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A Pilot for Standardizing Design and Contractor Training to Improve the Adoption of the Integrated Framework for Cost Estimating Workflows

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The construction industry rapidly evolves yearly, with new technology, tools, and workflows introduced by software vendors, professional organizations, individual companies, and industry members. This ever-changing work environment challenges existing industry participants to be effectively upskilled and new workforce members to be technically competent upon entry into the industry. While modern technology and tools can increase efficiency, improve safety, and enhance cross-disciplinary collaboration, adoption rates of model-based workflows by preconstruction teams continue to lag compared to other uses, such as coordination and clash detection. Integrated Estimating, a more recently developed workflow for cross-disciplinary model-based practices, shows promise to increase efficiency in the preconstruction process and improve collaboration. This paper describes how a pilot project implementation of this Integrated Estimating workflow helped the design and contractor teams to adopt a new approach to BIM-based collaboration. This pilot process utilized team training sessions focused on discipline-specific and "just-in-time" support. The results indicated the successful adoption of the workflow, promoting comprehension of the technical aspects and confirming the use of the workflow for collaboration purposes by new industry users. The preliminary results also show that the Integrated Estimating framework can be scalable and replicated across multiple independent project teams through training and application.

Keywords: Model-based Estimating, Workforce Development, Preconstruction, Collaboration

Introduction

The preconstruction discipline within the Architecture/Engineering/Construction (AEC) industry is rapidly changing to support new delivery models, confront challenging economic conditions, and adopt new technology and tools. There have been over $135 billion in investments in AEC-related software and technology since 2014 and over $30 billion alone in 2023 in the form of software applications and technology vendors attempting to make the process more efficient, accurate, and less costly (Blanco et al., 2023). Preconstruction tasks, such as quantity take-off, historical cost, and basic estimating functions, are major activities the software industry targets for process improvement. Other investment areas include subcontractor pre-qualification and solicitation, bidding, and supporting the buy-out process.

Model-based estimating is an area of the preconstruction profession that has seen many attempts over the last two decades to develop and apply software solutions to address the challenges associated with model-based workflows. However, the software solutions developed, though many, have not successfully resolved the challenges to adoption and the common barriers to entry. Challenges to adoption include model quality, model completeness, Level of Development (LOD), and others (Igwe et al., 2023; Pilgrim et al., 2024). These identified challenges are largely symptoms of issues related to workflow, training, and process, not necessarily a lack of features and functionality of the software used in these processes. What is needed to address these challenges is the implementation of a simple, scalable, workflow that can be taught quickly with an appropriate level of training, adopted easily because of low barriers to entry, and replicated across multiple projects while working with different teams and project partners.

The Integrated Estimating framework is a workflow developed and utilized on many projects, with early successes showing promise for overcoming previously identified barriers to adoption and scalability (Pilgrim et al., 2024). The framework is identified as software agnostic, meaning it does not rely on vendor-specific applications. Instead, it relies upon five essential characteristics that describe a framework to create a process-oriented structure for teams to achieve consistency in work product, a baseline level of standardization, and improved quality (Pilgrim, 2020). As with any new process or introduction of a new tool, some level of training is required to achieve success. While the Integrated Estimating framework was developed to be an easy-to-use, entry-level form of standardization, it still requires some level of base training to introduce and familiarize users with the concepts (why) and the execution (how) of the workflow. Additionally, because the framework targets a cross-disciplinary, collaborative workflow, training of both the design and the preconstruction disciplines is required.

This base level of training should introduce the project team to the framework, achieve a baseline level of understanding of the five characteristics, and the discipline-specific requirements and responsibilities necessary to be effective with the workflow.

