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BIM and Project Management in AEC Industry

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Abstract

Building Information Modeling has altered project managers' role in architecture, Engineering and Construction (AEC) industry. In theory Building Information Modeling (BIM) has promised the project managers to enhance communication and collaboration aspect of managing their projects, thus increasing the efficiency and success rate of the AEC industry projects. However, in real world application, project managers had challenges and barriers with BIM implementation into their processes. This study intends to highlight the main characteristics of the BIM, its benefits, barriers and risk management capabilities to elaborate on why BIM adoption has been slower than anticipated. Based on quantitative data collection through surveys, this study then asserts BIM impact on production efficiency rate. Findings of this research paper show that project managers had been facing 2 main challenges when implementing BIM into their project management processes: 1. Lack of knowledge of the software 2. Lack of knowledge of project management role shifts that had to take place once BIM was implemented. The findings of the quantitative data analysis show that BIM increased the production efficiency rate where it was implemented. In conclusion, the research paper asserts on the main question identified in the problem statement on why project managers in AEC industry should implement BIM into their project management processes.

Keywords

Building Information Modeling; Project management; AEC industry; Efficiency; Risk Management; Benefits and challenges

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Introduction

According to a study by Jrade & Lessard (2015,), currently a lot of construction projects are suffering from inefficiency, insufficient labor productivity and poor design requirements documentation and information. These are criteria that can cause financial loss to any Architectural, Engineering and Construction (AEC) project. Any financial loss on such project will result in project managers to fail delivering a successful project. A study by Lee, Yu, & Jeong (2013) asserts that technological advancements in developing more intelligent software, specially Building Information Modeling (BIM), have had a positive impact on resolving such issues (Lee, Yu, & Jeong, 2013, p.1).

According to Zou, Kiviniemi, & Jones (2015), The advancement of new technologies and methodologies in the recent decades has impacted AEC industry's projects immensely across the globe. These new tools are not just simply a software or technology, but they are affecting the project management processes by impacting the efficiency of the process and by altering the traditional paradigm of project management (Zou, Kiviniemi, & Jones, 2015, p.1).

Per Sawhney, Khanzode, & Tiwari (2017), currently stakeholders including project owners, project managers, execution teams etc. are re-thinking the execution processes. In doing so the AEC industry is at a stage that its stakeholders are considering implementing such tools into their everyday practice (Sawhney, Khanzode, & Tiwari, 2017, p.9).

Some researches show that there are apparent benefits to implementation of such new technologies (Demian & Walters, 2013). However, it's worth to note that other researches show that sometimes there are barriers in utilizing these technologies that might result in project failures (Azhar, Hein, & Sketo, 2015).

This paper intends to research the key components of Building Information Modeling as one of the biggest emerging tools among these technological advances to document the benefits, risks and challenges of this new tool. The paper also intends to investigate the alterations in project managers' roles and methodologies that BIM has brought upon AEC industry's projects to be able to measure BIM implementation reliability in various projects and organizations types.

According to National BIM Standards website (2015),

> A BIM is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward. (p.1)

Travaglini, Radujkovic, & Mancini (2014), asserts that "BIM is a system and its main objective is the managing of the information and because of that it is also a project management matter (Travaglinig, Radujkovic & Mancini, 2014, p.1058)."

Problem Statement and Justification

According to Sawhney, Khanzode, & Tiwari (2017), the Architecture, Engineering and Construction (AEC) industry's project managers have begun to leverage the recent technological developments as it relates to BIM. The article further asserts that these project managers can leverage the benefits of BIM in order to deliver their projects in a more efficient way. Same study is supporting the fact that BIM has positively impacted collaboration and coordination aspect of project which are key elements of successful project delivery (Sawhney, Khanzode, & Tiwari, 2017, p.8).

According to Talebi (2012), BIM is an integral part of the AEC industry as a main tool for executing and coordinating the projects. However, adoption of BIM has been slower than anticipated due to technical and managerial reasons (Talebi, 2012, p.2).

After comparing the two researches above, one can realize that there are benefits that are associated with BIM processes, but at the same time the rate of adoption has been a challenge due to managerial reasons.

The indication of slow adoption in the research literature has called for an investigation to look into various aspects of BIM adoption across the industry and basically the role of AEC industry project managers in the increase or decrease of BIM adoption rate. In any AEC type project, there are many stakeholders from different organizations involved. Each of these stakeholders have their own project manager. This means that there are multiple project managers involved in these types of projects. There are times when not all these project managers are utilizing same project management platform to execute and deliver their portion of the work. In AEC type projects, architects are the sole responsible entity for delivering a well-documented and coordinated drawing set and thus they become the main project managers of such projects. BIM and its 3D modeling capabilities has become very popular among architects. As it will be discussed later in this paper, it has altered project managers' traditional roles. If the adoption of BIM among other stakeholders are slower than anticipated and not in alignment with their counterparts in these projects, detrimental conflicts could occur that will eventually cause in project failures.

According to Sawhney, Khanzode, & Tiwari (2017), project management is the key element for success of a project. With that being said, if project management is of such a significance in ensuring project success, managerial reasons behind the slow rate of BIM adoption can certainly cause some serious damage to the projects for which managers are not willing to

adopt BIM. And that is why this issue needs to be addressed to avoid further damage to the body of AEC projects (Sawhney, Khanzode, & Tiwari, 2017, p.10).

The author's assumption is that if project managers in the AEC industry implement BIM into their project management processes, then production efficiency increases resulting in a rise in the success rate of the projects. Thus, it is important to investigate why BIM adoption rate has been slower than anticipated, and why project managers should recognize BIM as the main tool for managing projects. The potential answer lies within careful analysis of BIM impact on project manager roles, risks and barriers, and benefits of BIM adoption for various AEC industry projects.

Proposed Solution Approach

Data collection is a key component for evaluation of the claims made in the problem statement section of this research paper. To collect comprehensive data to support or oppose the hypothesis, the author has selected to utilize both primary and secondary data.

Primary Data

To evaluate the hypothesis, quantitative data must be gathered to evaluate BIM promises and how it alters project management role within an organization compared to the traditional methodology.

The surveys will ask the project managers and BIM experts to provide their feedback on BIM adoption rate, stakeholders' alignment in BIM utilization, clients' participation in decision making process regarding BIM utilization, BIM promises, BIM organizational and upper management uptake.

For the purposes of this phase, the following steps shall be followed:

1. Prepare a list of small, medium and large-scale projects across 4 design studios utilizing marketing sector's assistance.

2. Identify the project managers for each of the projects listed in the previous step using project definition manuals produced in each projects' lifecycle.
3. Reach out to identified project managers via E-mail to determine if BIM was utilized to execute their projects.
4. Setup a meeting with selected project managers to describe this research phase's intention.
5. Send out the quantitative survey via Email to the participants.
6. Compare and synthesize the collected data against problem statement claims.

Secondary Data

This paper utilizes secondary research methodology to provide an analysis of over 20 research papers. This paper first gives an in-depth introduction of BIM and its main characteristics and promises. This paper then analyzes the role of project managers in traditional project management setting and the post-BIM era in the AEC industry. The literature review suggests a major shift in such role. As part of this step, the analysis shows that BIM has positively impacted project management processes by enhancing collaboration, coordination and communication. There are many researches supporting the benefits of BIM, but at the same time there are arguments supporting the opposite. Thus, the next step is to evaluate BIM benefits and barriers as they relate to BIM adaptation and implementation into the project management processes.

In the conclusion section, the author will re-evaluate the hypothesis if it still holds true in accordance to the various literature reviews throughout this paper and give recommendations on how BIM adoption rate can be enhanced.

