

Factors Hindering the Incorporation of Virtual Design and Construction Services into Construction Management Firms in the Southeastern United States

Tiffany T. Blackmon, MSc, Jeffrey S. Kim, MSc and J. Mark Taylor, PhD, JD
Auburn University
Auburn, AL

Due to the complex and fast growing nature of the technologies associated with virtual design and construction (VDC), many companies and owners have begun to discuss and establish recommended best practices. However, there is a disparity between the perceived usefulness and value when implementing VDC services. The tools are there but very few companies fully understand or fully embrace what VDC services are capable of, both for their company and for the industry as a whole. Consequently, there is a need to discover and analyze the hindrances to the implementation of VDC services. With an online survey, this study seeks to identify the hindrances that are troubling the adoption of VDC services within construction management companies in the Southeastern United States. Results from the survey indicate that a large number of the companies have VDC departments and several were able to share common issues that hampered their efforts with using and paying for VDC services. For those companies that did not have VDC services to offer, poignant opinions were recorded that seemed to affirm why technology adoption struggles in the construction industry.

Key Words: VDC, BIM, Implementation, Construction Coordination, Collaboration

Introduction

The construction industry is largely a project based process industry requiring complex communications, data sharing and collaboration (Holt, Benham, and Bigelow, 2015). In addition, technology has begun to modernize the construction process and incrementally increase efficiency, even though the maximum benefits have yet to be realized Holt et al., (2015). With the introduction of new and innovative technologies there is a shift toward better communication, data sharing and collaboration within the architecture, engineering and construction (AEC) industry (Gustafsson, Gluch, Gunnemark, Heinke & Engström, 2015). One such technology, commonly designated as building information modeling (BIM) is seeing more prolific use (Azhar, 2011). As collaboration between multi-disciplinary functions increases, we are seeing the development of a new management paradigm, known as virtual design and construction (VDC) that combines BIM along with other technologies (e.g. mixed reality, drones, laser scanning and robotics) to enhance communication, coordination and data transfer. Although VDC is having an impact in the construction industry (Gustafsson et al., 2015) (Succar, 2009), research has focused more on BIM and other innovative technologies individually rather than looking at VDC as an all-encompassing service. Because of the complex interconnectedness of the technologies that make up VDC services, deliberation is ongoing to create best practices when using and implementing these services (Succar, 2009) (Howard & Björk, 2008). Therefore, there is a need to implement strategies and protocols (Jung & Joo, 2011) that promote the benefits of VDC services (Howard & Björk, 2008) (Succar, 2009). As the implementation of VDC gains traction (Smith, 2014), standards are needed in order to increase the effectiveness of implementations (Hartman, Meerveld, Vossebeld & Adriaanse, 2012).

Smith (2014) concluded that VDC services have the greatest chance of success if the project owner supports them, yet according to Gustafsson et al., (2015) and Howard & Björk (2008) owners lack knowledge about VDC services and are finicky about supporting these less than traditional value-added services. Moreover, Abuelmaatti & Ahmed (2014) posited that companies, which are formulating their VDC services fail to achieve the maximum benefits of implementation suggesting that hindrances exist that complicate the use of VDC services. VDC services have the potential to modernize the 21st century approach to managing a construction project through increased communications, data sharing and collaboration (JBKnowledge Construction Technology Report, 2016). Because

there are challenges to accepting this new approach, it is important to understand and identify the hindrances to its acceptance. Evaluating the hindrances for the entire AEC industry would be too overreaching since the myriad of differences between participants creates a multitude of possibilities to analyze; therefore, this research limited its focus to the construction management discipline of the Southeastern United States. Therefore, the aim for this research is to determine what factors hinder the implementation of VDC services for construction management firms within the Southeastern United States.

