 

# Building Information Modeling's Impact on Team Performance

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BIM has the potential to impact the way professionals approach building projects, the way teams interact and how they achieve project goals. This study strives to identify, 1) To what extent does BIM appear to be related to team performance? And 2) To what extent is there a relationship between team performance and team experience with BIM? To understand the impacts of BIM on team performance, attributes were identified to provide a basis of specific areas of concentration. This study identified forty-five attributes that may affect team performance. These attributes were compiled and categorized to provoke conscious thought concerning BIM's potential effects on project teams' execution of these attributes. A meta-analysis was used to collect data from existing case studies on project teams' experiences while using BIM. The evaluation of these attributes helps identify the level of impact BIM may have on team performance. Through the evaluation of these BIM case studies, potential supporting data was identified that suggests that BIM may have a perceived effect on team performance, and that factors such as industry professionals 'experience level' also impact performance level. This work has the potential to provide project teams with useful information about the impacts of BIM on team performance without selling a product, tool, or process. The value and significance of this study is based on the fact that the collected data comes from reported case studies in which real project teams practiced BIM technologies and processes, and conveyed their experiences. Based on this potential supporting data, project teams could perform more effectively in the field.

**Key Words:** Building information modeling (BIM), Team performance, Team attributes

## Introduction

Building Information Modeling (BIM) may change the way professionals approach building projects. With BIM, the process no longer consists of reviewing a project, creating an estimate, and bidding the lowest price. Rather professionals including designers, architects, contractors, construction managers, engineers, and MEP trades are getting involved in the early project stages and are using BIM to solve building conflicts and promote innovative design solutions before construction begins. With this potential project approach that BIM may support, professionals can look at challenging projects and see possibilities, rather than costly obstacles (AIA Calif., 2007).

BIM may impact the way building teams interact. Because of the interactive environments in which professionals are asking questions, sharing ideas, and exchanging project information among the various professions and trades involved. As project teams work with BIM processes and technologies, they may experience more collaboration which in turn may impact the relationships and communications among the project team members. The mechanical engineers and architects, for example, maybe less likely to experience conflict in their project plans; rather together they can share ideas, plans, and utilize clash detection in the initial design phases to reduce conflicts during construction. This environment has the potential to open opportunities for building professionals to collaboratively achieve higher standards.

Therefore, BIM as a tool, may drive teams to achieve their project goals and objectives. By putting these new practices and technologies into use, building professions are challenged to change the way they approach a project, how they interact with one another, and ultimately how they seek to achieve their project goals on budget, on time, efficiently, and with the highest quality. As a managerial tool, that encourages these outcomes, BIM could revolutionize the building industry (Hardin 2010, Jernigan, 2007).

With these new processes and technology, the industry is striving to understand how to react to the impacts of BIM. Without a proper understanding of the impacts of BIM, teams may experience poor performance due to a lack of knowledge or unjustified expectations, putting the project team at risk of failure. However, this risk can be avoided if a team understands the impacts of BIM. This raises the following questions: 1) To what extent does BIM appear to be related to team performance? and 2) to what extent is there a relationship between team performance and team experience with BIM?

## Team Attributes

This study used a meta-analysis to review team performance related literature. Forty-five team attributes reported to enhance team performance have been identified and summarized in Table 1. The attributes listed were identified by the authors of the articles as essential attributes to successful project teams (Brenner, 2007; Carr et al, N.D; Chan et al, N.D; Keyton, et al, 2010; Ling 2002; Roadmap, 2007; Mathieu & Schulze, N.D; Thorton & Smalley, 2008; Van Scotter & Motowidlo, 1996).

The identification of these attributes was done to help better understand the relationship of BIM and team performance and to identify essential team attributes, which can provide specific areas within team performance to be investigated. Team attributes are the specific characteristics of team performance. Team attributes are investigated here first, because they help to define what may contribute to team performance. Without knowledge of the specific team performance attributes, it is difficult to improve a team's performance level. If specific team attributes are not prevalent in a team, a decrease in the team's performance can be expected. Team attributes are important in all fields, but especially in the construction industry where teams change from project to project. Thus, adapting to these changes and working as a team is essential to success (AIA Calif., 2007; Ling, 2002; Van Scotter, & Motowidlo, 1996).

The groups of attributes in the first column of Table 1 were collected from professional team performance and industry specific articles that reported these attributes as essential to successful project teams. The attributes that were identified in the articles were then clustered into six groups based on the similarities of the attributes.