Next step for future research is to analyze real world case studies that utilized BIM in their project management processes. Lessons learned and root causes for failure or success of BIM adaptation in to those projects are main components to be further analyzed.

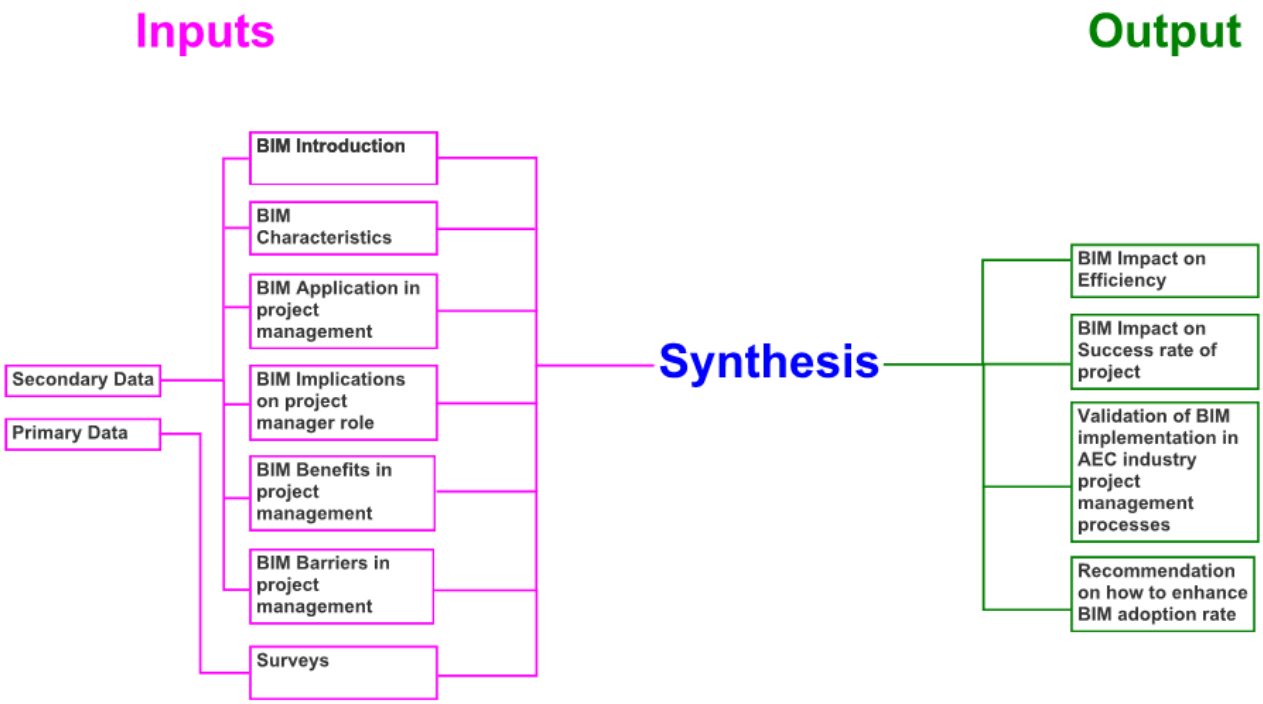

Figure 1-High level research work plan

Literature Review -- Analysis of Related Work

A Shift in Project Managers' Roles

The research done by Sawhney, Khanzode, Triwari (2017) focuses on the impacts that recent technological advancements has brought upon project managers' roles in Architecture, Engineering and Construction (AEC) industry. The authors first discuss the roles of project managers as it is outlined in international project management standards and then elaborate on how Building Information Modeling (BIM) has altered some of these roles and responsibilities through the lifecycle of project and through various phases of design and construction. Authors emphasize on the positive impacts of BIM utilization on some of the most important aspects of project management such as communication, collation and collaboration in this research. However, they also recognize that there have been some challenges in BIM adoption by various industry leaders. The authors assert that contrary to the common belief, BIM is not a project management workflow that can be prescribed for all projects sizes and even all organizations. BIM adoption for the projects is a decision that needs to be made considering project size, demand and the culture of the organization. In other words, the value that BIM brings for a specific project in an organization should be carefully analyzed and compared against the business goals. The lack of such analysis might have been a reason that BIM adoption has sometimes failed project managers in AEC industry. In the conclusion section, the authors discuss how and why it is the responsibility of project managers to perform this analysis and help organizations decide if they should be adopting BIM approach in delivering projects. The article by Sawhney, Khanzode and Tiwari is probably one of the best resources for the purpose of this research paper as it is directly related to the problem statement outlined in previous chapters.

Building Information Modeling's Impact on Stakeholder Management

The paper done by Azhar, Khalfan and Maqsood (2012) is an overview of BIM, its definition, risk and barriers, benefits and future trends as they relate to Architecture, Engineering and Construction (AEC) project types. The paper starts by giving a definition of BIM by National Building Information Modeling Standards (NBIMS) and Associated General Contractors of America (AGC). By the comparison of the two the authors assert that BIM is beyond just a technology and also can be perceived as a process. The authors discuss that BIM is making major changes in the projects' lifecycle work flow. The authors further elaborate on the BIM implications on various phases of AEC type projects and how they change the workflow of each. The authors also elaborate on what this means for project managers in this industry and what they need to be aware of when managing projects utilizing BIM. One of the highlights of this research is BIM adoption implication on stakeholder management. Stakeholders in this paper refer to project owners, designers and constructors who are the main stakeholders on any AEC type project. Stakeholder management is one of the crucial roles of project managers. It is an ongoing task throughout the lifecycle of the project. Knowing how BIM is impacting this task and how project managers should respond to those changes is highly important for successful project delivery. The authors work highlights various aspects of BIM implications on specific project managers' roles and thus very helpful for the purposes of this paper's problem statement. One gap that was noticed in this research is the different levels of recognition that have been given to the BIM by industry leaders and its root causes.

Challenges and Advantages of BIM Implementation

To respond to the gap mentioned in the previous literature review, this research done by Talebi elaborates on some those concerns and questions regarding challenges that organization face when implementing Building Information Modeling (BIM) into their routine work flow. The paper compares both advantages and disadvantages of BIM implementation in to the project management. The benefits determined by the author is the increased efficiency in collaboration and coordination amongst various stakeholders involved on the projects as well as increased productivity. The author believes that the reason for such benefits is indeed the fact that BIM provides more information and data for project managers. In Architecture, Engineering and Construction (AEC) projects, one of the reasons that delays or failures happen is because data collection can become a challenge. Thus, BIM and its reputation for being able to provide more information and data compared to traditional workflows can benefit project managers in eliminating some of the risks associated with data collection. The author then elaborates on some of the challenges that project managers face when trying to implement BIM into their workflow. The challenge is mainly mentioned to be lack of knowledge about BIM and how it alters the roles and responsibilities of project managers from that of the traditional process. Another challenge is mentioned to be lack of knowledge with regards to technological aspects of BIM but this challenge is not the subject of this paper. In short, the author believes that there is not a clear guideline for project managers on how to implement BIM into their projects. It usually takes a lot of time for them to adapt to the new changes and figure out the best practices utilizing this technology.

