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Building Information Modeling (BIM) outsourcing among general contractors

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ABSTRACT

Building Information Modeling (BIM) is a process used by Architecture Engineering Construction (AEC) stakeholders which simulates a construction project in a multi-dimensional digital model and provides multitudes of project benefits from project inception to its occupancy. However, a variety of barriers impede a holistic BIM implementation. Due to these barriers, some general contractors outsource the creation and use of BIM models to specialized Information Technology (IT) firms. Since limited literature currently exists for BIM outsourcing, this study aims to identify BIM outsourcing patterns among the general contractors across the US and the perceived impacts it has on construction projects. Analysis of two-hundred and fifty-two complete responses from general contracting firms determines that 45% of responding companies have outsourced BIM, this signifies that outsourcing has become an important facet of BIM implementation. Data was also collected on company demographics, BIM outsourcing locations, strategic reasons for outsourcing, and various other aspects related to BIM outsourcing. The results indicate that respondents perceive BIM outsourcing as less efficient than in-house BIM implementation. However, continued use of outsourcing for BIM functions also displays the adaptability of the industry in meeting challenges and embracing new technology through alternative methods, despite the potential risks.

1. Overview

The US is a major consumer and producer of Building Information Modeling (BIM) products and solutions [1]. The rapid adoption of BIM services and products is attributed to the benefits it offers to adopting companies. Some primary benefits, perceived by project stakeholders, include enhanced efficiency, opportunities to boost collaboration among project stakeholders, better visualization [2–5], improved project sustainability [6], integration of building systems, and conflict resolution [7]. Additionally, BIM adoption can result in a positive return on the BIM investment for project stakeholders through savings from reduced project costs [8–10]. The various benefits generated by BIM implementation to a potential adopter can be associated with the numerous functions provided to assist designers, contractors, owners, and other project stakeholders. For these reasons, many project owners, such as General Services Administration (GSA), Veterans Affairs (VA), State of Wisconsin, and other public as well as private owners are requiring BIM adoption on their projects [31–33]. However, BIM adoption has its own set of complexities that include inadequate software interoperability [8,11,12], additional (hard and soft) costs, and lowered productivity at the beginning stages of implementation. Using content analysis, Criminale and Langar [34] identified thirty-six challenges with BIM implementation that may impact at either a project or organizational level. These identified challenges are hindering accelerated and holistic BIM adoption throughout the construction industry.

Given the mix of advantages and challenges associated with a holistic BIM adoption, different BIM implementation strategies have been explored by adopting companies to address their individual needs. Mulder and Heintz [40] investigated CAD outsourcing among Dutch Architects and the benefits of incorporating the same among the adopters. The study indicated that three major strategies could achieve outsourcing: establishing an office in the remote area, buying services from independent specialized companies, & a hybrid strategy of contracting specialized companies (mostly offshore) for temporary services and keeping them involved throughout the process. The first two methods were two extremes regarding energy, money, and time invested by the firms that outsourced tasks. The hybrid strategy of contracting specialized companies for temporary services and keeping

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them involved throughout the process was indicated as one that was offering more benefits than the earlier two types, and it reduced the risks. Given how a project may be outsourced, the authors believe that complete in-house use, partial in-house/outsourcing, and fully outsourcing BIM processes are some of the strategies that are used by the adopting General Contracting Companies.

In the course of benchmarking BIM implementation among construction professionals within the US, Ku and Taiebat [12] found that outsourcing certain BIM functions was an existing strategy. However, many of their respondents were implementing BIM functions in-house at the time of the study. The study also found two primary barriers to BIM implementation: "*Cost/Time constraint* and a *Lack of skilled professionals*." Criminale and Langar [34] also identified "*Time needed for hiring/training people to use BIM, cost of hiring or training people to use BIM, and no official standard or process to evaluate BIM use*" as the most identified challenges associated with organizational BIM implementation. In summation, some of the most frequently encountered challenges with BIM implementation are resource intensiveness (temporal and monetary factors), a skilled workforce requirement, and a potential adopter's holistic understanding of BIM. Given that BIM outsourcing may address challenges associated with its implementation among general contractors, this suggests that companies are adopting BIM outsourcing services offered by specialized Information Technology (IT) firms rather than using in-house BIM personnel for the creation and application of their BIM models. Further, strategic reasons for outsourcing BIM include globalization, information digitization, and standardization of certain architectural aspects, which may facilitate outsourcing [19,40], resulting in benefits such as cost reduction and improved business performance [13]. However, because outsourcing adds a new dynamic to the traditional BIM process, it may affect how BIM is used as well as the recognized impacts BIM usage has on projects. A 2008 McGraw-Hill Construction study [14] suggests that general contractors are more likely to outsource BIM functions than other project stakeholders, such as Architects or Engineers, but general contractors are less likely to outsource than Project Owners. It also found that only 7% of the contractors outsourced BIM in 2008 but expected the number of contractors associated with the practice to increase considerably over the years.

Since the limited available literature on BIM outsourcing indicates its usage is increasing [8,12,14], the goal of this study was to determine BIM outsourcing patterns among general contractors in the US for an understanding of the significant role BIM outsourcing plays in modern BIM usage. This study also identified the reasons for outsourcing, the perceived value generated by the process of outsourcing, and the geographic locations of which such tasks were outsourced. Data on company demographics, outsourcing practices, BIM functions commonly implemented by contractors, and the functions often outsourced were analyzed to examine possible relationships. This study tested the following hypotheses:

- Contractors primarily outsource BIM to ease the transition into developing and using in-house BIM capabilities.
- In-house BIM usage is perceived as having a more positive project impact than outsourcing BIM.
- A positive correlation exists between company annual revenue and BIM outsourcing.

1.1. Definitions of Building Information Modeling (BIM) and BIM outsourcing

BIM can be adopted and implemented in numerous ways [15,16], but it is essentially a software-facilitated process used by architects, engineers, and contractors in the construction industry [15]. The use of BIM models is an integrated process, but designers and contractors can derive many functions from its use. For example, Ku & Taiebat [12] identified seventeen different BIM functions that contractors could use, and Langar & Pearce [5] identified sixteen different BIM functions that designers could use to assist in the completion of a project. Of these identified functions, nearly 50% did not overlap and were determined as specific to either the architecture or construction industry. Therefore, though all stakeholders in a project can use BIM functions, such as visualization, constructability, and others, certain functions exist which are specific to the individual stakeholder.