The attributes included in each of the categories were based upon the analysis of the articles' descriptions of the various attributes and the instances in which they were experienced. A database of these instances was compiled for easy comparison in this systematic qualitative process. Once the descriptions of each attribute were identified, a qualitative analysis of each of the attribute descriptions was executed and conceptually related themes were identified in each attribute, before they were placed in one of the six thematic categories. Each of the articles used various terms, but upon comparing and contrasting the attribute descriptions and the situations in which the teams experienced them, it was determined that those with similar characteristics could be clustered in thematic categories for the purpose of this study. The six categories identified were: 1) project communication; 2) shared project goal clarity; 3) organized leadership; 4) interactive planning; 5) team reliance; and 6) team rapport, as shown in the second column of Table 1. These six categories were identified to provide exclusive topic areas within project management, without having excessive overlap in definition and striving to maintain the specific attributes within the categories for clarity.

Table 1 is compiled from the gathered and categorized attributes to provoke conscious thought about how project teams practice and experience these attributes while using BIM. Understanding the team-focused building industry and collaborative BIM processes, it is clear that these attributes are essential in the building industry and can have a critical effect on the building teams' execution of BIM and their ultimate performance as a team.

Project team members could use these attributes to self-identify what qualities their team is most skilled at and which attributes or categories they may need to improve upon. For example, if a team is good at communicating, they can further evaluate in which specific communication areas they excel. Do they effectively communicate with the client or are they more skilled at communicating among team members? A team may identify their lack of ability to share information and documentation among the project team. This identification can be helpful in raising the awareness of the project manager and team, so they can strive to improve upon their weaknesses.

 

Table 1

Team Attributes and Categories

| Team Attributes | | Categories |
|---|---|---|
| Client Communication<br>Flexibility<br>Interpersonal Facilitation<br>Social Skills | Team Communication<br>Flow of Information<br>Open Communication | **Communication** |
| Early Goal Definitions<br>Group Goals<br>Meeting Client Expectations<br>Performance Expectations | Goal Oriented<br>Outcome Oriented | **Shared Project Goal Clarity** |
| Accuracy of Design<br>Early Key person involvement<br>Knowledge of constructability<br>Knowledge of Leadership<br>Useful/Appropriate Technology | Continuous Learning<br>Leadership<br>Scheduling<br>Team Motivation | **Organized Leadership** |
| Agreeableness<br>Brainstorming/Charrette<br>Innovative<br>Judging/Perceiving<br>Systematic decision Making | Initiative<br>Decision-Making<br>Intensified Planning<br>Problem Solving | **Interactive Planning** |
| Confidence of Work<br>Job Dedication<br>Mutual Respect | Trust/Transparency<br>Loyalty | **Team Reliance** |
| Cohesion<br>Conscientiousness<br>Interdependence | Conflict Management<br>Coordination<br>Share resources | **Team Rapport** |

## Attributes Impacted By BIM

As a way of associating BIM's linkage to these attributes, fifteen case studies of industry implementation and experiences with BIM were reviewed (Becerik-Gerber & Kensek, 2010; Buckley, 2009; Carroll, 2009; Dossick & Neff, 2010; Greer, 2008; Jay, 2009; Rowlinson, 2010; Sebastian & can Berlo, 2010). These case studies were reviewed and the project team's perception on team performance was compared and contrasted to the attributes in Table 1 to identify a possible association between the attributes and the case studies of BIM experiences. The methodology of this process began with a compiling of specific instances mentioned that could be identified and related to one or more of the attributes in Table 1, to various degrees. This was an iterative process in which each of the case studies' instances of experiences with BIM were compared to each other to determine which case study experienced a higher or lesser degree of impact on team performance. For example, if a specific instance in a project mentioned that the team's client communication had more clarity when using BIM technology to explain a specific aspect of the project, this instance was reviewed and compared to the other articles' instances which also suggested having some impact with BIM and communication. Next in this comparison process, to determine if one specific article's instance had a positive or negative effect on team communication, it was compared to the other reviewed articles. These categorizations of the levels of impacts were based on the analysis of the industry professionals' description of the team's performance found in each of the fifteen case studies. Based on this process, and the evidence that the article authors suggested, the results suggest that teams' experience with BIM technology and processes can result in different outcomes. This can be seen in Table 2 where positively and negatively affected categories of instances are noted by the number/letter codes for each of the 15 articles' instances.