Risk Management Using BIM

The research paper done by Zou, Kiviniemi, & Jones (2015), is an extensive review of researches that assess risk management through new tools available to project managers such as Building Information Modeling (BIM). According to this article, risk management is one of the crucial components of project management process on all projects across the globe. Architecture, Engineering, and Construction (AEC) projects are no exception to this rule. The article asserts that failure to manage risks associated with AEC industry projects, not only results in the failure of the project itself but it will impact the future growth of the built environment adversely. Thus, it is highly important to think about how BIM can alter the paradigms in risk management. This paper first elaborates on traditional risk management in projects and then discusses how the advancement of new technologies such as BIM can alter, benefit or even pose a risk on this process. This research confirms that there has not been a comprehensive real-world application of BIM in risk management process yet but with system-thinking of all disciplines involved in AEC industry projects, considering various implementation strategies and supporting such practices, the industry can potentially overcome this gap. The article further elaborates on the benefits that BIM can bring to project managers in their risk management processes, emphasizing on its data collection capabilities. Lastly, the article touches on the challenges that AEC industry project managers are facing in BIM implementation in risk management.

Considering that risk management is one of the most important components of managing AEC projects, and that BIM can be implemented into project management practices to address such issues, this article is beneficial for addressing the issues outlined in problem statement.

Project Control Methodologies and Productivity Improvement Using BIM

The main objective of this research paper done by Kenley & Harfield (2015) is to develop project management theory as it relates to Architectural, Engineering and Construction (AEC) industry with a focus on project control. The authors utilize a subset of a larger study that used surveys of 50 different international construction project control professionals for their research. The article discusses the benefits of the 3 most common project control methodologies:

1. Building Information Modeling (BIM)
2. Earned Value Management (EVM) and
3. Location Based Management (LBM).

Pre-structured interviews of the mentioned professionals that were done as part of this effort, show a common problem in commercial and infrastructure projects; The surveys and interviews showed that all organizations used at least one of the three mentioned tools. However, those tools were not effective across all teams or across all aspects of different projects. The authors believe this ineffectiveness can be resulted from the following reasons: 1. One reason for this deficiency could be different teams' capabilities in adopting and implementing these tools in their everyday practice. Or 2. The other reason could be lack of knowledge about the mentality and philosophy of these tools and methodologies. The authors believe that the main cause for such deficiency is the latter. These three tools should be looked as systemic methodologies. Their goal is to increase efficiency and productivity as it relates to managing projects. This in turn is highly dependent on continuous collection of data, validating the data, controlling the data and reporting to different stakeholders as appropriate.

The gap in this literature which also provides basis for future research ideas is to seek how to educate teams and individuals on the philosophy of BIM and how to effectively implement this

tool into every day practice. Another gap noticed in this paper is the determination of the role of each stakeholder in collecting and controlling data in AEC industry. In all AEC projects, there are too many different stakeholders involved, coordination and communication between all these different parties is an everyday challenge for project managers as they need to work with other project managers with different perspectives.

This article is directly related to the topic of this research paper. Project control is an important phase of project management as it controls cost, time and quality. This research can provide information regarding to what extent project managers should use BIM to control these three magnets of their project.

BIM and Project Management from Stakeholder's Perspective

According to this research by Traviglini, Radujkovic & Mancini (2014), in the recent years, the projects in the AEC industry has been getting more complex. As a result of such complexity, it has become more challenging to manage these types of projects. To respond to this shift, Information Technology (IT) has developed multiple platforms to better resolve project management complexity of such projects (Traviglini, Radujkovic & Mancini, 2014). This research paper further asserts that among all these platforms, Building Information Modeling has been proved to be the answer to this project management role. This research elaborates on the relationship between BIM and project management suggesting that BIM is a project management matter since its main objective is to manage project information. This research paper has conducted extensive literature review as well as interviewing stakeholders who are key in BIM adoption to extract its results and conclusion. The main problem that this research paper will address is to answer what type of stakeholder in an AEC type project will be adopting BIM?

The points discussed in the research paper by Traviglini, Raduikovic Mancini are very helpful to address the problem statement drafted by the author of this paper in previous sections. This research paper clarifies the power matrix in BIM adoption. As it will be discussed in this research paper, one of the reasons that BIM implementation adoption rate is lower than expected is that the management role of the BIM is not yet fully understood by key project players. To prevent conflicts, it is important for the team players in an AEC project to fully understand who is mainly in charge of BIM adoption and drafting the roadmap of BIM implementation into project management. Without such realization, conflicts are more likely to happen and thus project failure will be a major risk that project managers can potentially face.

One gap that the author has noticed in this research paper is lack of information on the details of responsibilities of each of the key members in BIM implementation and how these responsibilities should be communicated with all stakeholders to improve the efficiency of communication when it comes to BIM.

Review of BIM Benefits in AEC Projects

The article by Doumbouya, Gao and Guan elaborates mainly on BIM adoption benefits in AEC type projects. It asserts that BIM will effectively increase the efficiency and productivity throughout the lifecycle of project given that the project team is capable of notifying constructability issues at the very early stages, updating the information easily and as many times as needed, enhancing information sharing between project stakeholders. According to the writers of this research paper, the mentioned advantages of the BIM will eventually result in a reduction in the number of errors associated with building systems' design, reduction in the construction cost as a byproduct of improved efficiency and smoother project management work flow.

One of the highlights of this research paper is that the authors analyze the BIM role in all stages of design and construction. This article then elaborates on factors that influence BIM adoption rate and often causes the rate of acceptance and implementation to be slightly different among the industry professionals. The authors further assert that a full realization of BIM role and how it alters the traditional paradigm of AEC project management is key in successful implementation of this new technological advancement.

The findings of the article by Doumbouya, Gao and Guan will help the author of this research paper to be able to elaborate on benefits of the BIM throughout all phases of design and construction.

One area for future research is to investigate the challenges and disadvantages of BIM implementation in all phases of design and construction.

BIM Promises Versus Reality

The research article by Miettinen and Paavola analyzes the BIM as a technology and also as a project management practice. The authors first elaborate on the four main characteristics of BIM in detail throughout the article. These characteristics are as follows:

1. All the information needed for a successful delivery of an AEC project can be incorporated into one single platform
2. BIM allows for easier collaboration between disciplines involved in AEC project and allows new ways of working
3. It can be maintained and updated throughout the lifecycle of not only the project but also the building
4. BIM's main promise to increase the efficiency of project's documentation process

Then the authors discuss how project managers have been utilizing and implementing BIM into their project management process. In the next step, the authors discuss how new technologies can be effectively introduced so that the users accept and implement such new tools into their everyday practice. The authors assert that the key is continuous learning and collaboration with these end users are the key. Finally, the authors give recommendation on how BIM implementation can be enhanced among the project managers.

The research paper by Miettinen and Paavola evaluates the key points and assumption made in the problem statement of this paper. Also, it will provide good basis for make recommendations in the conclusion section of this paper.

One area for future study would be to investigate the validity of the four main characteristics mentioned in Miettinen and Paavola's work by real world case studies and projects.

Challenges of BIM implementation in Construction Projects

The article by Kerosuo, Miettinen, Paavola, Maki, and Korpela, elaborates on challenges and barriers of BIM implementation in construction projects in detail in four main interfaces of any AEC type project. These four interfaces are as follows:

1. Designers
2. Designers and the site managers
3. Designers, site managers and building managers
4. Designers, building managers and end users

In any type of AEC project, there are many project managers involved from various companies with different specialties. With all interfaces being analyzed in the authors' work, this article can help investigating the challenges and barriers in BIM utilization and implementation.

As mentioned earlier in this paper, the analysis of such challenges and barriers are essential in addressing the problem statement of this paper.

If the project managers fully understand the challenges that may arise from BIM utilization internally and externally, they can take actions accordingly to address such challenges and thus the risks associated with them. One gap in this research is the lack of recommendation from the authors on how to address these challenges.