At a generalized level, McGraw-Hill Construction defines BIM as "*The process of creating and using digital models for design, construction, and/or operations of projects*" [8]. Such digital models are meant to "*simulate the construction project in a virtual environment*" [9]. In the context of general contractors, BIM functions may integrate components of construction, including three-dimensional modeling, scheduling, resource allocation, estimating, code analysis, clash detection, and lifecycle management, into building objects in a virtual structure for the compilation of all project information [17]. Holistic adoption of these capabilities by a stakeholder can often create a domino effect for other stakeholders in a project, potentially leading to increased collaboration through BIM processes and greater overall efficiency. Another perspective about BIM can be observed in Succar's definition: "*a set of interacting policies, processes, and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle*" [18]. Succar's definition interprets BIM as a comprehensive process, and a subcomponent can be identified as the act of using a 3-dimensional, data-rich, object-oriented, and parametric model of a project. The project model consolidates all incorporated project information in a format from which stakeholders can extract and analyze information for decision-making. This formatted project model includes conformation to owner's specified project requirements as well as efficient delivery of the project. This study focuses on digital BIM models as a software tool for use in the collection of project information, rather than the all-encompassing processes and policies of the BIM concept, which companies may adopt.

BIM outsourcing is a field that is in a developmental state, and therefore limited research exists on the topic. Del Villar and Pollalis define outsourcing of architectural services as, "*separating their core operational processes from their non-core support and production processes, instead of using third parties to perform those processes for them*" [19]. The study also identified that the goal of outsourcing is to support and complement process, and not eliminate or substitute [19]. However, establishing a clear distinction between core and non-core tasks in an architectural office is very difficult and in most times is contextual [19]. For design intensive firms, design and associated tasks that support the creative endeavors of the firm can be termed as core tasks. Other ancillary tasks that support the design firms goals can be termed as non-core tasks. According to the authors [19], tasks that have a clear scope, have a low creative impact on architectural firms identity or outcome, have low-design content, require limited expertise, or involve repetitive actions are highly probable to be outsourced to third parties. These tasks translate to *rendering images*, *model making*, *drafting* and others in an architectural office, as per the authors [19]. However, when translating the study to a BIM environment, the complexity is magnified because BIM functions are contextual to an adopting stakeholder. Thus, BIM functions that may be considered non-core for a designer may not be categorized the same for a contractor. Additionally, not all contractors possess similar specializations or focus areas. At the same time, certain BIM tasks that have a clear outcome, require limited input from the company, and can have a low project impact can be easily outsourced to both contractors and architects. In this regard, *visualization*, *presentations*, *clash detections*, and *other* BIM functions that can be associated with a similar profile have a high probability of being outsourced with ease.

For this study, BIM outsourcing is defined as "*the contracting out creation and/or use of a BIM model by an organization for a project to a third-party that specializes in the BIM process*." It is assumed in this study that the companies to which such tasks are outsourced possess the

expertise to complete tasks allocated by the general contracting company. The use of outsourcing BIM functions is not hindered by geographical location and can withstand any distance between the organizations that use it. BIM can also be outsourced by any stakeholder (general contractor, owner, architect, and others) associated with a construction project. However, the scope of this study is limited to identifying BIM outsourcing trends among general contractors located within the US.

1.2. BIM background & purpose

Researchers have discussed the concept of BIM since the emergence of Computer-aided Design (CAD) tools a few decades back. However, at that time, the extent of the concept was a three-dimensional building model enriched with some additional graphical information [20]. Over the years, BIM has transformed to surpass concepts discussed in previous decades. Current BIM tools are parametric with user-defined rules which automatically update input changes up to the fabrication level [21]. Multiple software suites developed by software companies' offer specialized solutions that can potentially capture almost all relevant project information [22]. Also, the amount of information integrated with a building model has substantially improved.

The broad scope of modern potential BIM usage incorporates data management from the initial design and throughout a building's lifecycle [23]. This potentially provides the owners with an as-built model and helps the owners/facility managers with operations and maintenance during occupancy. Given the complexities associated with project and stakeholder requirements, tools in BIM software suites have been developed for diversely functional areas of construction, design, and life-cycle management. However, based on their specific needs and strategic plans, many companies determine specific areas they want to focus their efforts instead of attempting to use comprehensive BIM implementation. This has been observed in multiple studies that aimed to identify BIM adoption and implementation trends [8,12,14,24,25]. The reasoning attributed to this observation is that each BIM function implemented within an organization requires a significant amount of investment, experience, and knowledge for use. Thus, for strategic BIM implementation, some general contractors might become prone to focusing on certain BIM functions more than others.

BIM provides stakeholders with a remarkable ability to execute a project in a virtual and controlled environment, which was impossible in previous decades. The benefits of this type of BIM have been identified previously in this paper, documented in academic reports, and stated by many organizations who have used or studied the process [2–7]. However, they are not always apparent in individual projects. Some of the areas where positive impacts were reported more often than negative over a wide variety of projects include coordination improvement, scope clarification, project duration, quality, cost reduction or control, organization, communication, and risk management [10]. However, both BIM positives and negatives are contextual and vary by project due to differing factors, such as the variability of project types and characteristics of adopting organizations.

Due to the limited literature on outsourcing BIM among GC, the effect it has on the impacts of BIM for individual projects is unclear. A study discussing outsourcing of architectural services among architects, a practice somewhat similar to BIM outsourcing by contractors, noted that some limitations, tradeoffs, and constraints occur when choosing to outsource. The firm "*surrenders some level of control on their project*" by outsourcing, but it gains a "*meaningful support team*" [19]. However, the objective of increasing overall efficiency of a project in outsourcing BIM is still the same as the objective when using traditional in-house BIM.

1.3. Barriers to BIM adoption

Even though there is little consensus on the exact population of firms adopting/implementing BIM within the construction industry in the US, a consensus has emerged among researchers and industry professionals indicating that the number of companies adopting/implementing BIM is steadily increasing. Studies conducted by McGraw-Hill Construction [8,26] identify that BIM use among general contractors rose from 50% to 74%. The trend stands for the rest of the Architecture Engineering Construction (AEC) industry, which is evident by its continuous growth over time. Additionally, rising BIM use is found across all sizes of firms, and it increases with firm size. Larger companies reported ninety-one percent adoption, while smaller companies reported 49% in 2012 [26].

Though the trend in the industry appears to favor BIM adoption (especially for larger organizations), prospective adopters should be wary of potential obstacles. Barriers to BIM implementation and use of the latest BIM technology include intensive software training requirements, high upfront costs, and a lack of support from leaders who prefer more traditional approaches [20]. Significant resources (temporal and monetary) must be invested into an in-house BIM implementation for maximum effectiveness, and some organizations are cautious of risking the possibility for a low or negative return on investment. Another obstacle to BIM implementation is software interoperability between participating agencies in the project. Several programs developed to facilitate BIM lack a universal file format. So, one stakeholder's software may be ineffective with models created by another party or those currently being used, unless they have invested in the same program [20].

Contractual risks also affect parties involved in BIM use because it is a new technology, and laws are not in place for the protection of those who use it. One problem lies in the complexities associated with model ownership after project completion. An owner might feel entitled to the model since they spent resources on it; however, the organization responsible for its creation and use could have proprietary information included that would warrant protection. Also, in the event of errors, determining liability and reparations may prove difficult because models are continually built upon with contribution from multiple parties [9]. Further, due to the nature of the process, a stakeholder using resources to maintain the BIM model may not be the party reaping the gains of project efficiency that offset the BIM costs. These, in addition to other issues, such as a lack of updated BIM implementation standards and contract obligations, pose barriers to BIM implementation [20].