Literature Review

Defining VDC Services

John Kunz and Martin Fischer first coined the term Virtual Design and Construction in early 2001 as part of the mission statement for an organization called the Center for Integrated Facility Engineering (CIFE) at Stanford University. Since then the construction industry has adopted it as a way of describing, "*the use of integrated, multidisciplinary performance models of design-construction projects to support explicit and public business objectives*" (Kunz & Fisher, 2012). Moreover, VDC services are technologies used by a company that integrates the data that AEC professionals of different disciplines need for collaboration while completing a project (Kunz & Fischer, 2012).

VDC Services and Productivity

Construction professionals understand that AEC industry processes are fragmented and inefficient (Kunz & Fisher, 2012) (Mandujano, Mourgues, Alarcón & Kunz, 2017). In fact, the construction industry has been experiencing a loss of productivity when compared to other industries in the United States (Sveikauskas, Rowe, Mildenberger, Price & Young, 2014). The use of better technology could be a solution to the productivity problem. Many researchers have concluded that there is an increased acceptance of newer technologies in the construction industry yet implementation of these technologies is painstakingly slow (Arayici, Coates, Koskela, Kagioglou, Usher & O'Reilly, 2011) (Forsythe, 2014) (Howard & Björk, 2008). Despite the apparent haphazard assimilation of some technologies in the construction industry there has been an increased growth in the use of visualization technologies, such as BIM. The perceived benefits of BIM have been so convincing that owners now expect or require the use of BIM in the construction process. However, other VDC service technologies such as mixed reality, drones and robotics, are in need of best practices and some standardization if they are to succeed similarly to BIM. VDC services are slowly becoming rooted within the traditional practices of design and construction but without a singularly coordinated effort toward standardization (Kunz & Fisher, 2012).

Need for a Support Framework in VDC Implementation

The AEC industry constantly strives to implement techniques that improve all aspects of a construction project including cost, schedule, productivity and efficiency (Azhar, 2011) (Migilinskas, Popov, Juocevicius & Ustinovichius, 2013). According to research by Jung & Joo (2010) the use of BIM and other innovative technologies impacts a building project beyond its construction phase, yet there has been little effort to define concepts or a framework for implementation and support. Increased development of new technologies requires new definitions, strategies and frameworks in order to be implemented properly. As technologies are rapidly changing, there is also a need to form protocols and collaboration techniques in order to best use VDC services (Gustafsson et al., 2015) (Smith, 2014). Certain technologies that make up VDC services have claimed to improve quality, safety, management, efficiency, time and cost for construction projects (Gustafsson et al., 2015). According to current research, creating guidelines and protocols is becoming an important function for VDC professionals (Andersson, Farrell, Moshkovich & Cranbourne, 2016). However, VDC services are being implemented according to anecdotal practices with no clear guidelines or best practices to follow (Mandujano et al., 2017). This lack of direction leads to uncertainty and an informal VDC implementation plan that is difficult for companies to follow (Mandujano et al., 2017). Further investigation is needed to gain a better understanding of VDC services, as well as its terms and uses (Succar, 2009). Owners are faced with deciding whether to utilize VDC services based merely on perceived benefits, leading to what some would consider the largest barrier to implementation, acceptance and enforcement across the industry (Barlish & Sullivan, 2012). Currently, much of VDC research leads to intangible results, and it has been

difficult to justify the need for VDC implementation. Therefore, this research seeks to find the current barriers of VDC implementation in companies who have, or are thinking about implementing, VDC services.

Research Method

The design for this research included an electronic survey that was distributed to construction industry professionals. Both closed and open-ended questions were used to provide clarity to the research question regarding the exploration of hindrances to VDC services implementation in the construction industry. The survey was web-based and cross-sectional to provide a representation of the construction industry in the Southeastern United States. 60 responses were collected. A filtering of responses to keep the data consistent was performed which resulted in 57 survey responses considered for this study. Furthermore, the survey instrument included demography questions and questions specific to issues that influence the implementation of VDC services. Open-ended questions at the end of the survey allowed the respondents to provide more contextual feedback about their experiences, successes and failures with VDC in their organization.