Background

The AEC industry has been working toward improving efficiency and reducing project delivery time for decades. This is primarily driven by building owners who perceive some level of waste and long schedule durations as opportunity cost and lost revenue. This need to improve the overall efficiency of project delivery is one of the reasons design-build, integrated project delivery, and other project delivery vehicles and contract types have been developed (Ibbs, et al., 2003). Some forms of schedule and waste reduction are primary or secondary goals of many projects. This desire for an increase in speed often leads to a leaning of the upfront portion of projects, even though design and preconstruction services are a small percentage of project costs. Preconstruction services are often less than 1-3% of the total project cost (Ellis, 2024). Regardless, the pace of business has increased, project teams are lean, and the margin remaining for soft skill development and technical upskilling is lacking. The challenges that exist in the AEC industry related to training are multiple, including limited budgets for training, outdated training materials, and methods, employees having little margin due to talent shortages, and overall resistance to change (Brown et al., 2009; Artheton & Fasano, 2023). On-the-job training and a lean model of Just-In-Time (JIT) training are likely going to be the most effective forms of training in the industry in the future (Evernden, 2018).

A common onboarding process for new employees today includes a couple of days of corporate onboarding to deal with administrative tasks such as setting up insurance, obtaining computers and equipment, and possibly some form of new employee orientation. Following that brief period, new employees are sent to their respective project teams and begin the integration and assimilation process immediately. This often includes receiving initial project assignments and activities. New employees with little or no previous industry experience may participate in various forms of Core Skills training, technology training via self-guided video-based training, and perhaps some level of corporate-led training classes. New employees with existing experience are often expected to begin integrating into the project and contributing almost immediately. This fast-paced environment leaves little room for re-orienting to the firm's preferred best practices, upskilling, or teaching all new workflows.

This paper focuses on the process of training industry members, in particular design and preconstruction teams, in how to use the Integrated Estimating framework, which is a model-based collaboration developed on five characteristics that distinguish it from other industry practices by addressing the most common adoption challenges encountered with other workflows, setting clear expectations for practicing design and estimating integration with a model. The five characteristics of the workflow include 1) Intentional Model Authoring, 2) Qualitative and Quantitative Data, 3) Integration of Cost, 4) Use of an Estimating Standard, and 5) Application of Automation or Augmentation (Pilgrim and Valdes-Vasquez, 2024). Below is a summary of the characteristics.

- Intentional Model Authoring ensures that every object created (authored) in a model is done so with the knowledge and awareness that the model may be used in some downstream form of analysis, such as estimating or scheduling. The purpose of the model content is not simply for design documentation. This characteristic increases the baseline quality of the model.
- Qualitative and Quantitative Data ensure that the model objects created with intention contain the necessary information and parameters for the consumer to properly identify the object, the scope of work, or the building system it represents and that they can be quantified.
- Integrated Cost ensures that a digital link exists between the line item of cost and the model object, providing the source of the quantity data for the cost item. This characteristic establishes digital integrity in the workflow and the subsequent estimate.
- Use of an Estimating Standard provides estimators with a basic quantification strategy and standardized approach for models that contain objects of varying LOD. This characteristic enables lower fidelity models, for example, massing models, to be utilized in the estimating process during programming, concept, and schematic design phases of design.
- Application of Automation or Augmentation insists that some part of the workflow is capable of being automated, or augmented by machines. This characteristic aims to increase efficiency through automation features and helps reinforce the need for the first four characteristics.

These five characteristics must work in aggregate for a particular model-based workflow to be qualified as meeting the Integrated Estimating workflow definition. This workflow has been deliberately developed to leverage each individual aspect of the framework and specifically address the barriers to adoption that have been previously identified.

Research Approach

This pilot project aimed to demonstrate the effectiveness of the Integrated Estimating workflow as an intuitive, cross-disciplinary collaborative process that relies on a single model as the central source of project information. To ensure unbiased results distinct from the author's prior experiences with the workflow, the pilot was conducted with two independent industry members, representing a design team and a preconstruction team. While it was not a requirement, the selected participants had no prior experience working together or with this specific workflow, further emphasizing its adaptability.

