Barriers of Automated BIM Use: Examining Factors of Project Delivery

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Abstract

The use of Building Information Models (BIM) for design and construction processes are growing as a whole, especially in terms of mobility platforms that help with managing the construction process. One area, however, that is lagging in the use of BIM for automated or semi-automated processes such as estimating. Literature has explored some reasons for this lack of adoption of BIM for estimating as issues with the user trusting the model's accuracy when that model is created by someone else when using a federated model approach. In order to enhance user confidence of BIM results with automated processes two areas were examined: (1) the use of historic data to create a reliability model based on risk and financial impact of systems and (2) examining factors of project delivery that influence the use of BIM. This paper discusses a two part survey that examined the project delivery system and various other factors as to how they relate to the user's confidence in the accuracy of a model. Results indicate that personal relationships are more influential than contractual obligations. Finally, findings of the survey that identify common trends of respondents in terms of setting up a project delivery to maximize the utilization of BIM are included.

Keywords

Building information modeling • Estimating • Integrated project delivery

1.1 Introduction

Building Information Modeling (BIM) has grown over the past decades as a process for creating a computer-generated model of a building containing geometry and data for designing, planning, constructing, and managing the building [1]. BIM has been proven to lead to cost savings during the design and construction processes, which has influenced its overall rate of adoption [2].

Automating processes like material take-off and cost estimation with BIM can allow contractors to spend less time on material take-offs and more time reviewing and planning the project. Automated measurement is one method to speed up the material take-off process [3]. When it comes to trusting automated BIM processes, however, many contractors are cautious about how much they use BIM, especially if the use of BIM has high risk associated with it (e.g. estimating a job). Because the accuracy of the model is often not contractually binding, there is a degree of ambiguity about who is responsible for the accuracy of the data [4].

Common obstacles that have limited the use of BIM for automated processes include: ownership licensing, control, and responsibility of data entry into the model. Typically, a federation of sub-models from different authors is used for the purposes of creating a model for construction planning. These models are often created for different purposes and can have varying levels of development, making it complicated to understand the accuracy of data they contain once these models are integrated together [5, 6]. Specifically with estimating, estimators lack confidence in automatically producing something that

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was previously controlled manually because the automation process removes some of the manual interpretation required to create an accuracy estimate [7, 8].

The main objective of this research is to identify methods to increase the user's trust in the model's accuracy and the results of automated or semi-automated processes when the model authored by someone else is used. The research has been broken into two focus areas. The first was to develop a reliability model based on historic modelling accuracy data, financial impact to the project (level of risk of a building system), and other user inputs. The second area of research addresses user confidence in a model stemming from how a project is contractually set up to promote or inhibit a more complete BIM workflow. This area looks into how various factors of different project delivery methods can influence a user's confidence in the general accuracy of a BIM authored by a third party and in utilizing that BIM for automated processes. The study results can then influence the way projects are set up, contracts are written, and relationships are developed to support a more trusting BIM workflow.

1.2 Phase 1: Reliability Model

The first phase of the research developed a reliability model for quantitative assessment of automated BIM processes [9]. The reliability model was proposed as a tool for contractors to assess the accuracy of results from automated BIM processes.

The reliability model was organized by UniFormat [10] classification and used inputs of historically accuracy for each major system of construction, a total project cost and percentage cost for each major system, and the acceptable rate of error that the user would accept from the model and each of the systems. These inputs then allowed for the identification of a "confidence in accuracy" rating to be calculated through the statistical analysis described in Lucas et al. [9].

The workflow for the proposed tool (Fig. 1.1) was to take a federated model and input the features of that model (e.g. type of structure, type of cladding, etc.) into the reliability model. Based upon the systems identified within the federated model the algorithms within the reliability model calculates a confidence in accuracy of the model and the criticality of each system to influence the overall accuracy. Each system's criticality is based on the systems financial risk and historical likelihood of its accuracy. Based on the confidence of accuracy, the user can determine if it high enough to utilize the model for automated processes. If not, the user could manually check a defined amount of the most critical system identified. If errors were found, they can determine that edits would need to be made before the model could be used. If no errors were found in the model the reliability model would be re-run with "0" errors for the critical system. This would allow a new confidence of accuracy to be calculated. The process would complete until the level of confidence was high enough for the user to accept the model as accurate. The process of checking the critical system for errors would be accompanied by a list of common issues that have been identified as potential errors throughout the data collection process (e.g. concrete slabs may be notated as 4″ but drawn as 6″, wall types drawn at the wrong thickness could affect volume). This will allow a user some insight as to what might need to be checked.