Results

In order to test the sampling, a general population was derived from the 2012 Economic Census of the United States at the following website (https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid= ECN_2012_US_23A1& prodType=table). Filtering by state and the *2012 North American Industry Classification System* (NAICS) code for company specialization classification resulted in 5,562 companies. The NAICS code selection was limited to code *236220* "*Commercial and Institutional Building Construction*". Computing the required sampling size with a Confidence Level percentage of 90% and a Margin of Error of 10% resulted in a required sampling size of 67 required participants. While the sampling for this research is not statistically significant (57 responses received and 67 responses required), the data gathered is important to share as it documents the many successes and failures that companies have experienced in their attempt to implement VDC services. Furthermore, this data could be used to structure future VDC implementations in a manner that addresses the more prevailing hindrances that others have faced.

Demography

Among the population of 57 respondents, over 90% were employed by organizations that had revenues over $100 million annually and had more than 40 full time employees. 31% of participants identified themselves as VDC managers, 18% as project managers, 16% as human resources or development, 14% as project engineers and the remaining 21% as company executives or other leading role in their organization. Lastly, almost 90% of the respondents indicated that their company has a department that is dedicated to VDC related services.

Hindrance Groups

This research is concerned with the hindrances that organizations face while implementing VDC services, therefore, the remaining questions of the survey address this element specifically. In the opening section of this part of the survey, participants were asked if they could identify any group that reacted more adversely than others to the use of VDC services. Predominantly, trades workers (27%) were most resistant to the notion of using VDC services, followed by the owner (18%). When asked if they perceived difficulty while implementing VDC services, a combined 32% agreed (agreed to strongly agreed) that is was difficult while a combined 38% perceived no difficulty (disagreed to strongly disagreed). 30% neither agreed nor disagreed that the effort was difficult.

VDC Services

An open-ended question regarding the functions most employed by a VDC department resulted in the following top ten usages: (1) preconstruction and planning, (2) coordination, (3) clash detection, (4) laser scanning, (5) 4D models, (6) quality control, (7) mixed reality, (8) drones, (9) safety and (10) facility management. All other open-ended responses amounted to less than 1% of the total responses. A follow up question was asked concerning software preferences of the VDC department. Figure 1 indicates the most used software solutions within VDC departments.

Chronicle of Hindrances

Participants were asked to provide their opinion to hindrances that the industry faces when implementing a VDC department and using VDC services. The question was non-structured and open-ended and the results were analyzed using a descriptive coding that identified major themes within the responses. Figure 2 illustrates the most common responses received.