The designer included an experienced architecture professional with expertise in commercial, mixed-use, and modular construction projects. In contrast, the preconstruction professional featured a seasoned estimator with a strong BIM and VDC engineering background. Both participants provided critical insights into the Integrated Estimating workflow's application, scalability, and effectiveness as they progressed through the training and implementation phases. The pilot study also included a trainer, representing the Integrated Estimating subject matter expert, and six secondary industry members who acted as observers, meaning they were part of the training but did not manipulate the model.

For this pilot project, once the project team was identified and invited to participate, an initial kickoff call was established to introduce the team to each other and introduce the context of the pilot project. The team members were given a pre-read to help establish a base level of understanding. The pre-read included a description of the framework and each of its characteristics. During the initial kickoff meeting, the agenda covered a) people introductions, b) an overview of the goals and purpose of the pilot project, c) a thorough overview of the Integrated Estimating framework, d) the strategy for the pilot project, and e) administrative items. The purpose of this meeting was to discuss the "why" of the pilot project and answer the question, "Why are we doing this?". The five characteristics of the framework were introduced and reviewed in detail during this meeting.

A follow-up, one-hour meeting was focused on the "how" of the pilot project. This meeting addressed how the project team would implement the technical steps required in the pilot project. While this meeting was a form of technical training and covered all five characteristics of the framework, discipline-specific and focused training would be covered in a separate follow-up session and targeted only the design team member for the first two characteristics and only the preconstruction team member for the last three characteristics. This training touched on the five characteristics again, but this time in the context of the tools utilized in the pilot project.

Following this second training, the Programming and Concept Design phase of the pilot project officially began. The project facilitator, serving as the client in the project, introduced the project program of requirements (POR), and the subject building (a suburban office building) to the design team member. Table 1 lists the owner's program requirements, and Figure 1 shows the preliminary design ideas.

Table 1. Owner's Program Requirements

Program Function Description	**Program Area (SF)**	**Unit of Measurement**
Primary Office Space	20,768	NSF
Support Space	5,692	NSF
Multi-Purpose Space	5,885	NSF
BOH Space	5,000	NSF
Public/Common Area Space	5,960	NSF
SUBTOTAL	43,350	NSF
Gross-Up Factor	20%	
TOTAL Gross Square Feet	**51,966**	**GSF**

The project program was framed as a suburban office building between two and four stories, between 50,000 GSF and 100,000 GSF, with parking to support 150 parking spaces. The assumed construction type was described as a concrete tilt-wall building with steel columns, bar joists, and joist girders. The greenfield site was identified as approximately two acres. Then, in their own time, the design team member began the design process to develop a blocking and stacking, mass model of the program with initial design intent created for the building itself.