1.2.1 Findings from Phase 1

A proof-of-concept model was developed with sample project data input into a database for plumbing, HVAC, Fire Protection, and Electrical systems. Six participating firms participated in follow-up conversations and showed interest in the use of the reliability model should it be fully developed with a large enough dataset. A common theme among all firms was the amount of risk that they would place on the result of an automated process when they did not have direct and total control over the creation of the model. In open responses they also listed anecdotal evidence that they tend to rely on models more when they are more comfortable with the author who created the model. These types of comments led to the development of the second phase of the research.

1.3 Phase 2: Project Delivery and Trust

The second phase of the research was to further examine the challenges identified as to why construction personnel utilizing BIM were resistant to utilize BIM to its full capacity. The research began to look into how changes in the project delivery process may promote BIM in ways that can lead to project efficiencies. Areas considered within the second phase of the

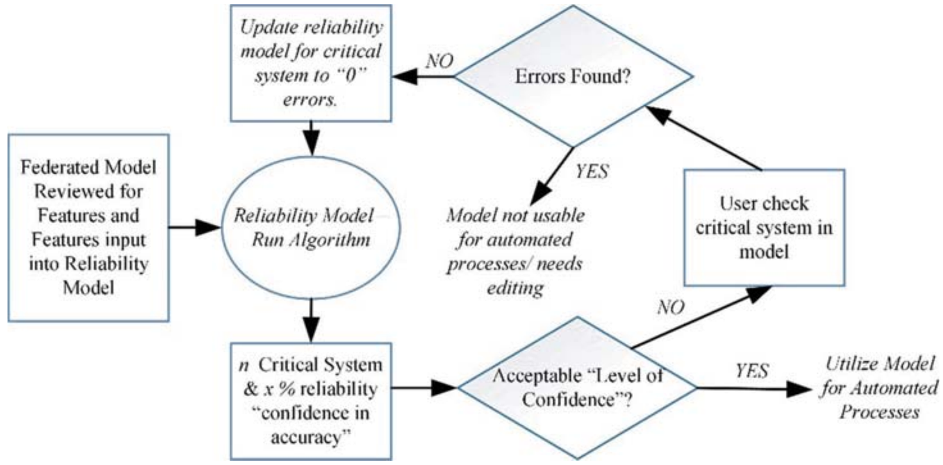

Fig. 1.1 Reliability model Workflow

research and are discussed in this paper include: cross-disciplinary teams, strength of interpersonal relationship, contractual obligations, formal BIM execution plans, and modeler/modeler's organization reputation and experience.

1.3.1 Research Design

Phase two of the research utilized a literature review and multiple surveys to identify consensus of influence among BIM users. The steps are depicted in Fig. 1.2.

1.3.2 Identifying Project Delivery Variables that Impact BIM Use

A thorough literature review and comments received through the first phase of the research created 29 variables that were organized into 9 categories of potential influence on user confidence in a model's accuracy. Three models of influence for affecting trust were highly influential in the categorization of the variables [11–13]. The categories and descriptions of variables are shown in Table 1.1.

1.3.3 Survey 1

In the first survey thirteen broad range questions were asked about the influence of each of the nine categories that were identified. A 7-Point Likert scale was used to allow for greater granularity of results. Convenience sampling techniques were used for the study based on contacts available to the research team from past experience and from those on the organization's Industry Advisory Board for a total of 50 companies invited to participate. Chain referral sampling was also suggested to try and enlarge the respondent pool. In total 29 responses were collected. Of those responses, 21 reached the experience threshold set at 4 years of using BIM for project planning. The experience level of the qualified respondents ranged from 4 to 14 years (mean average of 7.4 years).

The results of the survey were analyzed through descriptive analysis. Results were tested for statistical significance using t-test (p) calculations. Results with a $p < 0.05$ were identified as statistically significant. These categories are included in Table 1.2 below. From the seven categories identified as having statistically significant results, the Relational category had the highest level of agreement (6.238/7) and Intuition Question 2, Contractual, and Integrity had the lowest level of agreement (5.095/7). Other categories that suggest a higher level of influence include Competence (6.00/7) and Deterrence (5.762) All had an overall positive impact over the median of a 4 out 7 on the Likert scale where 1 was absolutely not likely or influential and 7 was extremely likely or influenced.

Other open response responses were coded for themes and included: BIM author's technical experience, depth of author's construction knowledge, authoring organization's culture on modeling, nomenclature and technical structure of model, verifiability of component accuracy, buy-in of project-specific participants, and phase of LOD of the model.