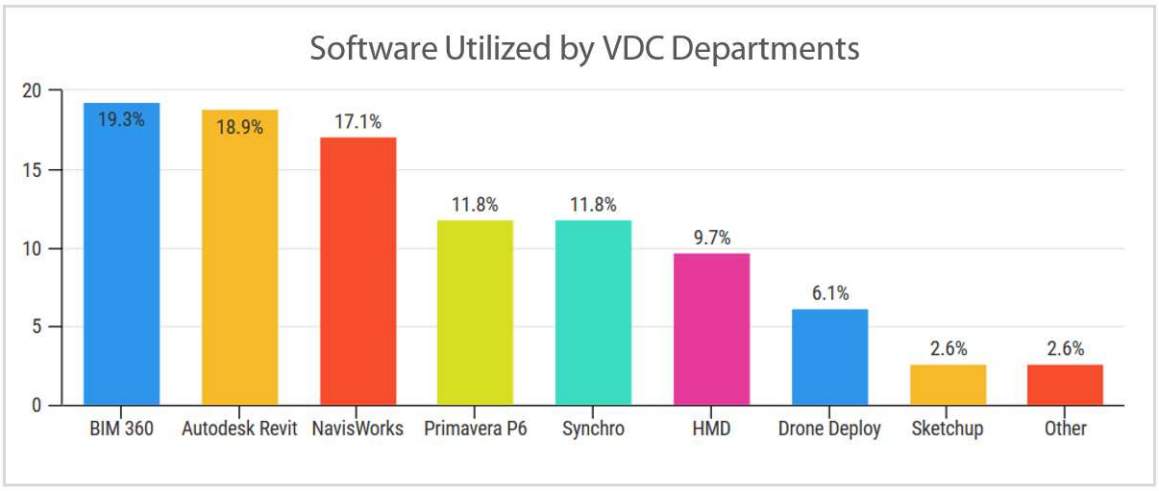

Figure 1

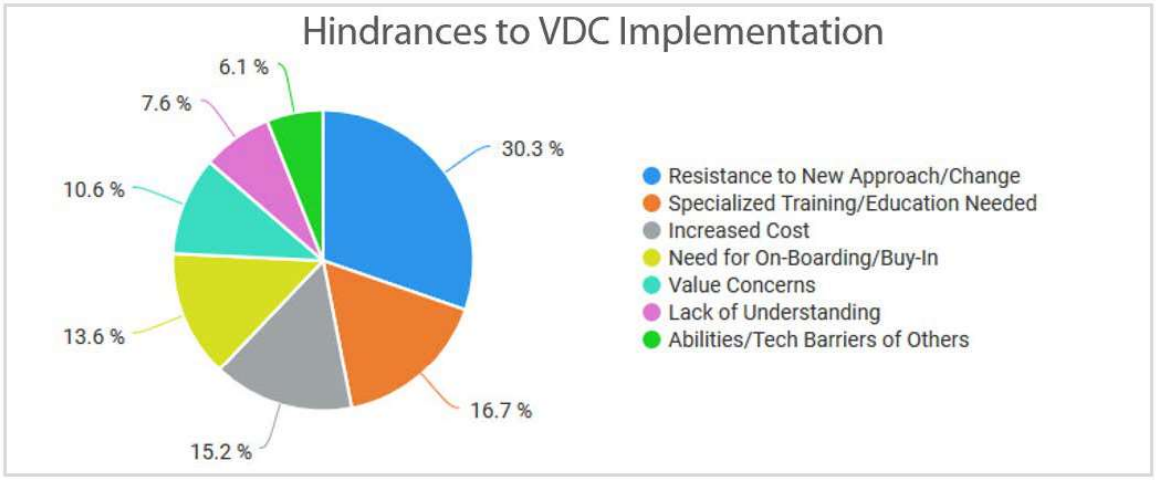

Figure 2

VDC Services and Cost

Funding and monetary support may affect the desire for organizations to start or to continue providing VDC services. Therefore, in order to understand how company finance influences implementation, participants were asked about their billing practices for VDC services. Table 1 summarizes the current billing practices of those organizations using VDC service.

Those without VDC Departments

Companies that responded that they did not have a VDC department or employed VDC services were asked if they used any of the aforementioned VDC technologies and 100% responded that they did not. As a follow up, these

participants were asked if VDC services were a necessary and an important part to advancement of the construction industry. 20% strongly agreed that VDC services are important and 40% agreed; while 40% neither agreed nor disagreed as to the importance of VDC services. Lastly, participants were asked to forecast where they perceived VDC services could be implemented in their organizations in the future (Figure 3).

Table 1. Current Billing Practices of Companies with VDC Departments (n=44)

Options for Billing	**Percentage of Participants**
Billed to Owner Per Job	61.3% (27)
Included in Overhead	36.4% (16)
None	2.3% (1)