Despite barriers, project stakeholders increasingly adopt BIM, and some owners require its use in their projects. Thus, a continuous challenge exists for general contractors to identify the best strategy for BIM implementation. Certain firms are consistently analyzing the value of complete In-house BIM implementation vs. the benefits offered by outsourcing BIM as an alternative, which entails delegating some risks and barriers to a specialized entity.

1.4. Reasons for the outsourcing of BIM

The outsourcing of IT activities in certain industries, not specific to construction, is not a new phenomenon and roots back to the 60's and 70's [27]. Many reasons exist to legitimize the decision by companies to outsource certain tasks as well as strategies for effectiveness. The traditional rationale for outsourcing is based on economies of scale and scope for an immediate financial benefit to the company having tasks outsourced. Particularly small and medium-sized enterprises may find that certain IT business processes may be cheaper and performed more effectively by other specialized and larger IT firms than when performed in-house [28]. However, even larger firms, in which the economies of scale rationale are not as evident, choose to outsource certain BIM tasks for the strategic benefit [8]. One such strategy these companies could be demonstrating is "commercial exploitation," where partnerships between the company and the outsourcing firm exist to minimize the risk and share the reward [13]. These are less the buyer-seller relationships of economies of scale, and they are more the alliances which focus on strategic initiatives together [27].

It is unclear which strategies are used by general contractors and

their purposes because of limited literature on the topic, but it is evident that BIM outsourcing is occurring in the AEC industry [19]. Possible benefits of BIM outsourcing include prevention of the primary barriers associated with BIM adoption. High investment in hardware, software, training, and other upfront costs associated with BIM implementation are not as inevitable for contractors because they do not necessarily have to maintain full in-house capabilities to use BIM. Moreover, the implementation of BIM outsourcing may differ by the contractor as each contractor has their own specific identity and tend to focus on specific services they can offer or the expertise they possess. In addition, the company size (annual revenue), geographic location, and cash liquidity can potentially impact on the contractor's ability strategize BIM implementation. Also, some contractors may outsource every functional area of BIM, others may outsource specific responsibilities while executing others in-house, and the remaining may perform all BIM tasks in-house. Likewise, project/owner requirements may influence the decision of a general contractor to outsource functions. Therefore, implementation of BIM outsourcing is company specific based on the method chosen and company beliefs regarding which strategy is the best investment to meet its goals.

The study aimed to understand BIM outsourcing patterns among general contractors in the US construction industry and to identify whether BIM outsourcing plays a significant role in overall BIM implementation. The study also identified reasons for BIM outsourcing, the value generated by the process of outsourcing, and the geographic locations to which responsibilities were outsourced. Company demographics, outsourcing practices, and BIM functions commonly implemented and outsourced by the general contractors were also analyzed. The study further investigated relationships between company demographics and BIM outsourcing. The three hypotheses listed earlier were also tested.

2. Method

A survey method was used to achieve the identified goals for the study. The method allowed researchers to collect data from a significant number of respondents, which permitted trend identification and determination of relationships at a given point in time [35]. Of the various methods available for conducting a survey [36,37], an online method was selected for the following reasons:

- A majority of the general population (e.g., general contractors) have access to the internet.
- Increased likelihood of prompt responses [38].
- Previous studies have used survey methods to identify implementation patterns for IT both outside and within the construction industry [25,26,36].
- Ability to identify undelivered survey invitation emails [30].
- The value generated by an online survey outweighed other methods [30].

The instrument was developed using an online tool (Qualtrics.com) and had four broad categories: company demographics, BIM usage, BIM outsourcing, and perceptions about BIM outsourcing. Evidence exists on both sides identifying a relationship between survey length and response rates [30]. The survey was designed so that respondents could typically finish within 10 min to mitigate potentially negative impacts associated with survey length.

In addition, the reliability and validity of the survey instrument were addressed through pilot testing. The instrument was pilot tested by three senior professionals (general contractors) and over fifteen graduate students from a research university. Upon completion of the pilot test, respondent recommendations improved the clarity of language, question comprehension, and survey aesthetics.

The target population of the study was general contractors geographically located within the US. For 2016, preliminary data from the Bureau of Labor Statistics (BLS) indicated that there were approximately 775,000 private companies associated with construction industry located within the US [39]. With a 5% margin of error and confidence level of 90%, it was determined that two-hundred and seventy General Contractor companies were the recommended sample size. However, surveys are often prone to poor response rates due to multiple considerations, such as a high amount of emails received by respondents, use of e-mail filters by those surveyed, changing and accuracy of email addresses, firewall issues, and more [25,30]. To account for a poorer potential response rate, there was an attempt to reach a large sample size. Thus, an invitation to complete the survey was distributed via e-mail to representatives from over one thousand and eight-hundred general contractors across the US with cooperation from a construction IT firm. The invitation to participate in the study was also e-mailed to member institute representatives of the Associated Schools of Construction (ASC) listserv with the request to forward the email to general contractors on their schools' Industry Advisory Boards (IAB).

Researchers have indicated that a follow-up after the initial survey increases the response rate [25,29,30], so three reminders to complete the survey were sent via e-mails. Each reminder was sent once a week. The response rate improved considerably after sending three reminders, thus validating that follow-up emails have a positive impact on the survey response rate.

The survey was active for approximately four weeks. Upon deactivation, a total of 460 responses were collected (response rate of 25.5%) and downloaded. All responses with significant missing data and duplicate responses were eliminated, resulting in the effective number of responses reducing to 252 (response rate of 14%, approximately) general contracting firms. Research indicates that it is difficult to obtain a high response rate for online surveys due to numerous reasons, such as information overload, an increasing number of online surveys generated in recent years, and other factors [30]. Thus, the effective response rate of 14% was accepted for this study.

After compiling all cleaned data, descriptive statistical analysis was conducted to identify the implementation patterns of BIM and BIM outsourcing practices among respondents located within the country. A Chi-square test was conducted to examine a possible relationship between BIM implementation/outsourcing and company demographics. The Chi-square test was conducted as the two categorical variables (BIM and Company annual revenue) were with reference to a single population (General Contracting Firms). In order to test the strength of the relationship, Cramer's V test was conducted to measure the degree of association. Additionally, a logistic regression model was applied to investigate a possible relationship between a Company's BIM Experience (years) and BIM outsourcing. Further, the researchers conducted an odds ratio (OR) to measure the probability of success for one group over that of another group. Odds ratio has been identified by Liao [41] as a useful tool in categorical data analysis for the use of analyzing associations. All statistical analyses (Chi-square, Cramer's V, logistic regression, and odds ratio) were conducted in STATA/MP 14.2 software.