Responses were also examined by age range. The two groups were broken into those with 4–6 years of experience (10 respondents) and those with 7 or more years of experience (11 respondents). Those with more years of experience only ranked Contractual Agreement and Institutional Based—Question 1 (Documentation Culture) higher than those with fewer years of experience. Though when looking at a regression analysis, even with statistical indication of a correlation, the subsequent scatter plot does not indicate a linear relationship.

1.3.4 Survey 2

The second survey took the categories that showed influence on someone's perception of the model delivery and created more specific questions to check the influence of specific variables. The survey consisted of twenty-nine (29) questions. 14 responses were received from the original 24 who were qualified to respond in the first survey. Since the second survey was to dig deeper and identify consensus about the influence of the test group, the same respondents were asked to further clarify their earlier responses.

After completing descriptive statistical analysis the top individual variables were identified (see Table 1.3). Five out of the top variables were from the top two categories from the first survey.

On the opposite end, three of the bottom five came from the 8th ranked category while the other two came from the top 3 (Table 1.4).

1.4 Findings and Observations

Based on the findings of the study, there is an indication that developing a relationship with the author (or authors) of a BIM is more influential to the confidence a user has in the overall accuracy of the model created by a third party than the contractual structure of the agreement to use BIM. Large scale validation of the findings need to be conducted with a larger response population and over a larger geometric area as most of the respondents were within the south-eastern United States. However, the study's findings suggesting that developing a relationship between the author and user of BIM as the most influential variable examined does coincide with previous literature. One study argues that in order to implement successful inter-organizational BIM and develop transparent technology use a team must create a social and organizational foundation to support collaboration [14]. Another study identified human-related factors (e.g. training, leadership, and experience) as essential for successful BIM implementation [15].

With the current study showing that user confidence in the accuracy of information within a BIM is higher with a developed relationship and other literature linking good social and organizational foundations to better collaboration and successful BIM implementation future studies on user confidence to project success are proposed to help understand if there is an actual link.

Another observation linked to the findings is to ensure project teams are not just spending time on technical specifications in terms of creating plans for using BIM. The industry commonly uses published methods for developing plans for BIM utilization. One of those documented methods is the *Building Information Modeling Execution Planning Guide* [16]. Within that guide, the authors place some emphasis on having the team members' work on setting up the execution plan to help clarify common goals, communicate strategy, and understand roles and responsibilities. This study enforces the importance of the team approach. Not only it is necessary to establish common goals and set up a project for success, but spending time to develop a relationship with the authors of the model was identify as a significant influence on a BIM user's confidence in the accuracy of the model they are receiving. Moving forward, it is recommended that project success in terms of BIM use and issues related to model accuracy be examined and compared to the relationship that the author and final user have developed to gain a quantitative understanding.

1.5 Conclusion

This study set out to look at how various factors of project delivery affect user confidence in using BIM for automated or semi-automated processes when the model was authored by a third part. Literature review summary and findings from an earlier study were used to formulate a list of variables. A two part survey was then completed to gauge the influence that each variable had on the user's confidence in a model's accuracy when the model was developed by someone else.