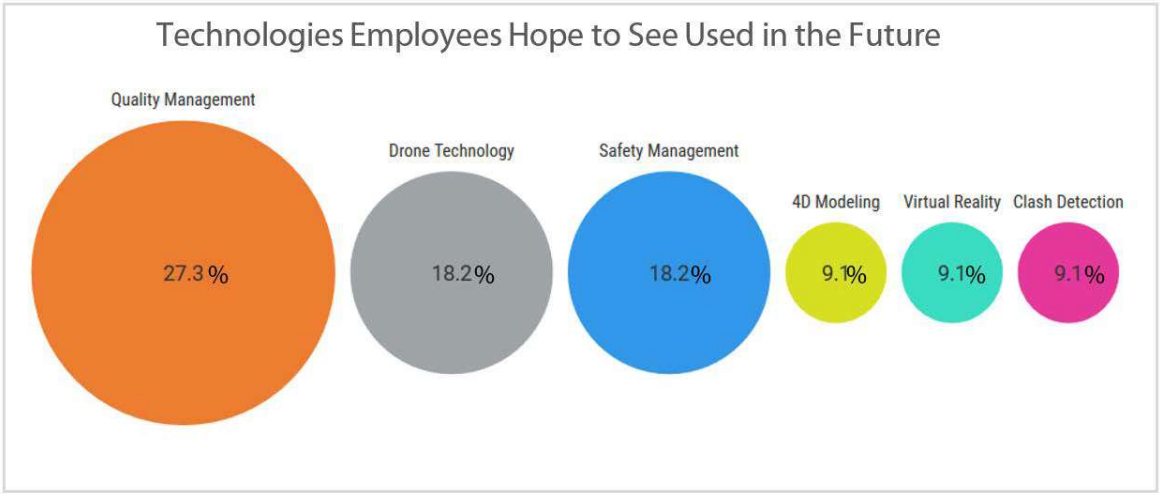

Figure 3

Discussion

Due to the nature of this research, data was analyzed graphically through tables and figures and through descriptive coding where the answers were not simply *yes* or *no* or scaled. Some questions in the survey were open-ended and provided a useful context to the more structured responses of the survey. The following will describe the results of the data.

Size of Organizations and VDC Departments

Cross analyzing the data from the respondents indicated that VDC services are overwhelmingly available in larger companies. Those reporting over $100 million in revenue annually and with more than 40 employees reported having a VDC department or utilized VDC services. Smaller companies with revenues below $1 million and less than 5 employees reported having no VDC department or VDC usage. This indicates a potential correlation between company size and implementation and acceptance of VDC services. As one respondent expressed:

"I do not know of any VDC applications that would be appropriate for the small-scale construction projects our company is designed for."

Highly Resistant Groups

The data indicate that trade workers, workers defined as those skilled in the building trades (carpentry, bricklaying, plumbing etc.), are considered the most resistant to implementation. The trade worker's inability to use technology

along with their limited technological resources impaired their ability to make use of VDC service technologies. As one participant indicated:

"Lower tier trade partners [do] not have the proper technology to implement."

The data indicate that owners were perceived to be the second largest group that resisted implementation. However, this indication did not align with the data that suggested that most owners are willing to pay for these services - there is an obvious disconnect here that could be further explored.

Bias as a Hindrance

Previous research has indicated that there is a discontinuity between designers and construction managers when it comes to collaboration. Design firms perceive that some project team members struggle to understand and implement the technical aspects of VDC hindering collaboration. Construction managers perceive that designers do not fully value the coordination process and often lack details in their design. Consequently, the results of this research indicate that perceptions between team members can hinders VDC implementation, as indicated in the following comments:

"Getting trade partners to buy-in on using it collaboratively."
"Getting the architects to provide a model that was intelligent enough to be used throughout the construction process."

Training as a Hindrance

It is well reported that the construction industry is currently facing a labor shortage (Engineering New Record online article accessible via https://www.enr.com/articles/42926-hurricanes-stir-inflation-as-labor-shortages-grow). Likewise, the participants in this research also indicated that there is a shortage of qualified individuals for training and support of VDC services. It is presumed that having individuals that are versed in VDC technology is extremely important in order to achieve the fullest benefits from VDC services. Participants responded to a lack of training and support as a contributing problem with implementation.