3. Results

As the survey period ended, approximately 460 responses were collected from general contracting firms, indicating a response rate of approximately 25.5%. Upon closer examination of the responses, it was recorded that 302 of the 460 (65.65%) responses were complete with no significant missing data.

Because the study aimed to identify a relationship between BIM outsourcing and general contracting firms in the US construction industry, only one response from each firm was accepted. By doing so, the effective number of responses was reduced to 252 (with a response rate of 14%, approximately) general contracting firms.

3.1. Survey demographics

Figs. 1–4 depict the breakdown of the survey respondents'

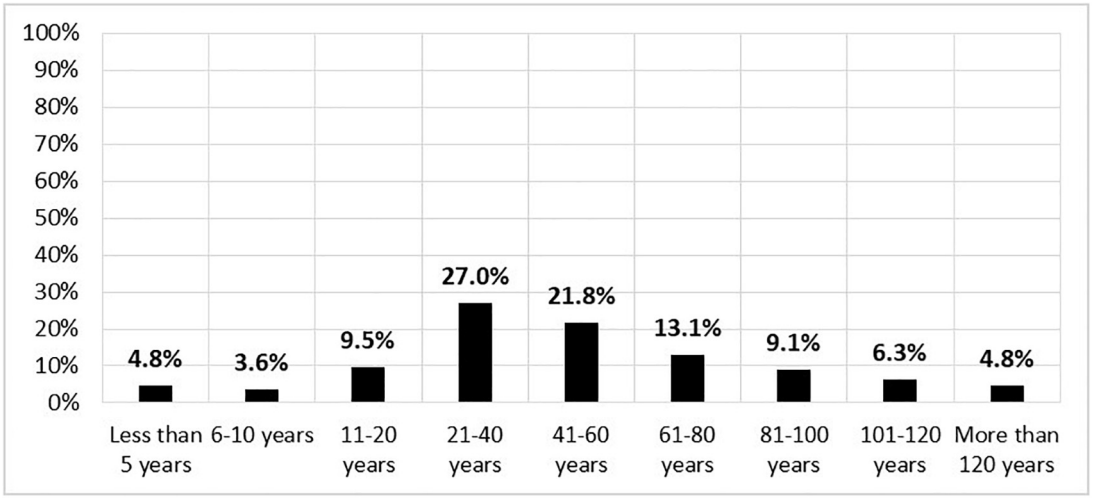

Fig. 1. Company construction experience (Years).

demographic information by company experience (years), average annual revenue (Million USD), geographic location, and executed project types. Responses were collected from contractors in all demographic ranges, but those with 21–40 years of experience, locations within Southern US states, and average annual revenue of $100–$499 Million were the most represented demographics.

3.2. BIM outsourcing trends

Seventy-two percent of all responding contractors reported BIM use within the past ten years. This percentage resembles the 74% identified by McGraw-Hill Construction (2012) survey [26] and emphasizes that the results found in this study are indicative of BIM usage among contractors in the industry as a whole. Of the companies who reported BIM use in the past decade, 62% reported having outsourced some aspect(s) of BIM processes to specialized IT firms. 45% of all respondents reported outsourcing BIM to some degree (Fig. 5).

When the contractors who reported outsourcing BIM were asked to identify which geographic locations they outsourced to, the two countries primarily reported were the US (94.7%) and India (22.1%). China and the Philippines followed the two with only 3.5% of contractors outsourcing to each nation. Other IT outsourcing hubs were also reported (Brazil, Mexico, Australia, Romania, Malaysia, and Poland), as indicated in Fig. 6. However, each of these account for < 3%. Fig. 6 displays the percentage of contractors outsourcing to each country. The percentages exceeded a total > 100% because many contractors reported outsourcing to more than one country. Evidence indicates that most US contractors are outsourcing a vast majority of projects to specialized IT firms geographically located within the US rather than offshore locations.

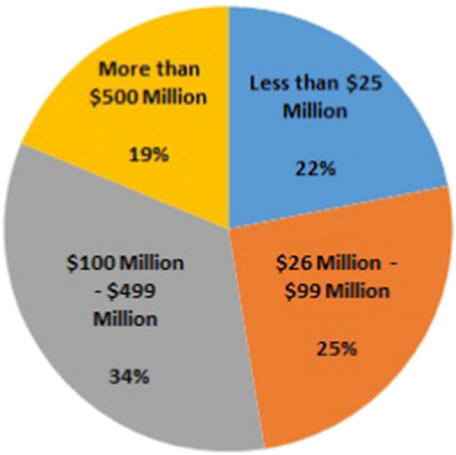

Fig. 2. Company annual revenue.

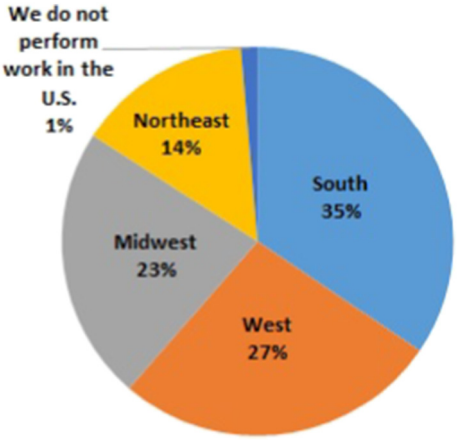

Fig. 3. Company regional location.

Approximately 13% of the respondents reported that they had not currently implemented BIM but were "*likely*" or "*very likely*" to implement BIM in the near future. When asked about their strategy to implement BIM, 44% of those who reported plans to implement BIM in the near future also reported that they intended to train in-house staff creating an "In-house" BIM department. 35% reported being unsure of the method they would use to implement BIM, and 32% reported potential plans to outsource BIM to specialized IT firms. The percentages do not equal 100% because many respondents selected multiple possible BIM implementation strategies (Fig. 7).

In a separate question, the firms who currently used BIM without outsourcing were asked the extent of their likelihood to outsource in the near future. Most of the respondents (approximately 81%) reported that they were either "*Unlikely*" or "*Very Unlikely*" to outsource BIM in the near future. The three primary reasons identified by the respondents for deciding not to outsource, as depicted in Table 1, are a communication gap, a lack of ability to manage projects, and poor quality.