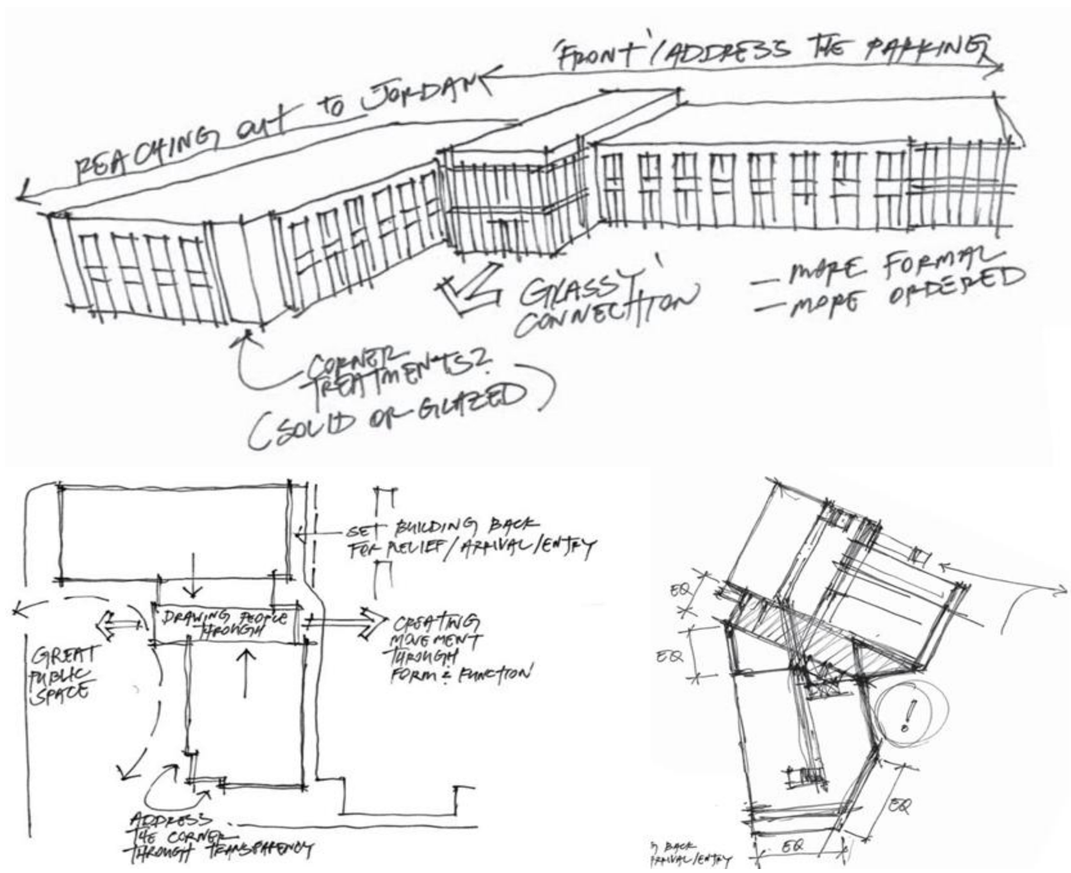

Figure 1. Initial programming and concept sketches provided by the trainer.

Next, individual, discipline-specific focused training on the next steps required for implementing the workflow was conducted with the design team member. Since the design team member was already trained and competent with the model authoring application used in the study, the training was brief and only addressed new requirements introduced by the Integrated Estimating framework. A follow-up meeting was conducted to review the work product, perform a quality review, including a model audit, and perform necessary updates to the work product to ensure compliance with the framework expectations. The quality review included a model audit to ensure the model authoring requirements identified as the first and second characteristics of the workflow were correctly performed in the resultant model. The model audit was performed by the pilot project trainer and a report listing any deficiencies was provided to the design team member.

Having completed the design process, the model was published, and the project shifted to the preconstruction team member. Again, discipline-specific training was conducted with the preconstruction team member to help facilitate their work, and the estimating tasks began. Since the preconstruction team member was already familiar and competent with the cost estimating application, training was only required on the steps specific to the Integrated Estimating framework.

A follow-up meeting was conducted to review the work product, perform a quality review of the estimate, and perform necessary updates to the work product. Figure 2 displays the concept design solution developed in response to the building program and design concepts.