BIM Projects Risk Factors

A study by Chien, wu, & Huang in 2014, investigates the risk factors associated with BIM implementation into AEC industry projects. The authors assert that BIM is eventually the future of AEC industry's project management processes and practices. However, just like any other new technological advancement, there are risks associated with its utilization in its early stages. The authors callout thirteen risk factors associated with BIM adoption throughout this study summarized as follows:

Inadequate precedents: As discussed previously, BIM is in its early stages of utilization and adoption. In other words, it is in the trial and error stage and thus some of the risks associated with is not fully known.

Inadequate governmental support and policies: Because BIM utilization is in its early stages of implementation into the projects, governments lack policies and standard roadmaps for its successful implementation. This deficiency will eventually cause organizations which utilize BIM to develop their own standards. Since in any given AEC type projects, there are many various stakeholders involved, their roadmaps for BIM utilization might not be properly aligned and thus can cause detrimental conflicts through the lifecycle of the project.

Inadequate educational and training infrastructure: Universities and educational institutes do not have BIM focused programs in the academic environment. Individuals who work with BIM in the industry learn it through experience. Thus, this new advancement is lacking proper and sufficient academic background.

Organizational Culture and BIM Utilization

The research by Almeida and Brasil de Brito Mello is an investigation of why Brazilian construction sector has not been successful in implementation of BIM into the project management processes of their projects. The authors assert that the Brazilian construction and design companies are indeed aware of the advantages of BIM. They do realize that BIM implementation if utilized effectively can result in improved efficiency and potential savings in time and cost. However, the authors confirm that organizational culture and the resistance to change are the main problems that such companies are facing. The results of this research paper are based on the questionnaires that were handed to industry leaders in the Brazilian construction companies. The questions question if the companies have interest in BIM implementation, what their current practice is, do they have the culture to receive and accept BIM, what shifts are needed in the organization culture to make BIM well received among project managers and most importantly, are these companies willing to go ahead and investigate in such major shift. In the conclusion section, the authors summarize the key findings based on these questionnaires.

The findings of this research paper support the author's point about BIM being something above and beyond just a drafting tool project documentation. BIM is not just a technology. It will alter the project management processes and thus, it will find its way to change the organizational procedures in project execution eventually. For companies to accept and implement BIM into their

project management practices, there will need to be a change in the organizational culture and not all companies accept to go under such change.

BIM Implementation in the Global Setting

A study by Dr. Peter Smith in 2014, investigates the issues related to the implementation of BIM into AEC type projects. This study asserts that the professionals in this industry are yet to establish effective roadmaps for project managers on how to utilize this tool for successful and easy project delivery in AEC industry. This article indicates that lack of such effective roadmap is one reason why BIM acceptance rate has been slower than anticipated despite the fact that it has been around for at least the past decade. However, the same study indicates that the acceptance rate has been increasing in various countries.

The authors further elaborate that there are multiple reasons for such successful implementation. These include support from governments, establishing national BIM standards that all engineers, designers and contractors can follow, and also educational and training programs held nationwide. Out of the reasons mentioned, the authors indicate that the government support is probably the most effective. Also, they assert that BIM implementation should start with the owners of the project in order to be well received between all stakeholders.

This study shows that BIM implementation can bring competitive advantage for the firms in this industry specially if they are competing in the international market. That being said it is not smart to use BIM for all projects. There needs to be a business case created for each project to evaluate the effectiveness of BIM implementation. If the return on investment is not justified, then using BIM will create barriers.

The authors of this article elaborate on legal issues in relation to BIM implementation. Since the project manager is relying on the information directly produced from BIM, and since

many stakeholders from various organizations contribute to BIM and its output, there is a risk of delivery of inaccurate information. The American Institute of Architects (AIA), which produces legal contracts between various participants in AEC projects, has been working on developing legal provisions to address this issue.

This article is a study that evaluates and supports the points made in the problem statement section of this paper. It indicates that BIM implementation is gaining more acceptance rate recently and also elaborates on some of the benefits and barriers in its implementation which are intended to be investigated throughout this paper.

Construction Organizations' and BIM model

A study done by Lee, Yu, & Jeong indicate that even though BIM is gaining popularity between the leaders of AEC industry, it is unclear why it is adopted and used. Therefore, the authors assert that there are concerns in conjunction with BIM acceptance model since there is not a clear answer to why BIM is adopted and is gaining such attention. The authors also indicate that this is probably due to BIM's promise of having reusable and updatable information. In this study, the authors will elaborate on main components of BIM acceptance model as it is utilized in the construction organizations.

The authors elaborate on a report issued by the National Institute of Standards and technology (NIST) issued in 2004. This report indicates that more than 15 billion dollars is being wasted in Architecture, Engineering, and Construction (AEC) projects annually. It is noted in this report that the reason for such financial loss lies within the inefficiency and lack of sufficient data during project execution phase. Sometimes such financial loss results in project managers to fail delivering a successful project. BIM's main promise is to solve all such problems with its data collection capabilities. However, the authors believe that BIM acceptance rate is in direct

relationship with the rate by which users accept new Information Technology. This concept known as Technology Acceptance Model (TAM), is affected by several factors such as users, the context, technology itself etc. Furthermore, the authors surveyed architects, engineers and contractors in order to test their research model.

According to this study, TAM depends on two major components:

1. How users perceive the new technology to help their job performance, or in other words its usefulness

2. How users perceive the new technology user friendly, or in other words ease with which they can start utilizing the technology without major failures

Lee, Yu, & Jeong also indicate that norms established within the concept of TAM are also affected by social norms. A user might find a certain technology useful and easy to learn in a certain country but not necessarily in another.

The authors then elaborate on BIM benefits by listing the major advantages BIM has brought for AEC industry. To name a few, authors assert that BIM will result in easier data management, easier implementation of changes, increased production efficiency and thus cheaper overall process. Also, the authors elaborate on the barriers that BIM casts upon construction industry. Lack of technological knowledge, lack of resources, lack of education and training and lack of clear liabilities and legal issues are named by the authors to be some of the most critical barriers in determining a clear BIM acceptance model.

Based on the extensive literature review on TAM and BIM barriers, the authors indicate internal and external variables for BIM acceptance. External variables include Organizational competency, technology quality, personal competency and behavior control. Internal variables include perceived ease of use, perceived usefulness and consensus on appropriation.

The research paper by Lee, Yu & Jeong supports the points made in the problems statement and introduction of this research paper about BIM's benefits and main promises. However, it is also elaborating on why it is not just about the advantages that this technology is bringing for AEC industry and many variables play significant roles in its successful implementation in AEC type project.

Time and Cost Management Utilizing BIM

The study done by Jrade and Lessard, elaborates on BIM capabilities regarding time and cost management on AEC projects. The authors confirm that the AEC projects suffer from decreased efficiency and productivity as well as poor and insufficient design information. The authors also assert that is it very crucial for designers and contractors to communicate regularly and effectively to be able to mitigate risks when it comes to time and cost. According to this study, BIM and its capability of designing the building shell, its interior and all building systems three-dimensionally, is very effective in producing more accurate information for the contractors. The issues are identified easier using BIM since the designers or engineers are looking at this three-dimensional model as a whole with all systems incorporated into one single platform. Because of such capability coordination becomes easier on these complex projects. With easier coordination and more information available, contractors and engineers are able to quantify the building components easier and in a more accurate manner. This will allow contractors to be engaged earlier in the design phase. They can identify constructability issues and conflicts and plan accordingly ahead of time. This eventually will translate to a better time and cost management. To better control cost and time an integrated BIM system has been identified and analyzed by the authors of this research paper that can potentially work hand in hand with BIM software such as Revit to improve Earned Value Management analysis.