3.3. BIM outsourcing characteristics

Since BIM implementation varies among firms, contractors who reported outsourcing BIM were asked which specific BIM functional

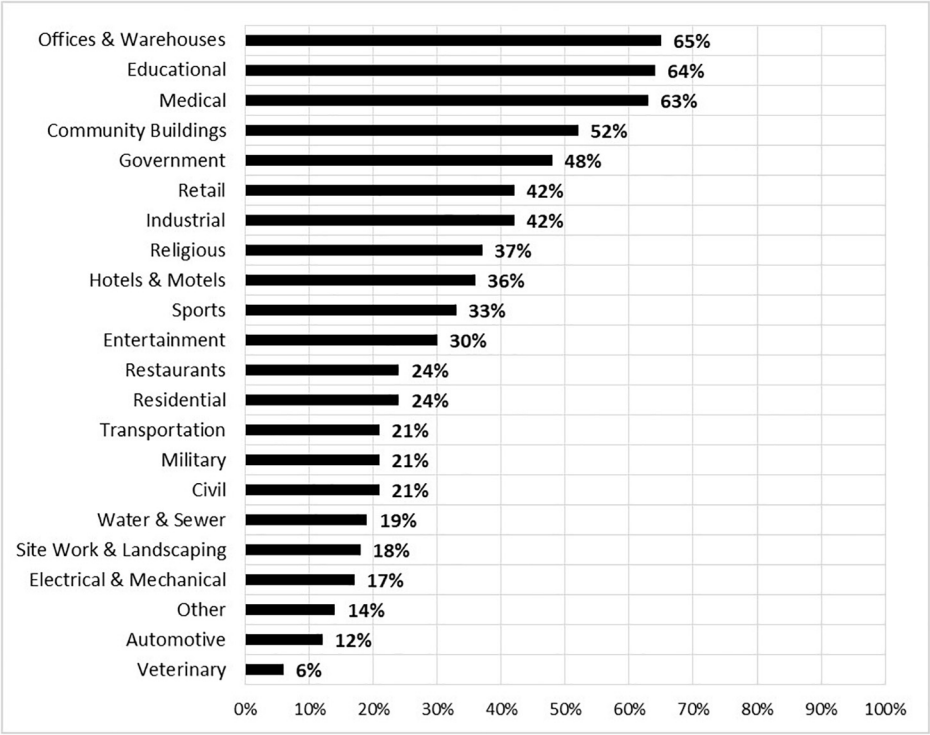

Fig. 4. Company project types.

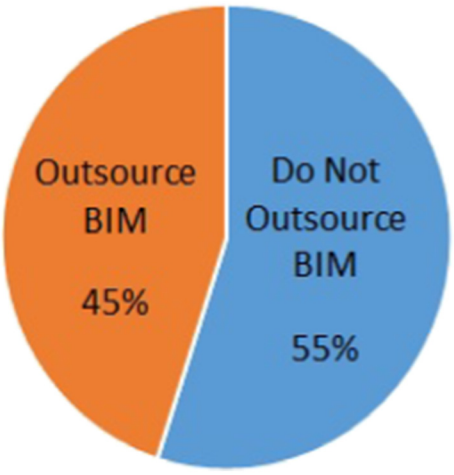

Fig. 5. Outsourcing of BIM by contractors.

areas were outsourced. The most commonly outsourced function was constructability (clash detection), with 56% of respondents reporting outsourcing this feature. The next most outsourced function was visualization (3D modeling) with 42%, and the third was as-built and shop drawings with 40%, as indicated in Fig. 8. The same three BIM functions were the most used overall in BIM (in-house and outsourced combined). Further, a substantial decline exists regarding the frequency with which other specified functions are outsourced.

Another important aspect of BIM outsourcing is the duration for which an outsourcing firm's services are engaged per project. When contractors who reported outsourcing BIM were asked, the majority (36%) indicated that the outsourcing period varies considerably by the project. Given the variety of responses (shown in Fig. 9) for the time spent on each project, it can be determined that the length of an outsourced project varies by the contractor, possibly depending on the chosen outsourcing strategy and project type. Some of the reasons for these different strategies and outsourcing durations may be attributed to project size, the extent of project scope to be outsourced, project complexity, and current BIM workload.

Contractors who have previously outsourced BIM were asked how they currently implemented BIM (results in Fig. 10). 41% of contractors choose to outsource even though they possess in-house capabilities. Further, a combined 54% of contractors disclosed that they either outsourced completely or outsourced functions of which they were not proficient. This finding, along with respondent ranking for motives to outsource BIM (shown in Table 2), indicates that there are three primary strategic uses for BIM outsourcing currently among general contractors:

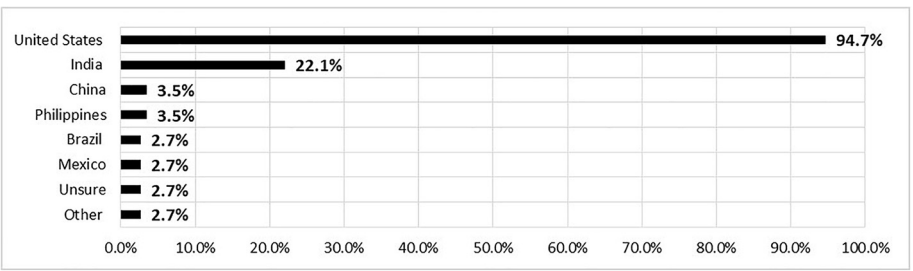

Fig. 6. Nations to which BIM tasks are outsourced.

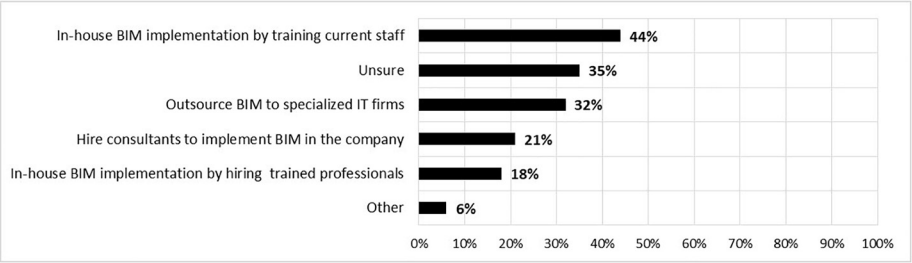

Fig. 7. Potential BIM implementation strategies for future adopters.

Table 1
Reasons not to outsource BIM.

Ranking	Reasons not to outsource BIM (1: most important, 5: least important)
1	Communication gap
2	Lack of ability to manage project
3	Poor quality
4	Poor service
5	Poor contract management

- BIM outsourcing provides the company an ability to use outsourcing only when required. This ability allows outsourcing to be used as a relief outlet when in-house BIM resources are burdened.
- BIM outsourcing is temporarily used by contractors to ease the transition from little or no BIM usage to complete BIM usage on projects.
- Outsourcing specific BIM functions for which general contracting companies do not possess in-house expertise to perform. Therefore, the use of outsourcing BIM functions allows general contracting companies to compete for projects that might require BIM implementation by the owner/decision makers.