Table 2 summarizes the analysis of the perceived positive and negative effects of BIM on particular team attributes in specific project instances. As presented in Table 2, the analyzed case studies reported far more positive than negative impacts on team attributes. Reported instances of positive attributes ranged from a low of 26 supporting instances in the attribute category of Team Report, to a high of 51 supporting instances in the Interactive Planning attribute category. Reported instances of negative attributes ranged from a low of three supporting instances in the Team Reliance category, to a high of seven supporting instances in the Organized Leadership attribute category.

In the article by Dossick, the author covered two project case studies that reported negative instances in which BIM was implemented. From these cases it was clear when comparing and contrasting instances, that there was poor leadership in the use and implementation of BIM, which may suggest a link to the decrease in the flow of information and communication team members experienced, as reported in the article. The use of BIM in these cases may also suggest a link to the frustration and lack of essential information flow among the various construction trades, which caused installation conflicts and increased cost and schedule time. Because of perceived poor leadership in the implementation of BIM, it is possible the team members' trust and respect for the other trades decreased as each of the professional groups tried to at least break even with cost and not lose money on the project (Dossick, 2010). This could suggest that if implemented poorly, there are potential risks while practicing BIM. Based on this example, the process of analyzing and relating each instance of a team performance is a complex process of relating the authors' words to the attribute categories in Table 1.

Overall, industry professionals who take a look at their team's performance can identify the potential impacts of BIM on these team performance categories, and compare their current experiences to the list of supporting cases below. If a team experiences lower levels of performance, in a category that has a higher number of supporting cases, such as communication, the team needs to evaluate what the causes are for this low performance. What are the potential factors that are causing the team to perform lower than the norm in this study? Teams can use this table to help gauge their team's potential performance and to evaluate what areas their team may need to improve upon.

Table 2

Team Attributes Impacted By BIM

| Categories | Positive Impacts | Supporting Instances | Negative Impacts | Supporting Instances |
|---|---|---|---|---|
| **Project Communication** | **Client Communication** | BB1, J1, D1, R1, R2 | **Flexibility** | D1, D2 |
| | **Team Communication** | BB1, BB2, J1, R1, R2, S1, G1, G2, G3,G4 | **Flow of Information** | D1, D2 |
| | **Flexibility** | BB1, BB2, J1, R1, R2, S1, G1, G2, G3, G4 | | |
| | **Flow of Information** | B1, BB1, J1, R1, R2, S1, G1, G2, G3, G4, C1, I1 | | |
| **Shared Project Goal Clarity** | **Early Goal Definitions** | R1, G1, G2, G3, G4, C1 | **Meeting Client Expectations** | D1, D2 |
| | **Goal Oriented** | R1, S1, G1, G2, G3, G4 | **Performance Expectations** | D1, D2 |
| | **Group Goals** | BB1, BB2, R1, R2 | | |
| | **Client Expectations** | B1, BB1, BB2, R1, R2, S1, G1, G2, G3, G4, I1 | | |
| | **Outcome Oriented** | B1, G1, G2, G3 | | |
| | **Performance Expectations** | BB1, BB2, R1, R2, S1, G1, G2, G3, G4 I1 | | |
| **Organized Leadership** | **Accuracy of Design** | BB1, J1, R1, R2, S1, G1, G2, C1, I1 | **Knowledge of constructability** | D1, D2 |
| | **Key Person Involvement** | BB1, D1, D2, R1, R2, S1, G1, G2, G3, C1, I1 | **Leadership** | D1, D2 |
| | **Knowledge of constructability** | BB1, BB2, J1, R1, R2, G1, G2, G3, C1,I1 | **Scheduling** | D1 |
| | **Leadership** | BB1, R1, R2, S1, G1, G2, G3, C1 | **Team Motivation** | D1, D2 |
| | **Scheduling** | BB1, J1, R1, R2, G1, G2, G3, I1 | | |
| | **Team Motivation** | R1, R2, I1 | | |