This paper gives an idea of how BIM can be improved further in the future in the project management area. If such project management improvements happen in BIM, it might be easier to convince upper management, decision makers and the organization to utilize and adopt BIM. Currently, even though BIM has indirect impacts on the project management process, its value is not being fully understood. With invention of such integrated system that allows project management to be directly related to BIM, then it will be easier to communicate its advantages.

BIM Contribution to AEC Projects Problem Solving and its Implementation Barriers

The research paper by Kushwaha in 2016, elaborates on BIM contribution to solving AEC projects' problems and also touches on the barriers that industry professionals face in its implementation even today. The author asserts that currently there is no doubt that BIM has positive impact on the productivity and efficiency of the projects with its three-dimensional modeling capabilities. According to the author, such capabilities will eventually translate into a better time and cost management. The author emphasizes on the importance of the collaborative platform that BIM has to offer to designers and engineers. It is now easier than ever for all stakeholders of any AEC project to be able to identify the deficiencies and building systems' conflicts using BIM. With such collaborative platform, it is also easier to quantify the building components and get an idea of cost and time. According to Kushawa (2016), "it can rightly be said that instead of implementing BIM as a technology it is rather implemented as a [project management] process" (Kushawa, 2016, p.100).

The author also introduces the fourth and fifth dimension that BIM offers within its platform. Kushawa claims that with BIM's capabilities, AEC professionals are now able to perform the scheduling effort earlier in the design stages. This has been recognized as the fourth dimension or time by Kushawa. The same concept holds true for the cost estimating efforts. With

all the trades working three-dimensionally in BIM and simultaneously as other trades, contractors can get engaged on the projects earlier and start preliminary cost estimates as the design and engineering systems improve. Thus, cost estimating is the fifth dimension of BIM as indicated by Kushawa.

Kushawa identifies the following as BIM capabilities which positively impact AEC projects' problem-solving efforts:

- The three-dimensional visualization capabilities that allows production of real-time information that is shared with all trades.
- Capability of BIM in utilization of parametric objects that improves the accuracy of documentation
- Improved communication through sharing real-time information with all trades
- Improved conflict management since all building systems are three-dimensionally modeled in one platform and thus conflicts are readily visible
- Faster delivery of the project through increasing the efficiency of production
- Easier change management through the previously mentioned features

Kushawa also elaborates on the barriers that BIM implementation can suffer from. Among such barrier are:

- Hesitation in adopting new technology. This goes back to the study done by Lee, Yu, & Jeong and the Technology Acceptance Model they introduced.
- Lack of BIM experts who know BIM holistically. The education and training currently offered is not a comprehensive training method.

- Lack of awareness about BIM benefits and how it can improve the project management processes. Thus clients, tend to rely more on traditional methodologies rather than the new ones.
- High initial cost of BIM implementation that might not be able to be justified at the end of the project. According to Kushawa, BIM is not suitable for small scale projects and an analysis of return on investments must be performed to evaluate whether or not BIM is an appropriate methodology in a given project.
- Lack of support from governments and other regulatory agencies. Smith in his 2014 research elaborated on this issue and how this support has been effective in BIM implementation in some countries.
- Lack of agreement in BIM implementation between stakeholders. BIM is a highly collaborative software and platform. This means that its successful implementation requires all stakeholders to utilize it.

BIM Adoption in UK's AEC Industry

A study by Eadie, Browne, Odeyinka, McKeown & McNiff (2015), investigates the current status of BIM adoption in United Kingdom's (UK) AEC industry and the changes it has brought upon such projects. This study indicates that since 2016, AEC projects in UK has been forced to start adopting BIM into the project management processes. The findings of this study assert that BIM has been perceived more important in the area project management processes than its technical purposes. These findings also suggest that client demand is very crucial in BIM uptake.

According to the authors of this research paper, BIM adoption has been facing challenges and barriers. They suggest that "BIM will require a paradigm shift and will change the dynamics

of construction projects (Eadie, Browne, Odeyinka, Mc.Keown, & Mcniff, 2015, p. 5" According to the authors, the project management and business processes within an organization as a whole should go through a paradigm shift and without this paradigm shift, BIM utilization will not be successful. The authors literature review also assert that managerial aspects of BIM is more important than its technical capabilities. From these findings the authors conclude that successful BIM adoption requires an evolution in project management practices. The authors suggest that BIM can create new roles on the project and alter project manager's role compared to the traditional methodology. This does not mean that the project manager should simply hire a BIM manager. A survey was conducted as part of this study. The participants agree that the project manager should also be BIM proficient and should be able to efficiently supervise the BIM management processes.

Throughout this research paper, the authors assert that the UK government has been having a significant role in BIM uptake by organizations by enforcing its utilization. The reason for such significance is because of the industry standards that develop as part of government involvement. The standardization of practices can help formatting a successful roadmap for BIM utilization. This study supports findings of Kushwaha's study earlier discussed in the literature review section.

In the conclusion section, the authors summarize their findings and assert that BIM is starting to gain more acceptance rate amongst AEC industry project managers. These findings suggest that even though the technical knowledge of BIM is significantly important in its successful utilization, full understanding of project management paradigm shift that BIM brings upon AEC industry projects is crucial in BIM's proper adoption. The areas for future study as

called out for by the authors are to interview focus groups to indicate the necessary changes that need to happen within organizations and their project management practices.

Findings

20 professionals in the architecture industry were surveyed as part of the quantitative analysis to either support or contradict the points made in the problem statement of this research paper. 17 individuals responded to the survey. They were asked for their position and years of experience with BIM software through the first and second questions. All respondents possess leadership and management roles within their organizations either as project manager, project architect and/or BIM manager. The average BIM experience of the surveyed group is 4 years. Here is an interpretation of each survey question.

The third question of the survey requests the participants to indicate how many of the projects they have been a team member of, have utilized BIM in documentation and execution. This question was asked to test the validity of adoption of BIM being slower than anticipated. Based on the responses of the survey as evidenced by attachment 4, about 82% of the participants have responded that 75% or more of their project had utilized BIM. This finding asserts that among AEC industry professionals, the utilization of BIM has started to gain acceptance among architecture professionals. Since architects are the ultimate responsible entity for delivering a coordinated and well documented set of drawings and thus they define the project delivery methodology, they have also been successful in convincing engineers and contractors to utilize BIM for execution. This finding however is also showing that BIM is not yet a fully accepted model in the industry and that the adoption rate is slower than what was originally anticipated. However, this analysis asserts that BIM is gaining popularity between the industry professionals which supports points made in the literature review section.

Questions 4 asks participants to indicate how much BIM alters project management processes compared to the traditional methodology (Computer Aided Design). As asserted by many scholars, BIM alters project management processes and thus project managers' roles. Many of these scholars have confirmed that one of the reasons for slow adoption rate of BIM is lack of such understanding of such shift in project manager role that eventually results in confusion, redundancy and decreased efficiency which means increase time and cost to the project. Increased time and cost to any project means failure and thus some of the project managers in AEC industry avoid utilizing BIM in many instances. This question validates whether or not professionals with BIM experience and knowledge have found BIM shifting project management role. Based on the responses of the survey as evidenced by attachment 5, about 65% of the participants agree that BIM alters project management processes. This finding supports the literature review analysis findings and confirms that BIM alters project manager roles. This indicates that knowledge about BIM is not just about knowing BIM as a software or piece of technology, but BIM knowledge requires project managers to realize its impact on the traditional methodology.

Questions 5 through 7 were designed to validate BIM's promises of improving communication, coordination and increased efficiency in documentation and project execution.