3.4. Perceived impacts of BIM outsourcing on projects

Contractors who had used BIM were asked about their perceptions of "*In-house BIM implementation*" and "*BIM Outsourcing*". The perceptions of contractors who have worked with BIM were used as a metric of project impacts because applicable data for how BIM in-house and BIM outsourcing usage impacts projects in comparison to traditional non-BIM practices can be difficult to obtain and was beyond the scope of this study. The majority of respondents viewed In-house BIM implementation as having an overall more positive impact on projects than BIM outsourcing. About 19% more contractors selected "*Very Positive*" in the category of money, 29% for the category of time, 70% for the category of quality, and 58% for the category of value, in favor of In-house BIM's Perceived Project Impacts. Therefore, it seems to be the opinion of most contractors that in-house BIM use is superior to outsourcing in every measured category. However, the perceptions of BIM Outsourcing's project impacts were more positive than negative (shown in Fig. 11).

3.5. BIM outsourcing and company demographic relationships

Previous research indicates that company average annual revenue plays a significant role in BIM adoption, with larger companies being more likely to adopt than smaller companies [5,26]. The researchers tested if a relationship existed between company's annual revenue and BIM use by the company in last ten years. The Chi-square test and Cramer's V (Table 3) demonstrates a significant relationship between a company's annual revenue and a company's utilization of BIM over the past ten years, χ^2 (3) = 36.91, p < 0.001, Cramer's V = 0.384. The odds ratio enabled the researchers to compare various company revenue categories with the reference category "*less than $25 Million*." The odds that a company with revenue between $26M and $99M utilized BIM in the last ten years are about 2.1 times (95% CI 1.02, 4.47) the odds that a company with less than $25M revenue utilized BIM for the same period. The odds that a company with revenue between $100M–$499M utilized BIM in the last ten years are about 10.1 times

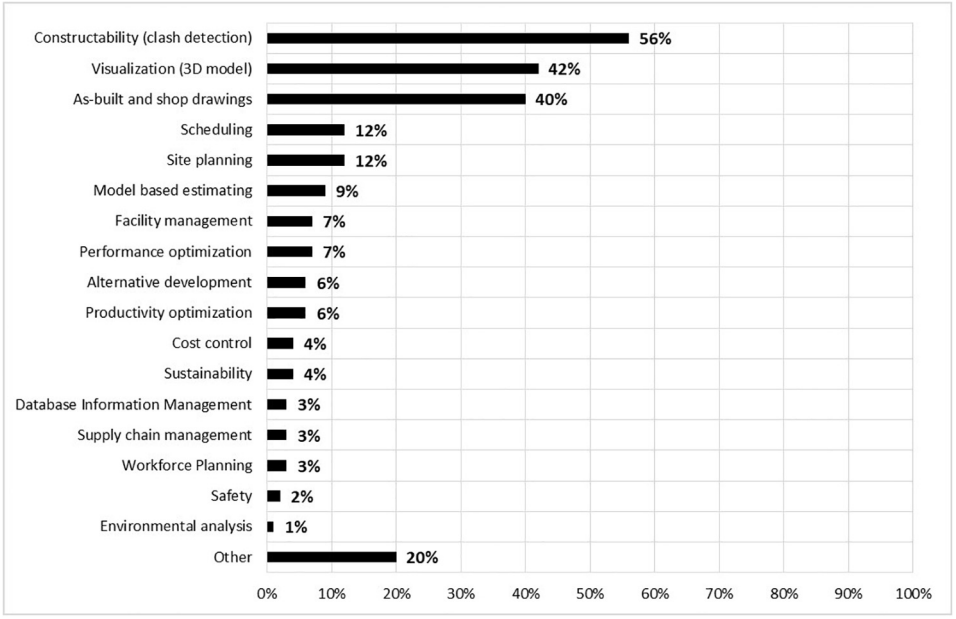

Fig. 8. Outsourced BIM functional areas.

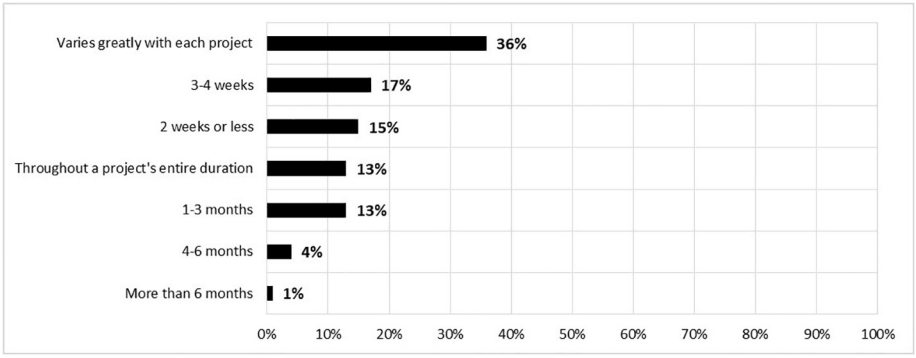

Fig. 9. The period for which specialized IT firm's expertise is used per project.

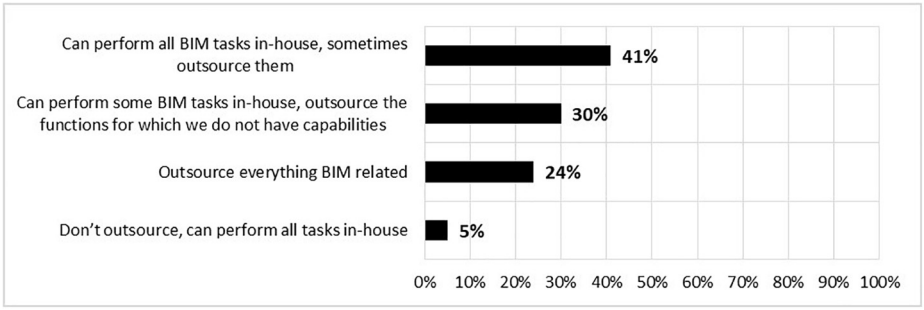

Fig. 10. BIM implementation among contractors who have outsourced previously.

Table 2
Importance of the motives to outsource BIM.

Ranking	Motives to outsource BIM (1: most important, 5: least important)
1	Ability to use BIM services only when needed
2 (tied)	Lack of in-house employees with BIM experience
2 (tied)	Outsourcing firms provide high-quality services
4	Lower costs
5	Lack of BIM professionals seeking employment

(95% CI 4.2, 24.22) the odds that a company with less than $25M revenue that utilized BIM. Lastly, the odds that a company with revenue greater than $500M utilized BIM in the last ten years are about 5.9 times (95% CI 2.3, 14.79) the odds that a company with less than $25M revenue that utilized BIM for the same period.

The researcher also assessed if relationship exists between a company's annual revenue and BIM outsourcing, using the chi-square test. The Chi-square test (Table 4) demonstrates no relationship between a company's gross annual revenue and a company's tendency to outsource BIM, χ^2 (3) = 3.767, p = 0.288, Cramer's V = 0.1443. The odds that a company with revenue between $26M–$99M outsourced BIM are 88% higher (95% CI 0.68, 5.15) than the odds for a company with less than $25M revenue. The odds that a company with revenue between $100M–$499M outsourced BIM is 66%% higher (95% CI 0.67, 4.12) than the odds for a company with less than $25M revenue. The odds that a company with revenue over $500M outsourced BIM are 176% higher (95% CI 0.97, 7.88) than the odds for a company with less than $25M revenue.