Perception of Value as a Hindrance

According to current research, understanding the value of VDC is instrumental to its implementation. Since there are currently no benchmarks set to measure value, time or cost savings this remains a leading barrier to implementation (Howard & Björk, 2008) (Smith, 2014) (Gustafsson et al., 2015) (Jung & Joo, 2011) (JB Knowledge Construction Technology Report, 2016). Every construction project is different so it is easy to understand how measuring value is a challenge. According to participants, this is mostly a problem for owners and trade workers, who are also the parties most resistant to implementation. Hindrances also include lack of understanding of VDC services and processes. Certain parties have a hard time understanding how VDC services are to be implemented and how VDC can help with the overall design and construction of a project. According to participants, value to the owner made all the difference in their company's ability to run a collaborative and VDC enhanced project.

"I believe that one of the biggest factors are owners not being able to see the value in it at first."
"… the biggest hurdle is taking the first step towards the use of those technologies. No matter who your project team is, either someone doesn't believe what it's going to bring to the table or don't think it will help them. The most important trait of a coordinator is to demonstrate how the technology will help and let it speak for itself."

Resistance to Change as a Hindrance

Participants were asked to share their opinions about what they believed was the one factor that hindered VDC implementation the most. The data indicated that the greatest hindrance was a resistance to change or considering new approaches to construction practices. The industry is maintaining its typecast adage of "if it is not broken, don't

fix it". Considering this prejudice towards change and technology, it is understandable why technological innovations are being met with such resistance. Consider the following comments:

"Interrupting people's current workflows and challenging the way they think something should be done."
"Getting people to change their view of how construction is supposed to go."
"New technology in a very "old-school" industry."

The Future of VDC Implementations

To determine what participants without a VDC department would forecast about the future of VDC, they were asked if they saw technological advancements as a necessity for the future of the construction industry. 40% of the participants responded neutrally with neither agree nor disagree, leading to conclude that the mindset of contractors without VDC departments is unresolved. However, a combined 60% agreed (strongly agreed to agreed) that VDC is an important advancement for the construction industry. This mindset will help with the implementation of VDC in the future.

Conclusions and Recommendations

After a review of the literature, it was determined, that research was needed to expose the potential hindrances to VDC services implementation. In addition, a framework, guidelines and standard practices for implementation of VDC services has yet to be established. This research is suggesting that the barriers to implementation must be mitigated before further integration of VDC services can continue, or increase in momentum. This research shows that there is a need to change the mindset of owners, trade workers and other professionals working in the AEC industry. Value must be measured and quantified in order to prove to the industry that the addition of VDC services is paramount in changing the industry's anemic productivity trend (Sveikauskas, et al., 2014). Based on some of the responses recorded in this research, it is evident that a change in mindset will be necessary to adjust the positions of those that are hardened to the notion of change.

This research suggests a need to establish protocols and frameworks that aid in the implementation of VDC services. According to the Roger's Innovation Adoption Curve, early majority and late majority adopters are most skeptical or thoughtful about adopting an innovation, while laggards require too much energy to convert. Consequently, focusing on those groups that tend to lag toward innovation may be less fruitful than focusing on those that are already accepting of the innovation (https://en.wikipedia.org/wiki/Diffusion_of_innovations). Once value has been established by the early and late adopters, the concerns that the laggards have about value may disappear altogether. Case studies and further research may be needed since there appears to be a correlation between size of the organization and its willingness to accept VDC. Overall, the results of this study lead to a need to change current perceptions of technology and begin measuring the value of VDC services. VDC departments need to work on clarifying the roles and uses of VDC in the industry. Clarification of how VDC services should be used and what it is meant to accomplish will help with the lack of acceptance from owners, trade workers and other industry professionals. First, the value of VDC services must be determined in order to change the perceptions of this long-standing industry. Value can only be determined by setting key performance indicators and benchmarks to measure performance on individual jobs. Once value has been measured and perceptions changed, the next step would be to begin researching and writing strategies for implementation and guidelines for best practices. Making VDC service implementation explicit may help the industry overcome the hindrances and adopt a better way of designing and building projects. Currently, the use of VDC has been limited to simple coordination tasks, but there are many other applications that have yet to be explored by construction companies such as robotics and mixed reality applications. Companies that already have VDC departments need to lead the way for the rest of the industry by expending resources classifying and organizing the needs and uses for VDC services, backed by data, in a formalized manner.