| | | | | |
|---|---|---|---|---|
| **Interactive Planning** | **Agreeableness** | G1, G2, G3 | **Decision-Making** | D1, D2 |
| | **Brainstorming** | BB1, BB2, R1, R2, I1 | **Problem Solving Abilities** | D1 |
| | **Decision-Making** | B1, R1, R2, S1, G1, G2, G3, I1 | **Systematic Decision Making** | D1, D2 |
| | **Initiative** | BB1, J1, R1, R2, G1, G2, G3, C1, I1 | | |
| | **Innovative** | J1, R1, R2 | | |
| | **Intensified Planning** | BB1, BB2, T1, G1,G2, G3 | | |
| | **Judging** | S1, G1, G2, G3 | | |
| | **Problem Solving Abilities** | T1, R1, R2 | | |
| | **Decision Making** | BB1, T1, B1, R1, R2, S1, G1, G2, G3, C1 | | |
| **Team Reliance** | **Confidence of Work** | J1, R1, R2, S1, G1, G2, G3 | **Job Dedication** | D1, D2 |
| | **Loyalty** | BB1, S1, G1, G2, G3 | **Trust** | D2 |
| | **Job Dedication** | BB1, T1, R1, R2, S1, G1, G2, G3 | | |
| | **Trust** | BB1, J1, B1, R1, R2, G1,G2 G3, C1, I1 | | |
| | **Mutual Respect** | BB1, J1, R1, R2, S1, G1,G2, G3, I1 | | |
| **Team Rapport** | **Conflict Management** | BB1, T1, R1, R2, S1, G1, G2, G3, I1 R2 | **Coordination** | D1, D2 |
| | **Coordination** | BB1, BB2, J1 | **Interdependence** | D1, D2 |
| | **Interdependence** | BB1, BB2, J1, T1, R1, R2, G1, G2, G3 | **Shared Resource** | D1, D2 |
| | **Shared Resources** | J1, R1, R2, S1 | | |

Note: Each letter/number combination in Table 2, references the article it was derived from and the instance within that article (ie. G = Greer and '2' refers to the second case within that article).

B1 - Becerik-Gerber & Kensek, 2010
BB1, BB2 - Buckley, 2009
C1 - Carroll, 2009
D1, D2 - Dossick & Neff, 2010
G1, G2, G3, G4 - Greer, 2008
I1 - Ireland, 2009
J1 - Jay, 2009
R1 - Rowlinson et al. 2010
S1 – Sebastian & van Berlo, 2010
T1 - Thorton & Smalley, 2008

## BIM's Level of Impact on Team Attributes

From a review of Table 2, it is clear that based on the fifteen case studies that were reviewed in this study; the majority of teams reported having experienced positive team performance while using BIM. It also shows however, that not every team's experience with BIM was the same, possibly due to various factors, such as team make-up, leadership, experience, and project requirements.

One of the frequently discussed factors that affect team performance is the team's previous experience with BIM technologies and processes, which ultimately impacts the project teams' overall performance (Carroll, 2009; Dossick, 2010; Hardin, 2010; Rowlinson, 2010; Jarnigan, 2007). This is the basis for question two in this study; to what extent is there a perceived relationship between team performance and team experience with BIM? Therefore it seems useful to evaluate these different perceived levels of performance improvement in the context of experienced use of BIM technologies and processes. Figure 1 and Figure 2 were created with the gathered data to illustrate the reported impact that BIM has had on team performance based on the essential team attributes from Table 2.

*Methodology of Figures 1& 2*

To better visualize this potential relationship between experience with BIM and team performance, Figure 1 and Figure 2 were mechanically divided into three levels of experience on the X-axis; low, medium, and high experience. This breaks down team performance into three categories, based on the articles' description of the teams' positive or negative experience with BIM. In the process of evaluating which level of experience each case study had, the categories of low, medium, and high were operationally defined as the following: low experience level is categorized as one to two years of experience, or zero to two completed projects in BIM. The medium category is 3-5 years of experience and or 3-5 projects with BIM. The highest level of experience is 6-10 years of experience in which the team used BIM and or 6+ projects completed in BIM. This information was gathered from each of the case studies' descriptions of project team's experiences with BIM, and then qualitatively compared and placed into the categories that described them best, based on descriptive information provided by articles.