Question 5 asks participants to indicate how much they think BIM improves coordination process on AEC projects. Coordination plays key role in delivering a successful AEC project. There are many different stakeholders involved in any such projects. To name a few of these stakeholders there are architects, mechanical engineers, electrical engineers, plumbing engineers, civil engineers, contractors, structural engineers, signage consultants, acoustical consultants, interior designers etc. All the work done by these professionals should be well coordinated. Otherwise, poor coordination between any of these entities has adverse domino effect on others

work as well. This can result in increased time spent to redo parts of the work which can then translate to increased cost or time. As mentioned previously in this research paper, BIM has promised AEC professionals to improve the coordination by its capability of providing real time three-dimensional information. Based on the responses collected as evidenced by attachment 6, about 60% of the participants agree that BIM improves the coordination process by 70 to 100 percent. This finding asserts that BIM improves the coordination process and thus reduces the risks associated with poor coordination between stakeholders' work.

Question 6 of the survey asks participants to indicate how much they think BIM improves communication process on AEC projects. A project manager should be able to effectively communicate scope of work and project requirements with all stakeholders involved in any projects. Poor communication can result in scope creep or even not meeting the base requirements of a project which can lead to project failure. BIM has promised to improve this process by reducing the need to communicate as regularly as before per its capabilities of providing real time information. Based on the responses received and as evidenced by attachment 7, about 52% of the participants confirmed that they think BIM improves the communication process by 70 to 100 percent. This number even though is showing that more than half of the survey participants agree that BIM improves the communication process, still about half of the participants do not agree that BIM has a significant impact on improving communication process.

Question 7 of the survey asks respondents about BIM's impact on increasing the efficiency of the project documentation. On AEC projects, documentation has direct relationship with coordination. The easier and the more effective the coordination, the efficiency of documentation increases. An efficient documentation process means saving time and thus saving cost and thus wider profit margins for all stakeholders involved in any project. Based on the responses received

and as evidenced by attachment 8, about 54% of the respondents agree that BIM will improve the efficiency rate by 70 to 100 percent. This is supporting the advantages of BIM as outlined in the introduction section as well as scholars' work analysis in the literature review section.

Questions 8 and 9 were designed to evaluate whether BIM adoption has been slower than anticipated simply because not all stakeholders involved in such projects agree to utilize this tool. As discussed previously, there are many different stakeholders involved in any given AEC project. These stakeholders are working for different organizations. It is expected that not all of them utilize same methodologies in their everyday practice. Thus, participants were asked to indicate how hard it is to convince these external stakeholders to utilize BIM over the traditional methodology.

Question 8 asks participants to indicate how hard it is to convince clients to utilize BIM based on a scale of 1-10 (1 being the easiest and 10 being the hardest). Based on the responses received and as evidenced in attachment 9, only 3 participants responded by a number more than 5. 14 participants responded by a number lower than 3. This finding means that clients do not place barriers or define the methodology used as long as the end results they receive meets their base requirements.

Question 9, asks participants to indicate how hard it is to convince other external stakeholders to utilize BIM based on a scale of 1-10 (1 being the easiest and 10 being the hardest). Based on the responses received and as evidenced by attachment 10, 8 of the participants responded with a number higher than 5. This finding supports the point made earlier in this section. It seems like it is sometimes hard for the architects who are the sole entities reliable for managing the projects successfully, to convince other stakeholders involved to utilize BIM. This finding also supports the points made in the problem statement about lack of technical knowledge of BIM software among the stakeholders involved in AEC projects.

Questions 10 and 11 were designed to validate the points made by Almeida and Brasil de Brito Mello regarding BIM and its impact on organizational changes that BIM will eventually result. As discussed in the literature review section, Almeida and Brasil de Brito claim that BIM is more than just a tool. The authors assert that BIM eventually will alter the organizational processes and many organizations decision makers are not willing to make such change within the already well-established structure.

Question 10 asks participants to indicate how much they think BIM has altered project management processes in their organization. Based on the responses received and as evidenced by attachment 11, all respondents agree that BIM has altered project management processes by more than 40 percent. This number supports the claim by Almeida and Brasil de Brito and is an indication that BIM should be considered more as a project management tool rather than a drafting software. This finding also supports the points made in the problem statement section of this paper that BIM adoption rate has been slower than anticipated due to the managerial reasons.

Question 11 asks participants to indicate how hard it is to convince upper management to utilize and adopt BIM into AEC projects. Based on the responses received and as evidenced by attachment 12, 7 participants responded with a number equal or greater than 5. This finding along with the findings of question 10, is a proof to the claim that organizations and their decision makers tend to avoid altering their already established processes. This finding indicates that one major reason for slower adoption of BIM is such managerial and political reasons within the organizations and not because of BIM capabilities.

Question 12 was designed to validate a point made by Sawhney, Khanzode, Triwari in their research article in 2017. The authors of that article claimed that BIM cannot be prescribed for all project sizes and that the slower adoption or failure of projects that implement BIM might be

because it was used for the wrong project in terms of size. The participants of this survey were asked to indicate what project size would benefit the most from BIM adoption and implementation. 15 participants (88 percent) responded that size of the project is irrelevant. This finding indicates that the claim made by Sawhney, Khanzode and Tiwari might not be valid in the real-world application and among the industry professionals.

Conclusion

This study has investigated the current status of BIM acceptance rate, the root causes why BIM's adoption has been slower than anticipated, benefits and advantages of BIM implementation and BIM adoption's challenges and barriers.

Throughout the literature review and the quantitative survey, it was determined that BIM will be the future of AEC industry because of its capability in producing real time three-dimensional information in one single platform. The findings of the literature review as well as the survey results' analysis indicated that this feature of BIM, results in a significant improvement in communication, coordination and production efficiency on AEC projects. This improved efficiency will eventually result in reduced time and thus reduced cost of the projects. This then in turn translates into wider profit margin for all stakeholders involved in any given AEC projects.

However, despite the advantages of BIM discussed through this research paper, it is also determined that BIM acceptance rate is not as expected, and that the adoption rate has been slower than anticipated. The literature review suggests the following reasons for such slower adoption:

1. Lack of technical knowledge: Since BIM is a new concept and it is still in its early stages of utilization. Thus, the technical knowledge of BIM is not yet comprehensive amongst stakeholders. Some disciplines use it more extensively while some disciplines

involved do not even have in house staff who knows BIM. The alignment of technical skill between the stakeholders is crucial in BIM's successful implementation.

2. Managerial reasons: This category is divided as follows:
    a) Organizational uptake: The literature review findings as well as the survey results indicate that BIM alters project management processes. Such paradigm shift suggests an organizational project management practice change. Some organizations are not willing to alter their already established methodologies and practices easily. As a result, it is often hard to convince the upper management to utilize BIM.
    b) Lack of knowledge on how BIM alters project managers' roles compared to the traditional methodology: The synthesis of literature review as well as the survey result suggests that BIM alters project managers' roles and might even introduce new roles into the AEC projects. Lack of full understanding on how BIM alters such roles can be detrimental to the project management as a process.
3. Lack of support from government agencies: A study done on BIM in UK's AEC industry elaborated on the importance of governmental support on BIM acceptance and utilization rate. Currently, government agencies do not force BIM utilization. Thus, there has not been any effort in producing a standard roadmap or guideline on how to utilize BIM effectively and successfully on AEC projects.
4. Lack of in depth training and academic programs: Throughout the literature review it was indicated that currently, the academic environment does not cover BIM concept as a focused study. Individuals in the AEC industry learn how to use BIM and BIM related

software on their jobs. Thus, they do not receive well training before entering the business.

Recommendation

Future studies should consider performing qualitative study in order to gain lived experiences of the BIM users based on their project management exposure. The future studies can also benefit from surveying individuals from different stakeholders that AEC industry projects usually utilize to get feedback from different entities involved.