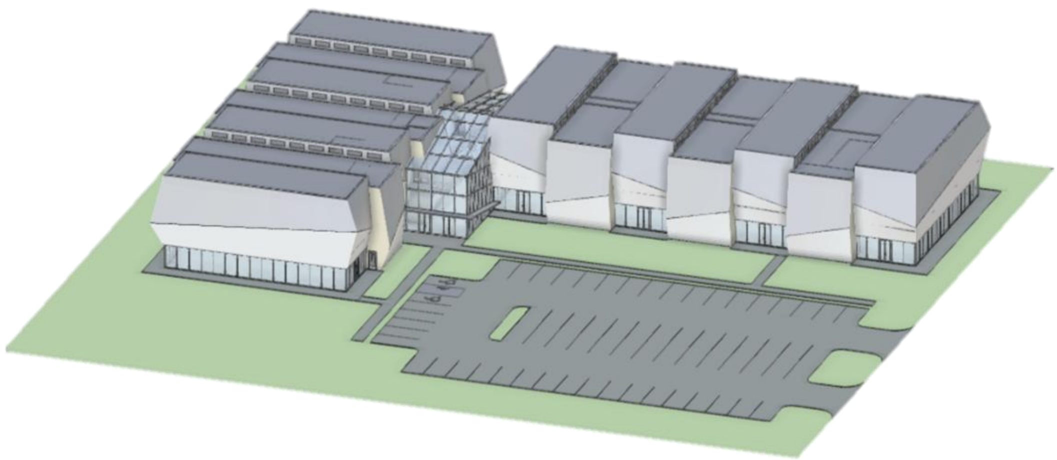

Figure 2. Resultant concept design solution

Finally, the whole team was assembled and reviewed the process deployed during the project's Programming and Concept Design phase. The team discussed lessons learned, various challenges encountered, and the value-added experiences gained from the exercise.

Figure 3 shows the relationship between the cost items linked to the digital model. In the image, the blue arrows are demonstrating the "digital connection" or link between the cost estimate line item and the model object it is mapped to, and where the quantity source for the line item originates. This visual represents the third characteristic of the workflow, Integrated Cost. The image shows the estimate filter on the left, isolating the Substructure division of the estimate Work Breakdown Structure (WBS) breakdown, the cost items associated with that WBS, and the model object tied to that cost item. This same sequence and process was repeated for the Schematic Design phase of the pilot project. However, as part of the Schematic Design phase, the team was able to demonstrate the change management process using the model where some model objects are modified, some are removed, and some are added to the model because of evolving from Concept Design to Schematic Design. This is an important aspect of the pilot project because it highlights the value of the fifth workflow characteristic, which is related to the use of automation as part of the workflow.

Figure 4 shows a representation of the automated change management process. In the image, the color coding is a feature of the software's change management function where red is used to identify model objects that were removed from the previous version of the model, yellow is used to identify model objects that have been modified from the previous version of the model, and green is used to identify new model objects that were introduced since the prior version of the model. In this specific workflow, the software transfers the cost item and model object mappings, or links, from the previous version of the model to the new version of the model and thereby automating the change management process for significant efficiency improvements.

Due to schedule limitations, the pilot project could not proceed into the Design Development and Construction Document phase.