Employee loss has been associated with the impact on businesses and sometimes impacting the ability to perform the tasks for which the companies might be hired. In some cases, resulting to outsourcing of the tasks. Therefore, the researchers assessed if the loss of BIM experienced employees had any correlation with company outsourcing BIM. The results of the chi-square test (Table 5) depicts no significant relationship between a company that loses employees experienced in BIM and a company's tendency to outsource BIM, χ^2 (2) = 0.0136, p = 0.907, $\phi\_c = -0.0093$. The odds that a company ever outsourced any aspect of BIM and never lost employees experienced in BIM to competing companies are 4% higher (95% CI 0.53, 2.03) than the odds for a company that has lost employees experienced in BIM. The baseline category, in this case, is the company that has lost employees to the competing companies.

The researchers also assessed if any relationship existed between a Company's BIM Experience (years) and BIM outsourcing, using a logistic regression model in STATA/MP 14.2. The results (Table 6) indicate that no significant relationship exists between a company that chooses to outsource BIM and how long a company has been utilizing BIM.

4. Discussion

Upon analyzing the responses from general contractors geographically located within the US, it is evident that outsourcing BIM plays a significant role in the modern construction industry. With 45% of all survey respondents indicating the use of outsourcing BIM, the practice has become notably widespread and commanded awareness. This study was necessary to facilitate future research and inform the construction industry to make strategic BIM-related business decisions.

Contrary to typical perceptions of outsourcing (i.e., sending projects overseas), the study identified that a vast majority of US contractors practicing outsourcing (95%) chose to outsource BIM tasks to other specialized companies located within the US. Among those contractors who had not yet implemented BIM but indicated they were likely to use it in the future, outsourcing was a strategy that many (32%) reported interest. However, among those contractors who currently implemented BIM but do not outsource, only 19% reported being likely to outsource in the foreseeable future. The strategy adopted by contractors to outsource BIM was also analyzed. The results determined that the three most used BIM functional areas for in-house BIM were constructability (clash detection), visualization (3D modeling), and as-built and shop drawings, which were also the most outsourced BIM functional areas. The study also found *Environmental Analysis*, *Database Information Management*, *Supply Chain Management*, and *Workforce Planning* as the BIM functions that were outsourced least often. The

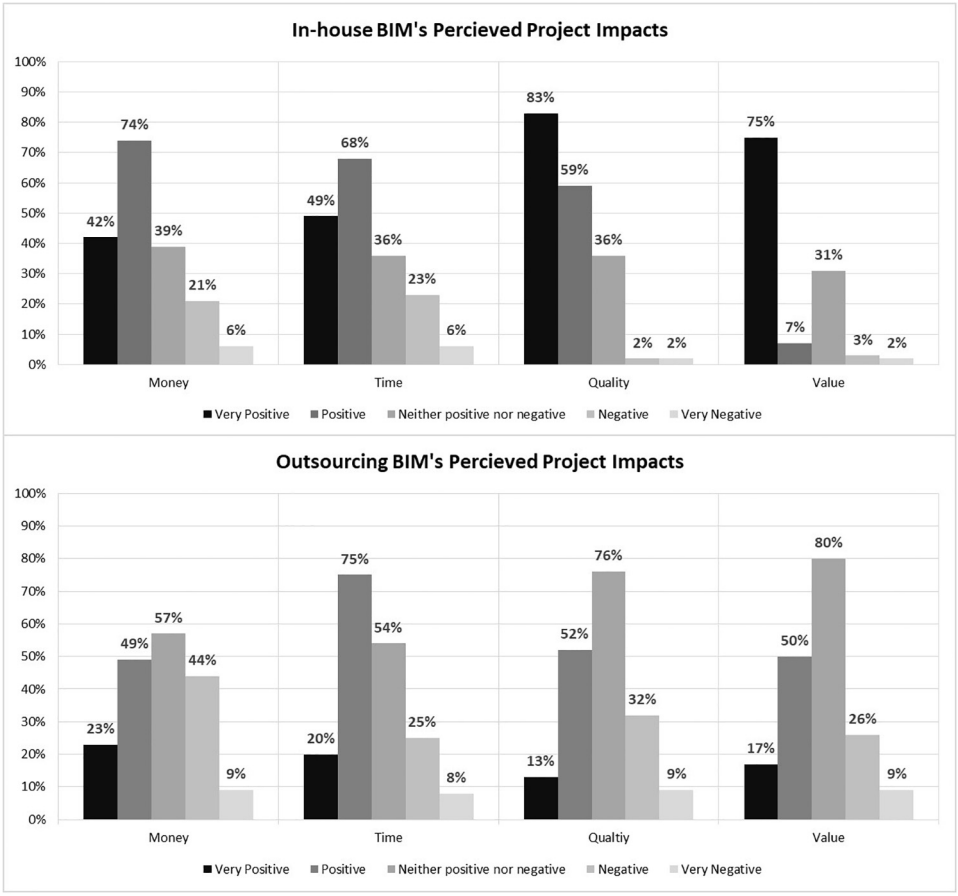

Fig. 11. BIM in-house vs. outsourcing project impacts.

Table 3
Correlation between company's annual revenue and BIM use by a company.

Company's gross annual revenue	The company utilized Building Information Modeling (BIM) in the last ten years					
	Yes		No		OR	(95% CI)
	obs	(%)	obs	(%)		
Less than $25 Million	25	(45.5)	30	(15.3)	–	
$26 Million–$99 Million	41	(64.1)	23	(17.8)	2.14*	(1.02, 4.47)
$100 Million– $499 Million	76	(89.4)	9	(23.7)	10.13*	(4.24, 24.22)
More than $500 Million	39	(83.0)	8	(13.1)	5.85*	(2.31, 14.79)
Total	181	(72.1)	70	(27.9)		
Cramer's V = 0.384						
Pearson Chi2(3) = 36.906						
p-Value < 0.001						

obs = observed count; % = row percentage; OR = odds ratio.
The reference category is "Less than $25 Million".
* Significant at the 5% level.

Table 4
Correlation between company annual revenue and BIM outsourcing.

Company's gross annual revenue	The company outsourced any aspect of BIM implementation to a specialized Information Technology firm					
	Yes		No		OR	(95% CI)
	obs	(%)	obs	(%)		
Less than $25 Million	12	(48.0)	13	(52.0)	–	
$26 Million–$99 Million	26	(63.4)	15	(36.6)	1.88	(0.68, 5.15)
$100 Million–$499 Million	46	(60.5)	30	(39.5)	1.66	(0.67, 4.12)
More than $500 Million	28	(71.8)	11	(28.2)	2.76	(0.97, 7.88)
Total	112	(61.9)	69	(38.1)		
Cramer's V = 0.1443						
Pearson Chi2(3) = 3.767						
p-Value = 0.288						

obs = observed count; % = row percentage; OR = odds ratio.
The reference category is "Less than $25 Million".

relatively low outsourcing of these functions did not indicate that general contractors were self-performing these tasks in-house, and instead, the overall adoption of these functions was low.