Future studies may also consider comparing BIM perceptions among architect without project management experience and those with project management experience to be able to synthesis the relationship between technical and managerial aspects of BIM.

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Appendix

Attachment #1

Position:

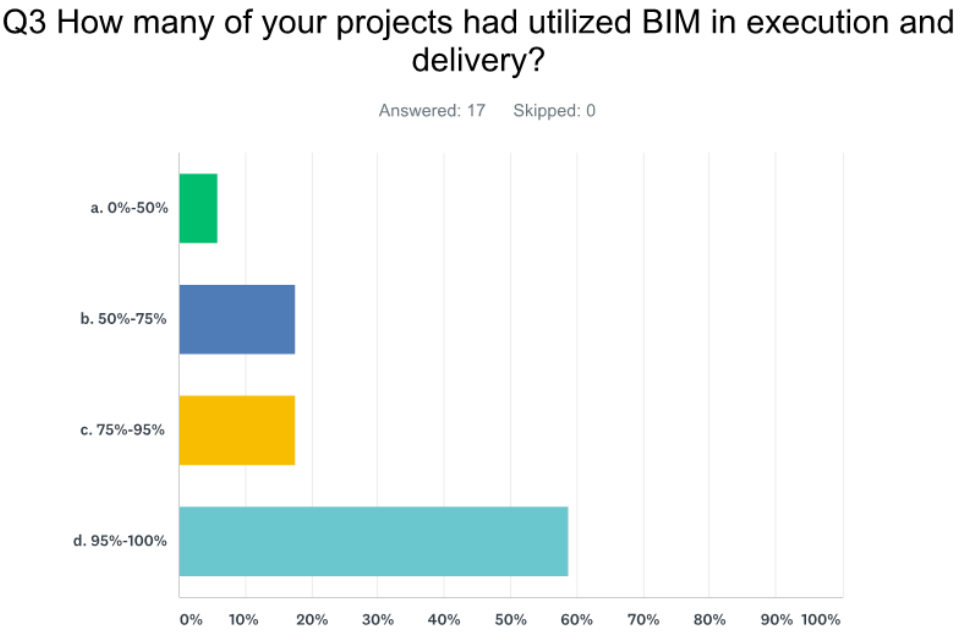
Years of Experience with Building Information Modeling:

1. **How many of your projects had utilized BIM in execution and delivery?**
a. 0%-50%
b. 50%-75%
c. 75%-95%
d. 95%-100%
2. **How significantly does BIM alter the project management process in your projects compared to traditional methodology (CAD)?**
a. 0-25%
b. 25%-50%
c. 50%-75%
d. 75%-100%
3. **By what percentage does BIM improve coordination in your projects?**
a. 0-25%
b. 25%-50%
c. 50%-75%
d. 75%-100%
4. **By what percentage does BIM improve communication in your projects?**
a. 0-25%
b. 25%-50%
c. 50%-75%
d. 75%-100%
5. **By what percentage does BIM improve the efficiency of documentation?**
a. 0-25%
b. 25%-50%
c. 50%-75%
d. 75%-100%
6. **On a scale of 1-10 (1 being the easiest and 10 being the hardest), how hard is it to convince your clients to use BIM for project delivery?**
7. **On a scale of 1-10 ((1 being the easiest and 10 being the hardest), how hard is it to convince your external stakeholders to use BIM for project execution?**
8. **By what percentage does BIM alter organizational project management processes in your company?**
a. 0-25%
b. 25%-50%
c. 50%-75%
d. 75%-100%

9. **On a scale of 1-10 (1 being the easiest and 10 being the hardest), how hard is it to convince upper management to utilize BIM for project execution?**
10. **What project size would benefit the most from BIM utilization?**

a. 500-20,000 sq. ft.
b. 20,000-100,000 sq. ft.
c. 100,000 sq. ft. and up
d. Size is irrelevant

Attachment #4

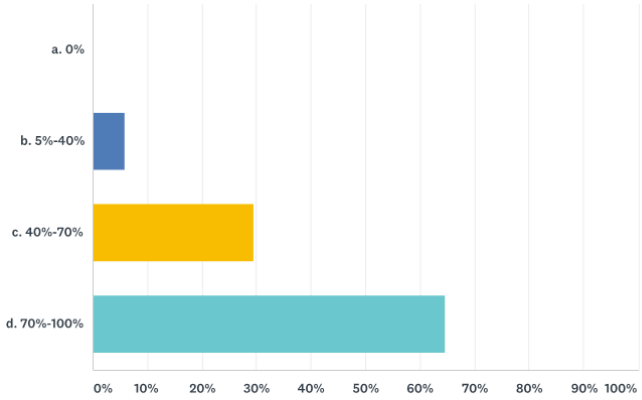


ANSWER CHOICES	RESPONSES	
a. 0%-50%	5.88%	1
b. 50%-75%	17.65%	3
c. 75%-95%	17.65%	3
d. 95%-100%	58.82%	10
Total Respondents: 17		

Attachment #5

Q4 How significantly does BIM alter the project management processes in your projects compared to traditional methodology (CAD)?

Answered: 17 Skipped: 0

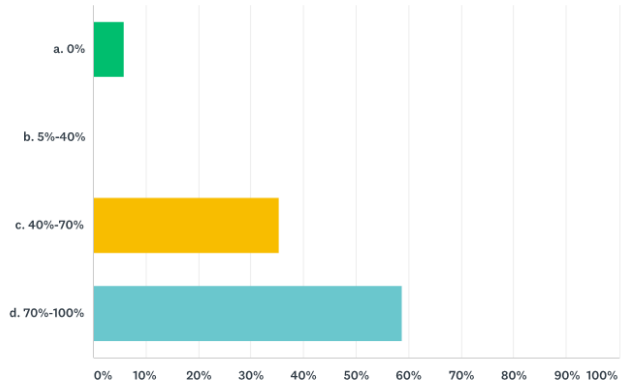


ANSWER CHOICES	RESPONSES	
a. 0%	0.00%	0
b. 5%-40%	5.88%	1
c. 40%-70%	29.41%	5
d. 70%-100%	64.71%	11
TOTAL		17

Attachment 6

Q5 By what percentage does BIM improve coordination in your projects?

Answered: 17 Skipped: 0

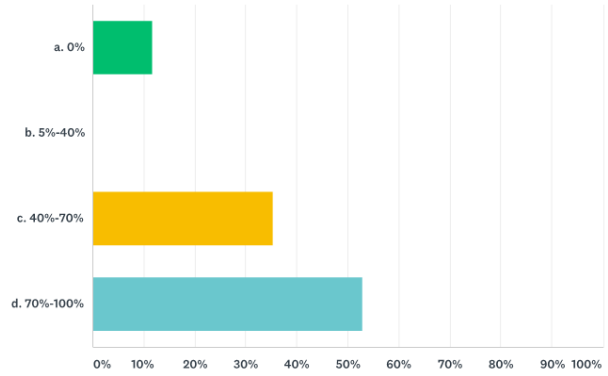


ANSWER CHOICES	RESPONSES	
a. 0%	5.88%	1
b. 5%-40%	0.00%	0
c. 40%-70%	35.29%	6
d. 70%-100%	58.82%	10
TOTAL		17

Attachment 7

Q6 By what percentage does BIM improve communication in your projects?