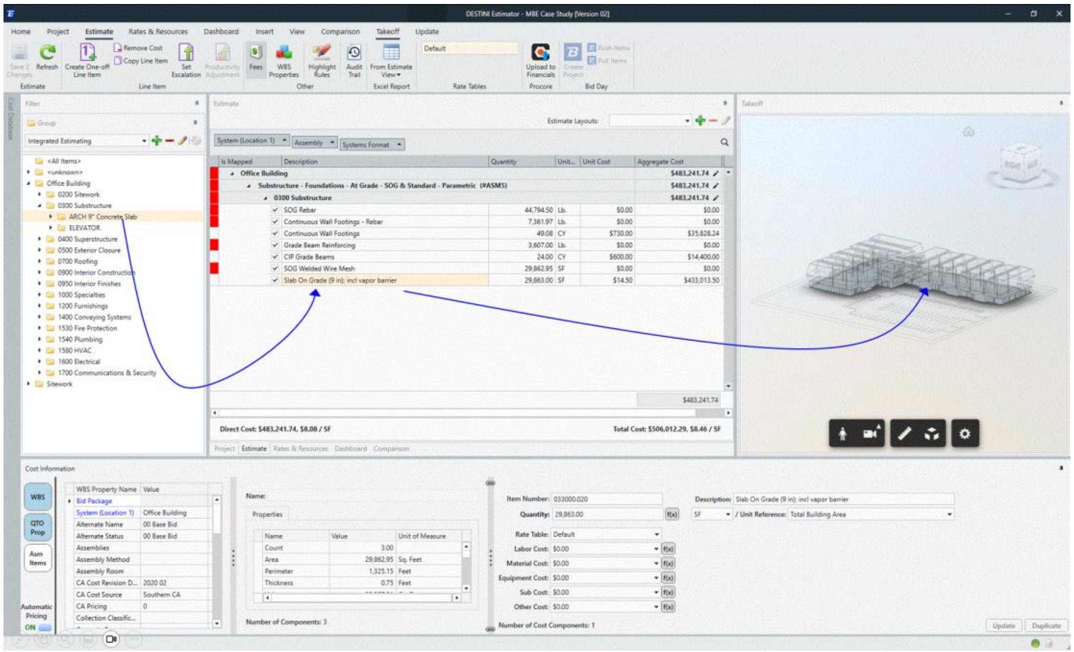

Figure 3. Display of the cost items linked to the digital project model

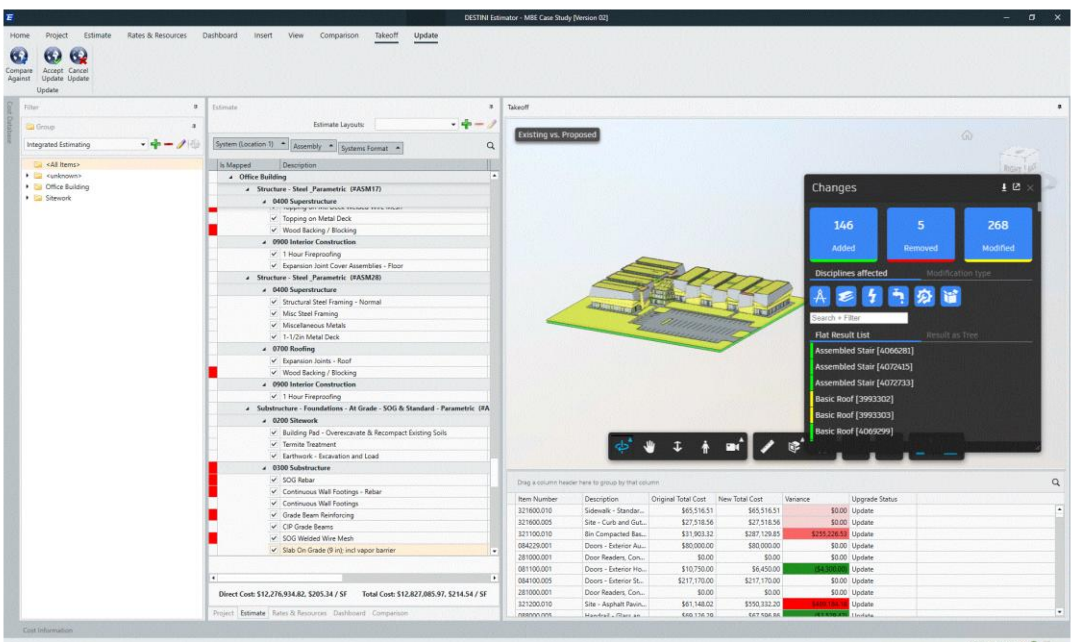

Figure 4. Display of the cost items linked to the digital project model

Results and Discussion

The pilot project achieved its stated goal of testing the implementation process of a new workflow. This initial pilot study was successful based on the survey responses provided by the participants, who responded positively to the survey questions. The pilot project yielded beneficial results in these areas but also provided additional value in testing a training and implementation strategy for the workflow. Additionally, since the design firm and preconstruction team did not have previous project experience together with this workflow, it also demonstrated the potential for broader adoption industry-wide. After the Schematic Design phase was completed, a survey was provided to each team member to provide independent reflections on their experience during the pilot project.

Design team member's Feedback

The design team member's perspective emphasized the workflow's impact on model authoring and data integration:

i. Regarding the first characteristic of the workflow, Intentional Model Authoring, the design team member commented:
    a. This characteristic does not represent a significant challenge to implement. It reduced the number of extra steps required (compared to other model-based estimating design team requirements) and streamlined the process compared to other model-based estimating workflows.
    b. This characteristic significantly improves model quality for the BIM
    c. This characteristic moderately improved collaboration capabilities with the preconstruction team.
    d. This characteristic allowed more freedom to explore the design space.

ii. Regarding the second characteristic of the workflow, Qualitative/Quantitative Data, the design team member commented:
    a. This characteristic is moderately challenging as it represents an additional QA/QC step for the design team member.
    b. This characteristic significantly improved model quality for the resulting Building Information Model.
    c. Significantly increased collaboration with the preconstruction team.