On the Y axis, a scale of A, B, C, D, E, and F is used to categorize the perceived performance improvement that was proposed in each of the case studies. Within this 'A thru F' scale of team performance, the 'A' category stands for the highest level of reported frequency that an article's instance suggested experiencing while practicing BIM and 'F' stands for the lowest suggested frequency of performance. In the 'A' category, team performance has a potentially positive link to BIM. It is categorized by some instances as the highest frequency of performance any of the reviewed case studies has experienced. The 'B' category is the frequency of improvement where case studies in this category suggest experiencing beneficial results potentially linked to the use of BIM, but still experiencing some less successful aspects of performance. The 'C' category is a categorization of the instances in which teams experienced a low frequency of improvements, but not a high satisfactory level. This category still has potential for improvement of performance in future projects.

Not all teams will experience an increased frequency of team performance. The 'D' category is made up of instances that suggested having had no significant frequency of improved performance while using BIM, but rather suggested a slight possible decrease in performance, possibly linked to their use of BIM. Category 'E' is based on instances in which one to two negative results occurred while using BIM, such as impaired communication and extended scheduling. Lastly, category 'F' is described as instances that report having highly negative experiences while using BIM. Some of the reported consequences in this category include conflict among team members that negatively impacted three or more categories of the team performance attributes defined in Table 1.

### *Explanation of Figure 1*

Figure 1 illustrates BIM's reported impact on team performance in the Communication attribute category, which is comprised of flexibility, flow of information, client communication, team communication, and interpersonal facilitation. Each of the case study experiences that reported having an effect on performance because of the use of BIM are distributed here using the team's experience level scale described above. Out of the six over-arching categories that were identified in Table 1, Communication had the most supporting case study experiences that impacted team's performance (Hardin, 2010; Jarnigan, 2007). Based on Figure 1 below, some important assumptions about the perceived impacts of BIM on communication can be concluded. From the graphed data, it suggests that there is a possible relationship between a project team that has low experience with BIM and that same team experiencing very low, if not negative team performance will practicing BIM. With less experience using BIM technologies and practices, these team members may be confused, decreasing their communication skills with the client or other team members. This graph also suggests a positive relationship between teams that have had more years of experience with BIM, and the high level of team performance they have experienced. This important to recognize, because simply by practicing BIM technology and processes, does not guarantee higher team performance, as some sources would suggest.