Answered: 17 Skipped: 0

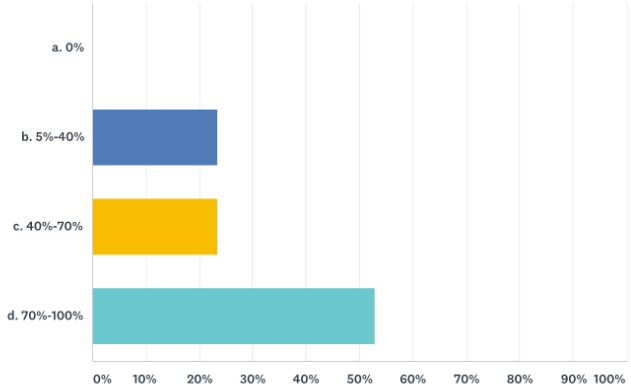


ANSWER CHOICES	RESPONSES	
a. 0%	11.76%	2
b. 5%-40%	0.00%	0
c. 40%-70%	35.29%	6
d. 70%-100%	52.94%	9
TOTAL		17

Attachment 8

Q7 By what percentage does BIM improve the efficiency of documentation?

Answered: 17 Skipped: 0



ANSWER CHOICES	RESPONSES	
a. 0%	0.00%	0
b. 5%-40%	23.53%	4
c. 40%-70%	23.53%	4
d. 70%-100%	52.94%	9
TOTAL		17

Attachment 9

Q8 On a scale of 1-10 (1 being the easiest and 10 being the hardest), how hard is it to convince your clients to use BIM for project delivery? *please use whole numbers only

Answered: 17 Skipped: 0

#	RESPONSES	DATE
1	3	6/26/2018 9:37 PM
2	1	6/26/2018 5:12 PM
3	1	6/26/2018 8:17 AM
4	3	6/25/2018 12:36 PM
5	2	6/25/2018 12:30 PM
6	7	6/25/2018 9:52 AM
7	1	6/25/2018 9:31 AM
8	8	6/25/2018 9:22 AM
9	6	6/22/2018 8:25 AM
10	3	6/21/2018 9:16 AM
11	2	6/21/2018 8:19 AM
12	1	6/21/2018 8:13 AM
13	3	6/20/2018 3:23 PM
14	3	6/20/2018 3:05 PM
15	N/A	6/20/2018 2:52 PM
16	1	6/20/2018 2:47 PM
17	1	6/20/2018 2:33 PM

Attachment 10

Q9 On a scale of 1-10 (1 being the easiest and 10 being the hardest), how hard is it to convince your external stakeholders to use BIM for project execution? *please use whole numbers only

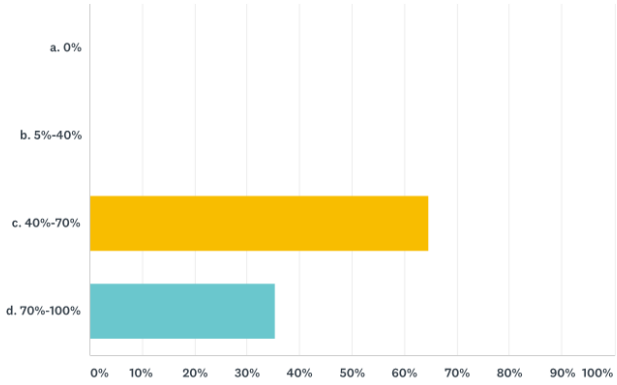
Answered: 17 Skipped: 0

#	RESPONSES	DATE
1	7	6/26/2018 9:37 PM
2	8	6/26/2018 5:12 PM
3	1	6/26/2018 8:17 AM
4	3	6/25/2018 12:36 PM
5	2	6/25/2018 12:30 PM
6	7	6/25/2018 9:52 AM
7	5	6/25/2018 9:31 AM
8	8	6/25/2018 9:22 AM
9	6	6/22/2018 8:25 AM
10	3	6/21/2018 9:16 AM
11	2	6/21/2018 8:19 AM
12	1	6/21/2018 8:13 AM
13	5	6/20/2018 3:23 PM
14	3	6/20/2018 3:05 PM
15	N/A	6/20/2018 2:52 PM
16	6	6/20/2018 2:47 PM
17	2	6/20/2018 2:33 PM

Attachment 11

Q10 By what percentage does BIM alter organizational project management processes in your company?

Answered: 17 Skipped: 0



ANSWER CHOICES	RESPONSES	
a. 0%	0.00%	0
b. 5%-40%	0.00%	0
c. 40%-70%	64.71%	11
d. 70%-100%	35.29%	6
TOTAL		17

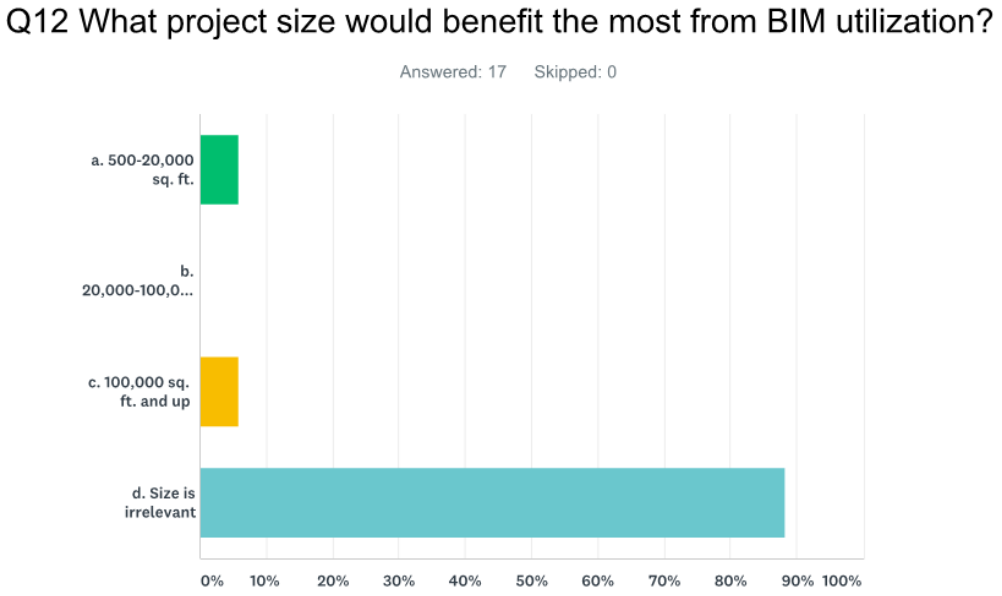
Attachment 12

Q11 On a scale of 1-10 (1 being the easiest and 10 being the hardest), how hard is it to convince upper management to utilize BIM for project execution? *please use whole numbers only

Answered: 17 Skipped: 0

#	RESPONSES	DATE
1	5	6/26/2018 9:37 PM
2	1	6/26/2018 5:12 PM
3	3	6/26/2018 8:17 AM
4	3	6/25/2018 12:36 PM
5	4	6/25/2018 12:30 PM
6	3	6/25/2018 9:52 AM
7	5	6/25/2018 9:31 AM
8	8	6/25/2018 9:22 AM
9	7	6/22/2018 8:25 AM
10	4	6/21/2018 9:16 AM
11	4	6/21/2018 8:19 AM
12	5	6/21/2018 8:13 AM
13	8	6/20/2018 3:23 PM
14	1	6/20/2018 3:05 PM
15	3	6/20/2018 2:52 PM
16	5	6/20/2018 2:47 PM
17	3	6/20/2018 2:33 PM

Attachment 13



ANSWER CHOICES	RESPONSES	
a. 500-20,000 sq. ft.	5.88%	1
b. 20,000-100,000 sq. ft.	0.00%	0
c. 100,000 sq. ft. and up	5.88%	1
d. Size is irrelevant	88.24%	15
TOTAL		17