One surprising and encouraging outcome was the design team member's response regarding the belief that the workflow was more sophisticated and structured than traditional 2D-supported design and preconstruction exercises and, therefore, would grant the designer more freedom in exploring the design space. This encourages the design profession to investigate the potential of this workflow and give design exercises more support.

Preconstruction team member's Feedback

The preconstruction team member highlighted the workflow's scalability, efficiency, and impact on collaboration. Specifically, regarding the overall application of the workflow, the preconstruction team member commented that the workflow:

- enabled significant improvement in my ability to comprehend the project's design intent.
- enabled a significant reduction in the time to perform quantity take-off activities related to estimating.
- is highly scalable in terms of a formalized estimating standard or strategy for QTO.
- provided exceptional improvement to the efficiency of the estimating process.
- provided significant improvement to managing change between design phases.

- provided significant improvement to the underlying model quality.
- provided significant improvement to the underlying estimate quality.
- is highly scalable in terms of the potential for industry adoption

Observer's Feedback

Observers involved in the pilot project offered additional perspectives, noting the workflow's broader implications by indicating the following about the workflow:

- It offers significant improvement in collaboration opportunities with design teams.
- It offers significant improvement in communication of design intent for the project.
- It significantly improves the underlying quality of the Building Information Model.
- It offers moderate improvement to the quality of the cost estimate.
- It is scalable in terms of the potential for industry adoption.

This initiative presents a unique opportunity for cross-disciplinary collaboration, significantly enhancing communication and understanding of design intent among new design and preconstruction team members with no prior workflow experience. By functioning as a single source of truth (SSOT) for project data, it delivers substantial improvements in model quality and can achieve labor reductions of up to 50%. The pilot approach promotes the earlier integration of models into the design process and offers the lowest barrier to entry for BIM standards in the industry, such as ISO19650. Additionally, it facilitates quicker access to cost information, supporting more informed decision-making while effectively eliminating scope gaps and uncovering design discrepancies. The process enables prompt feedback from subcontractors and accommodates lower Levels of Development (LOD) along with simplified model structures during the initial design stages. Moreover, it incorporates change management features that expedite the processing and analysis of design modifications, ultimately streamlining the entire design workflow.

Additionally, lessons learned from this pilot project included techniques to deliver succinct, just-in-time training, applicable to cross-disciplinary teams. This training supported upskilling individual participants from a base-level of technical skills and existing product knowledge to a new set of technical skills and extended product knowledge. Other lessons learned included how to structure a pilot project with volunteer industry participants. This pilot project also exposed additional areas for future research.

Conclusion

The results of this pilot project are encouraging. It demonstrates support for the hypothesis of engaging both the design and construction teams to collaborate and encourages those in the industry interested in model-based estimating to pursue this specific workflow. This pilot project was a solid step in further testing the validity and effectiveness of the Integrated Estimating Framework with more rigorous testing. It takes the next step of using independent participants to determine if the workflow can be taught and adopted by other companies. In order to increase the adoption and implementation of model-based estimating practices in preconstruction teams, existing industry participants will need to be capable of adopting and implementing model-based preconstruction workflows, and academia will need to incorporate the teaching of these principles into a curriculum that prepares future industry participants to identify and work with model-based preconstruction workflows.

In the future, further pilot projects can consider other aspects of the process this project could not analyze. For example, future pilot projects and/or case studies should include other design phase exercises, such as the design development and construction document design phases, to evaluate the effectiveness of the workflow in these stages. Future studies should consider the involvement of the project owner to seek their perspective on the process and what potential benefits might be received by the building owner. Finally, future studies would benefit from a better understanding of how many other industries have more formal training and onboarding experience and how long that process is before expecting the new employee to contribute to the firm in a meaningful way.

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