References

Abuelmaatti A., Ahmed V., 2014. Collaborative technologies for small and medium-sized architecture, engineering and construction enterprises: implementation survey. *ITcon*,19, 210-224, http://www.itcon.org/2014/12. (10.28.16).

Andersson, L., Farrell, K., Moshkovich, O., Cranbourne, C., 2016. *Implementing Virtual Design and Construction Using BIM: Current and Future Practices*. Routledge.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., O'Reilly, K., 2011. BIM adoption and implementation for architectural practices. *Structural Survey*, 29(1), 7-25.

Azhar, S., 2011. Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, 11, 241–252. doi:10.1061/(ASCE)LM.1943-5630.0000127.

Barlish, K., Sullivan, K., 2012. How to measure the benefits of BIM — A case study approach. Automation in Construction, 24, 149–159. doi:10.1016/j.autcon.2012.02.008.

Forsythe, P., 2014. The Case for BIM Uptake among Small Construction Contracting Businesses. *ISARC Proceedings 2014 Proceedings of the 31st ISARC*, Sydney, Australia, 480–487.

Gustafsson, M., Gluch, P., Gunnemark, S., Heinke, K., Engström, D., 2015. The Role of VDC Professionals in the Construction Industry. Procedia Economics and Finance, *8th Nordic Conference on Construction Economics and Organization* 21, 478–485. doi:10.1016/S2212-5671(15)00202-6.

Hartmann, T., van Meerveld, H., Vossebeld, N., Adriaanse, A., 2012. Aligning building information model tools and construction management methods. *Automation in Construction*, 22, 605–613. doi:10.1016/j.autcon.2011.12.011.

Holt, P. E. A., & Kearney, N., 2015. Emerging Technology in the Construction Industry : Perceptions from Construction Industry Professionals. *American Society for Engineering Education*, (Paper ID#12604).

Howard, R., Björk, B.-C., 2008. Building information modelling – Experts' views on standardization and industry deployment. *Advanced Engineering Informatics, Network Methods in Engineering*, 22, 271–280. doi:10.1016/j.aei.2007.03.001.

JBKnowledge Construction Technology Report, 2016. http://jbknowledge.com/2016-construction-technology-report-survey.

Jung, Y., Joo, M., 2011. Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, 20, 126–133. doi:10.1016/j.autcon.2010.09.010.

Kunz, J., Fischer, M., 2012. Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions. *CIFE*, Stanford University. doi: 10.2816.

Mandujano, M. G., Mourgues, C., Alarcón, L., Kunz, J., 2017. Modeling Virtual Design and Construction Implementation Strategies Considering Lean Management Impacts, *Computer-Aided Civil and Infrastructure Engineering*, p. n/a–n/a. doi: 10.1111/mice.12253.

Migilinskas, D., Popov, V., Juocevicius, V., Ustinovichius, L., 2013. The Benefits, Obstacles and Problems of Practical BIM Implementation. *Procedia Engineering* 57, 767–774.

Smith, P., 2014. BIM Implementation – Global Strategies. *Procedia Engineering*, Selected papers from Creative Construction Conference 2014 85, 482–492. doi:10.1016/j.proeng.2014.10.575.

Succar, B., 2009. Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction* 18, 357–375. doi:10.1016/j.autcon.2008.10.003.

Sveikauskas, L., Rowe, S., Mildenberger, J., Price, J., Young, A., 2014. Productivity Growth in Construction.s.1.: *Bureau of Labor Statistics (BLS)*. https://www.bls.gov/osmr/pdf/ec140090.pdf.

United States Census Bureau. Census.gov, 2016. https://www.census.gov/data/tables/ 2014/econ/ susb/2014-susb-annual.html.