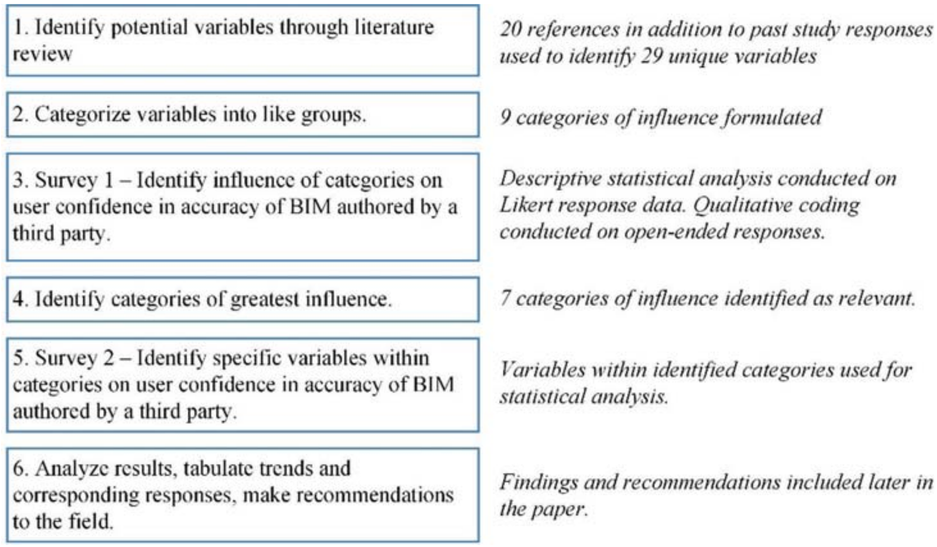

Fig. 1.2 Research steps

Table 1.1 Categories of potential influence

Category	Factors in category
Integrity	Integrity, fairness/transparency
Competence	Historic performance, reputation, apparent knowledge
Intuitive	Perceived risk involved, intuition (gut feeling)
Calculus-based	Economic self-interest, transaction cost analysis, perceived risk for self-interest
Relational trust	Personal experience with someone, historic interactions and past communications
Institutional-based	Inclusion of a boundary role person, legal systems in place, regulations, organizational policy and affiliations, comparison of institution to societal norms
Deterrence-based	Sanctions for breach of responsibilities
Knowledge-based	Fairness or transparency of interactions, knowledge of a person's or company's reputation/performance
Education	Certifications and formal education
Contractual agreement	Model level of detail, BIM execution plan, boundary role person/model coordinator

The first study looked at broad categories of variables and identified issues related to "Relational" aspects of project delivery ranked at the top and "Contractual" variables at the bottom. The second study examined the variables in more detail of those that proved to have a statistically significantly impact from the first survey.

The second study identified that personal experience with the person and company ranked highly among individual variables. The more technical aspects of project delivery that included defined contract addendums, owner-specified requirements for BIM execution plans, and level of detail specified for the BIM model all fell within the five least influential variables.

Many companies put great effort into developing a detailed BIM execution and utilization plan to ensure that rolls, responsibilities, and requirements related to BIM are clearly outlined. The BIM execution plans often include agreed upon strategic goals for the project team. The results of this study would caution against solely focusing on defining these aspects of the plan and not developing a relationship that can formulate a higher level of confidence in the models that inter-organizational team members are creating.

Table 1.2 Statistically significant categories ranked by mean

Category	Question	Mean	SD
Relational	How much of an affect does repeated interactions with the BIM models and its author(s) have on your level of trust in the accuracy of information?	6.238	0.971
Competence	How much of an effect does previous interactions with the author(s), past experiences, reputation of the author(s) or their associates entities have on of your trust in the accuracy of the BIM model?	6.000	0.976
Deterrence	If the accuracy of a BIM model is a contractual obligation and any breach of trust (e.g. Errors in accuracy) is penalized through economic sanctions or other means to motivate the creation of a more accurate model, how likely is this to affect your confidence in the accuracy and use of said BIM model?	5.762	1.630
Institution	To what extend does the documentation culture at your organization to make BIM models along with AutoCAD drawings, architectural visualizations, etc. influence your confidence in BIM model accuracy?	5.667	1.084
Knowledge	To what extent does your personal opinion of a BIM author influence your trust in their professional competence and ability to deliver an accurate model?	5.381	0.999
Education	To what extent does the formal post-secondary education of BIM techniques for the BIM's author influence your acceptance of the model as being accurate?	5.238	1.151
Institution	To what extent does the author's affiliation with a reputed organization/company affect your confidence in the BIM model's accuracy?	5.095	1.231
Contractual	To what extent does the inclusion of contractual obligations of BIM use (such as an owner required BIM execution plan, formal deliverables) affect your confidence in the accuracy of a model developed by another party?	5.095	1.444
Integrity	To what extent would you say that your level of confidence in model accuracy is fueled by the author's integrity? Meaning you believe that the author(s) will look out for your best interests in addition to their own	5.095	1.630

Table 1.3 Survey 2—top variables by mean

Category	Prior rank	Variable	Mean
Relational	1	Personal experience	6.45
Relational	1	Personal history with the author	6.45
Competence	2	Repeated interactions with the author	6.08
Knowledge-based	5	Integrity of the BIM author	5.90
Institution	4	Author's organization's policies on BIM	5.82
Relational	1	Personal history with the organization	5.63
Knowledge-based	5	Reputation of the BIM author	5.63
Competence	2	Overall performance of the BIM author	5.58
Integrity	7	Forthcoming in identifying model changes	5.58
Integrity	7	Openness to share model	5.50

Table 1.4 Survey 2—lowest variable by mean

Category	Prior rank	Variable	Mean
Contractual	8	Owner required BIM execution plan	3.42
Relational	1	Restricted nature of information sharing	3.82
Contractual	8	Inclusion of formal contract addendum	4.07
Deterrence	3	Promise of future business with the BIM author influencing severity of sanctions	4.25
Contractual	8	Level of development of the BIM model being specified in the contract	4.28

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