination, processing RFIs to obtain information needed by coordination, Submittals after the sign-offs, etc. BIM/3D coordination and related field activities cannot be successfully and efficiently performed without getting these tasks accomplished in a timely fashion. A discussion with the VC Manager in the GC/CM firm revealed that something like the BIM Coordination Dashboard that keeps action items and their status tracked would be useful.

This paper provides some opinions for making the decision towards a VC team member or someone from the project team to lead the BIM coordination process: These two options may need to coexist based on the situations of individual projects as well as the capacity of the VC team and the project team. There are multiple factors to consider before making the decision. In general, the VC team members are more familiar with the BIM/3D coordination process and more skillful and sophisticated due to their cumulated experience by performing this task repeatedly. The advantages of a project team member leading the process lie in the team member's deeper understanding of and daily involvement with the project and subcontractors. This person is more familiar with the project detail, what is going on in the field, and what is needed by the project on a daily basis. Ideally, the coordination follow-up activities can be incorporated into the team member's daily duties (such as preparing RFIs, processing Submittals, etc.).

Looking inside the project team, a project engineer is currently at a better position for playing this role. The project manager is so busy and has multiple things going on. Leading the information intensive BIM coordination and tracking things that need to be followed up may affect the manager's ability to manage and control the project well. However, it would be beneficial for the project manager and superintendent to understand the process and sit in some coordination meetings if time allows. This enhances their understanding of project complexity and coordination progress as well as their ability to follow up some unresolved BIM coordination problems through their interactions with subcontractors and during the weekly project coordination meetings. If they cannot attend each coordination meeting, the Coordination Lead will need to inform them when their presence is critical and necessary.

Project engineers are suitable to lead the BIM coordination process when the following conditions are met: 1) Not overwhelmed by their daily responsibilities; 2) having necessary project experience and a proper level of understanding of the trades they will be coordinating. This ensures their confidence level to lead the process and abilities to offer useful suggestions/advice for solving conflicts and maintaining the fairness among different trades during the coordination process; 3) having proper training including the use of hardware and software and understanding of the coordination procedures; and 4) having proper personality that encourages positive communication and helps create a team environment as well as the power to enforce rules and make sure commitments being made and fulfilled.

Conclusions and Future Research

This paper presented a case study of the BIM/3D trade coordination process by reviewing and assessing the related documentation, observing the coordination process, and having personal communication with the involved project personnel. All this information came from three largest projects of a GC/CM firm's Columbus, Ohio region. This research found that in general the BIM/3D coordination led by the GC/CM firm was appropriate and complied with the requirements in the BIM/3D coordination portion of the project specification. However, there was a noted gap between the real-world practice and expectations from the GC/CM firm. In particular, 11 issues/challenges were observed during the BIM/3D coordination meetings. Although the quality of the final coordination results was admirable, the BIM/3D coordination process itself did not achieve satisfactory efficiency. How to hold trade contractors involved in the coordination accountable was still a critical issue, for which some recommendations for continual improvement were made in this paper. This paper also provided opinions for who should lead the BIM coordination process and how other project management team member(s) can be involved. Future research will be focused on identifying detailed requirements for the development of the proposed BIM Coordination Dashboard and the performance evaluation/rating system for the BIM/3D coordination process and participating trade contractors.

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References

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering, 11*(3), 241-252.

Bahar, Y. N., Pere, C., Landrieu, J., & Nicolle, C. (2013). A thermal simulation tool for building and its interoperability through the Building Information Modeling (BIM) platform. *Buildings, 3*(2), 380-398.

BIMForum. (2009). MEP spatial coordination requirements for building information modeling. AGC BIMForum Specialty Contractors Subforum. Washington, D.C.

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modeling (BIM). *International Journal of Project Management, 31*(7), 971-980.

Cerovsek, T. (2011). A review and outlook for a 'Building Information Model' (BIM): A multi-standpoint framework for technological development. *Advanced Engineering Informatics, 25*(2), 224-244.

Clough, R. H., Sears, G. A., & Sears, S. K. (2008). *Construction project management: A practical guide to field construction management*. John Wiley & Sons, Hoboken, NJ.

CRC Construction Innovation. (2007). Adopting BIM for facilities management: Solutions for managing the Sydney Opera House. Cooperative Research Center for Construction Innovation, Brisbane, Australia.

Eastman, C., Teicholz, P., Sacks, R. & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors.* John Wiley & Sons, Hoboken, NJ.

Eisenmann, S. & Park, B. (2012) Building information modeling's impact on team performance. *In: Proceedings of the 48th ASC Annual International Conference*, April 11-14, 2012, Birmingham, UK.

Ghanem, A. A., & Wilson, N. (2011). Building information modeling applied on a major CSU capital project: A success story. *In: Proceedings of 47th ASC Annual International Conference,* April 6-9, 2011, Omaha, NE.

Goedert, J. D., & Meadati, P. (2008). Integrating construction process documentation into building information modeling. *Journal of Construction Engineering and Management, 134*(7), 509-516.

Goucher, D., & Thurairajah, N. (2012). Advantages and challenges of using BIM: A cost consultant's perspective. *In: Proceedings of the 49th ASC Annual International Conference,* California Polytechnic State University, San Luis Obispo, CA.

Grilo, A., & Jardim-Goncalves, R. (2010). Value proposition on interoperability of BIM and collaborative working environments. *Automation in Construction*, *19*(5), 522–530.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction, 19*(8), 988-999.

Howell, I., & Batcheler, B. (2005). Building information modeling two years later—huge potential, some success and several limitations. *The Laiserin Letter, 22,* 4.

McGraw-Hill Construction. (2012). *The business value of BIM in North America: Multi-year trend analysis and user ratings (2007-2012).* McGraw-Hill Construction, New York.

Nuntasunti, S., & Bernold, L. E. (2006). Experimental assessment of wireless construction technologies. *Journal of Construction Engineering and Management, 132*(9), 1009-1018.

Succar, B. (2009). Building information modeling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction, 18*(3), 357–375.

Zhang, S., Teizer, J., Lee, J. K., Eastman, C. M., & Venugopal, M. (2013). Building information modeling (BIM) and safety: Automatic safety checking of construction models and schedules. *Automation in Construction, 29*, 183-195.