The current state of BIM outsourcing among general contractors is a testament to the adaptability of the industry to meet challenges and embrace new technology through alternative methods despite potential risks. Even though outsourcing was perceived by most as a somewhat unsuitable trade-off to in-house implementation, it is still being used advantageously in circumstances where the use of BIM may have been impossible otherwise, or the immediate return on investment may have been uncertain. Thus, as BIM use rises in the future, it is likely that BIM outsourcing will continue to increase as well.

The first hypothesis of this study, "*The primary strategic motive to outsource BIM is to ease the transition into developing and utilizing in-house BIM capabilities*" was rejected (i.e., not found significant). While easing the transition into in-house BIM capabilities was determined to be one primary use, 41% of all outsourcing contractors reported outsourcing

Table 5
Correlation between losing BIM experienced employees and BIM outsourcing.

Lost employees experienced in BIM to competing companies	The company ever outsourced any aspect of BIM implementation to a specialized Information Technology firm					
	Yes		No		OR	(95% CI)
	obs	(%)	obs	(%)		
Yes	37	(62.7)	22	(37.3)	–	
No	63	(63.6)	36	(36.4)	1.04	(0.53, 2.03)
Unsure[a]	13	(54.2)	11	(45.8)		
Total	113	(62.1)	69	(37.9)		
Cramer's Phi = −0.0093						
Pearson Chi2(2) = 0.0136						
p-Value = 0.907						

obs = observed count; % = row percentage; OR = odds ratio.
The reference category is "Yes".
[a] Category excluded before calculation of Cramer's Phi, Chi-square test statistic, and odds ratio.

Table 6
Relationship between company's BIM experience and BIM outsourcing.

Company ever outsourced any aspect of BIM implementation to a specialized Information Technology firm?	BIM use (years)			
	m	(sd)	OR*	(95% CI)
Yes (n = 112)	7.64	(7.42)		
No (n = 68)	6.23	(3.16)		
Total (n = 180)	7.11	(6.19)	1.05	(0.98, 1.13)

m = mean; sd = standard deviation; OR = odds ratio.
* Results from binary logistic regression model treating years and a continuous predictor.

even though they possessed in-house capabilities. Outsourcing permits contractors who already have in-house capabilities the ability to use BIM only when necessary and allows outsourcing to be used as a workload-sharing outlet to offset the burden from in-house BIM resources. This provides for immediate scalability to accomplish large or numerous projects without investing extensively in BIM resources that might be left unused when the company's temporarily large scale of work decreases. Therefore, BIM outsourcing can be a continuously used as a solution in times of need, rather than a temporary practice.

The second hypothesis of this study, "*In-house BIM is perceived as having a more positive project impact than outsourcing BIM*" was found significant. Contractors who had used BIM before rated in-house BIM as having a more positive project impact than outsourcing BIM on average in all four impact categories: Money, Time, Quality, and Value. Thus, the overall opinion of most contractors is that in-house BIM is superior to outsourcing. However, the strategies indicated above and the number of contractors currently outsourcing show that BIM outsourcing has a notable place in the industry.

The third hypothesis, "*A positive correlation exists between company annual revenue and BIM outsourcing*" was rejected, as per the results. At the same time, the study identified a significant relationship between *company annual revenue* and *BIM Implementation*. The study also found that the odds of a company utilizing BIM increased with the increase in their annual revenue. Thus, the likelihood of a company implementing BIM was greater for a company with a higher annual revenue than one with a lower annual revenue.

5. Future research

Because limited research is available in examining BIM outsourcing among the general contractors, there are many unexplored opportunities for future investigation. Many of the same methods used to examine in-house BIM could be replicated except for organizations that outsource the process. Case studies may be performed on projects where BIM functions were outsourced, followed by a comparison of case studies on similar project types where BIM functions were performed in-house. The comparison may reveal differences and encourage further analysis. The members of the AEC industry who outsource BIM (other than general contractors; e.g., architects, engineers, subcontractors, and owners), as well as the specialized BIM outsourcing firms themselves, may also be examined.

6. Conclusion

Seventy-two percent of the contractors responding to this survey reported using BIM within the past decade. Of those companies that used BIM, approximately 62% reported having outsourced some aspect of the BIM process to specialized IT firms. This implies that 45% of the responding population (general contractors) have outsourced BIM to an extent, thus signifying the importance of research investigating the topic.

Regarding the nations to which BIM is outsourced, a majority (94.7%) of the responding contractors choose to outsource to other specialized firms geographically located within the US. In addition, contractors are outsourcing BIM projects to offshore locations such as India (22.1%), and a smaller number are outsourcing to other offshore IT hubs located in China, Philippines, and Brazil. At the same time, it is evident that most outsourcing occurs to specialized firms geographically located within the US. The three most commonly outsourced BIM functions for general contractors were *constructability (clash detection)*, *visualization (3D modeling)*, and *as-built and shop drawings*. These areas were also the most used functional areas in BIM usage overall (in-house and outsourcing combined). Commonly outsourced BIM functions tend to have characteristics such as a clear scope and low creative impact, as identified by Del Villar and Pollalis [19]. Thus, even though the outsourcing function characteristics identified by Del Villar and Pollalis [19] remained the same, but the BIM functions vary from stakeholder to stakeholder. For architects outsourced tasks translate to *rendering images*, *model making*, *drafting* [19], and for general contractors (as per this study) translate to *constructability (clash detection)*, *visualization (3D modeling)*, and *as-built and shop drawings*.

For many outsourcing contractors (36%), the period for which they use a specialized IT firm's services for a project varies per project. Three major strategic reasons for which contractors outsourced BIM were also identified:

1. To provide temporary relief for in-house teams when over-burdened with projects.
2. To alleviate the impacts associated with the transition from a non-BIM environment to BIM implementation on projects.
3. To outsource BIM functions for which general contracting companies do not have in-house expertise needed to perform while remaining competitive for projects that may potentially require BIM implementation by the owner.

For companies that currently use BIM without previously outsourcing BIM functions, a majority (81%) reported being unlikely to outsource BIM in the near future due to the following reasons (in order of importance): *communication gap*, *lack of ability to manage the project*, and *poor quality*. Additionally, the bias towards outsourcing can also be a reason for such a strong response.

Respondents who identified themselves as potential BIM adopters, showed no single strategy for BIM adoption and implementation. Many of the respondents indicated that they intend to train "*in-house staff*" and create an "*in-house*" BIM department, but 32% reported that outsourcing BIM to specialized IT firms would be a major step of their implementation strategy. Thus, with the presence of identified strategic

reasons, BIM outsourcing is a significant feature in the modern construction industry.

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