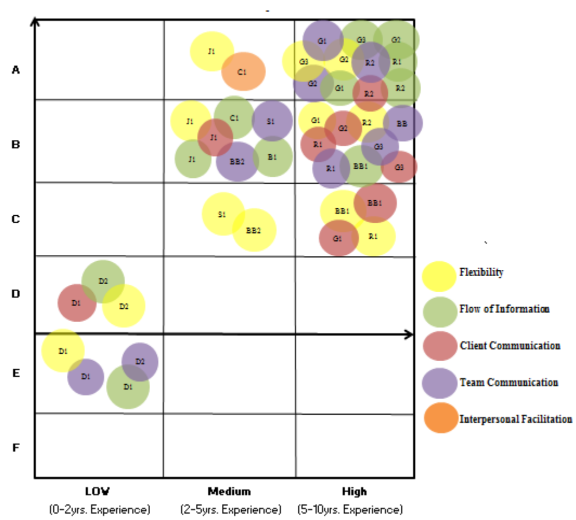


Figure 1

## BIM's Level of Impact on Communication

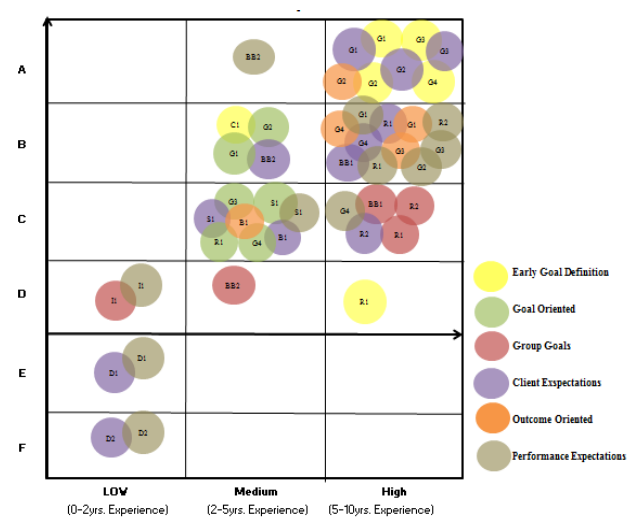


Figure 2

## BIM's Level of Impact on Project Goal Clarity

Each data point in Figure 1 illustrates an instance from the case studies where the level of perceived impact of BIM on each of the specific categories of team attributes and the team's experience level with BIM. To understand how each of the forty-two Communication data points in Figure 1 were distributed, look at the green 'BB1' data point located in the high team experience category and the team performance level of 'B'. The location of this point was based on an instance in the case study; in this case, the project team had a high level of experience, meaning they had practiced BIM technology and processes for 5+ years and/or had completed multiple projects using BIM. They were very experienced when it came to BIM processes and technology. Their team's performance level was high in category 'B', meaning that based on the 6 categories of team attributes in Table 2, this team had very good communication skills and were able to process and transfer information among the appropriate parties in an organized and timely manner. Thus, there were only a few reported instances in this project when the proper information was not distributed to various professionals or where miscommunications that occurred. With less experience in BIM, teams more often report negative impacts when using BIM. For example, in the Figure 1 for Communication, the points that occupy the top right corner most frequently are instances of the flexibility attribute. The figure suggests that potentially, with more experience using BIM, the attributes saw a higher frequency of improvement in the level of communication, which opened conversations among team members, sharing ideas, and ultimately increasing their flexibility to adapt to project changes. Based on this example, Figure 1 provides a visual illustration of the collected instances and their distribution on the graph, based on the data provided in each of the articles' instances. While this shows a highly positive experience with BIM, it is just as important to recognize that not all case studies reported a highly positive relationship with BIM and team performance.

### *Explanation of Figure 2*

In Figure 2, there are forty-five instances that relate to the Project Goal Clarity category. This data shows a similar trend as that in Figure 1. The data that makes up Project Goal Clarity heavily populates the upper right hand corner of the figure, where there is a high level of reported experience, and thus illustrates a relationship to increased team performance. The information in this graph also illustrates perceived team performance as reported by project teams that have limited experience in BIM. From the information represented here, it is apparent that those instances in which teams had previous experience with BIM, reported experiencing team performance benefits, but not to the highest level of potential. This is important to note that as teams implement BIM on projects, that they do not become prematurely discouraged and decide that BIM is not beneficial or more work than it is worth. With additional experience, teams can enhance skills and see potentially higher team performance. In Figure 2, the instances that had the highest level of experience and the highest outcome of project goal clarity were especially successful in defining early project goals. With more experience, teams can become more successful in practicing BIM, and ultimately improving their project performance, and possibly saving time and money. But this figure suggests that this is process of getting to that level and does not instantly occur when BIM is first implemented.

## Conclusion

Based on an analysis of Figures 1 and 2, it is clear that there are potentially both positive and negative impacts of BIM and persistence may be required to experience the more positive results. From the plotted instances in both figures, it can be assumed that as a team's level of BIM experience increases, the perceived impact on team performance level also appears to increase. These two figures propose outcomes of the potential impact of BIM on team performance that industry professionals can evaluate to consider, what their potential outcomes of the implementation of BIM maybe.

From the gathered team attributes and evaluated BIM case studies, it appears that BIM does have a perceived effect on team performance and that there are additional factors, like teams' experience level, that affect the levels of team performance. In this study the 'experience level' of teams with BIM was a factor which was investigated. This is practical and applicable information for industry professionals to better understand the impacts of BIM on team performance. The identified attributes in this study help to describe elements of 'team performance' and provide professionals with specific attributes on which to evaluate their team's performance. The outcome of this research clarifies that there are both positive and negative influences of BIM on team performance as reported in the reviewed case studies. This study identified also that there are various levels of impact that a team may experience with the use of BIM, as represented in Figures 1 and 2, which suggests persistence with using BIM may increase team performance. These tables and figures give insight to the building industry about what performance outcomes can be expected when professionals implement BIM for the first time, or after several years of experience. From this research, BIM emerges as a tool that has the potential to revolutionize the industry by altering the way building teams perform. This will only occur if teams fully understand that there is a learning curve related to their level of experience and team performance. This work has the potential to provide project teams with useful information about the impacts of BIM on team performance without selling a product, tool, or process. The value and significance of this study is based on the fact that the collected data comes from reported case studies in which real project teams practiced BIM technologies and processes, and conveyed their experiences.

Future work for this study can expand on the various impacts that BIM has on team performance by identifying other factors that may also affect team performance with BIM, for example the size of the projects, the number of project members involved, etc. The expansion of this work could help to further identify additional impacts of BIM technologies and processes, as it relates to team performance.

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