

Design-Assist Delivery for Prefabricated Building Components

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Prefabrication offers a potential means for improved construction value. It allows for better quality control, waste control, improved worker efficiency, improved worker safety and shorter project schedules. One of the major variables of prefabrication is design collaboration. In many cases prefabrication benefits from the early collaboration between the designer and the contractor.

Design-assist delivery methods offer an opportunity for early contractor design involvement to address prefabrication constructability concerns. Contractors can directly influence the design team to aid in the incorporation of prefabricated components. This allows for greater collaboration between major construction team members so that they can address design issues together.

This study aims to tackle the coordination issues of prefabrication in the design phase of construction. Specifically, the research investigates the feasibility of design-assist delivery for prefabrication projects. This entails input from contractors to address prefabrication constructability issues during a buildings design. The views of prefabricators/subcontractors, general contractors and designers are examined.

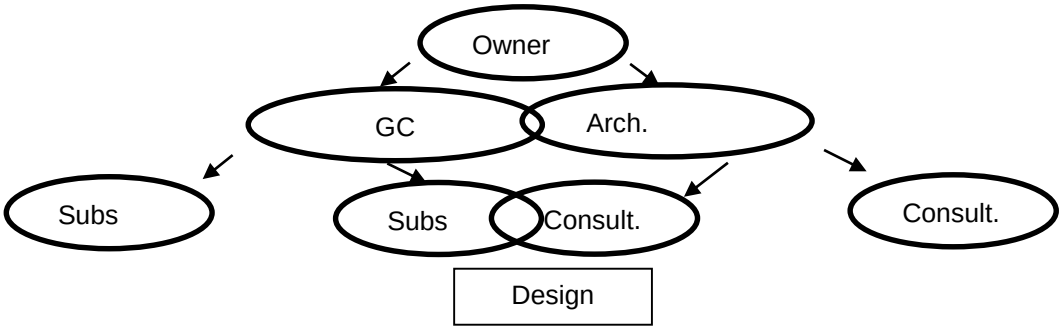
Keywords: Prefabrication, Design-Assist, Delivery Methods

Introduction

Research has shown that prefabrication and modular building processes are effective strategies for improving productivity and efficiency in the construction industry. The assembly of building components in an offsite, controlled environment allows for the production of a higher quality product (SmartMarket Report, 2011). Projects typically have shorter schedules due to the elimination of onsite predecessor activities that would delay the start of the construction of these building components (Olsen and Ralston, 2013). Prefabrication also allows for a more efficient control of material, which drastically reduces waste generation (Tam et al., 2007). While there are significant advantages to the implementation of prefabrication, there are also some major limitations.

Prefabrication and modular building have major implications that affect the design and coordination processes. Prefabricated building components have higher building tolerances than site-built components, and in turn require more detailed design information. This process can be slow and costly, as initial designs often have to be remade or reworked to fit modular specifications (Schoenborn, 2012). Multi-trade prefabrication, is defined as those building components which are the collective work product of multiple trades. If the decision to use multi-trade prefabrication is made after the initial bid process, its incorporation into the project can be contentious in that it often requires certain subcontractors to reduce scope in order to make room for the prefabricated components. As a result, subcontractors are often resistant to prefabrication (Olsen and Ralston, 2013). Research indicates that many of the problems associated with using prefabrication are made much worse through poor coordination between the design team and the prefabrication contractor (Schoenborn, 2012). One logical solution to this would be the implementation of design-assist delivery.

Design-assist delivery entails the collaboration of the owner, architect(s), general contractor and subcontractors (including prefabrication contractors) during the design phase of construction (Hart, 2007). The contractors, subcontractors and prefabricators essentially play a consultant role in the design process. This early influence gives the design-assist contractor the opportunity to influence then design and facilitate objectives such as prefabrication. The design-assist contractor could be made responsible for defining the scope of prefabrication that will be reflected



in the contract documents. Input from the prefabricator will ensure that the architect accounts for all factors affecting the feasibility and efficiency of prefabrication. Furthermore, design-assist could eliminate some resistance from other subcontractors, as these contractors' original bids will already exclude the portion of work that will be prefabricated since those modules will be identified in the contract documents. Design-assist contacting could also be structured to include target value design principles (Andre, 2012). Target value design incorporates financial considerations into design criteria. This could allow for a more effective method for comparing prefabrication and site-built component costs.

Literature Review

Prefabrication and Modular Construction entails the assembly of building components in an offsite location, followed by delivery and installation. Multi-trade prefabrication is when multiple subcontractors collaborate on a single building assembly in an offsite location. Single-trade prefabrication, on the other hand, refers to a component that would traditionally be constructed by a single subcontractor (or trade) (Schoenborn, 2012).

There are several methods that can be used for single-trade and multi-trade prefabrication. A contractor or contractors can prefabricate a building component in an open space onsite or in a warehouse. Building components can also be prefabricated in a factory offsite. This is typically done by a manufacturer. There are many variables including proximity to resources and jobsite, worker efficiency, etc., that impact the feasibility of prefabrication. These different methods are suitable for different situations (Legmpelos, 2013).

Advantages of Prefabrication

Prefabrication has several potential advantages for a construction project. These advantages include:

- Shorter project schedules through the reduction of critical path activities which are performed off site ahead of time without on-site constraining predecessors (SmartMarket Report, 2011)
- Improved quality and efficiency through greater control means, more productive work space and quality feedback loops (SmartMarket Report, 2011)
- Waste reduction through improved material control procedures (SmartMarket Report, 2011).
- Safer work environment with more controlled work conditions and hazard mitigation (Legmpelos, 2013)
- Improved work conditions in climate controlled, organized environments (Legmpelos, 2013)
- Less work disruptions in a weather-protected work environment (Schoenborn, 2012)
- Decreased labor costs and costs associated with the moving of workers (Legmpelos, 2013)
- Improved Supervision in an open, controlled environment (Legmpelos, 2013)

Coordination and Collaboration

According to Azhar et al. (2012), a key factor in the implementation of prefabricated construction is effective collaboration in the early project stages. This is especially relevant for multi-trade prefabrication, as these assemblies need to be design and planned for at an early stage to maximize value. (Olsen and Ralston, 2013). Planning for prefabrication in the design phase will eliminate the need for additional shop drawings and design rework in the later stages of construction. This requires additional design costs up front, but it reduces design costs and requests for Information (RFIs) during construction. If a project does not plan for prefabrication initially, the

original drawings will entail a significant amount of wasted design work. In addition, the work on the project will be bid as if it were to be site-built. This would greatly limit the potential for prefabrication, as some of the subcontractors may not have the capacity for prefabrication. Furthermore, contractors would have to rework their budget to reflect a more manufacture like production. The design plans will have to be reworked to allow prefabricated components to be delivered and installed correctly. This has significant implications on other systems within a building (Schoenborn, 2012).

Design-Assist Project Delivery

In design-assist delivery, the owner(s), architect(s), general contractor and subcontractors (including prefabrication contractors) collaborate during the design phase of construction. In contrast to design-bid-build delivery, design-assist allows for contractors to have a major role in the design process. This includes analyzing and advising issues concerning constructability, cost estimating, scheduling, materials, systems, labor, equipment, procurement timing and design development. The design-assist approach is similar to the integrated project delivery system, however, it does not have some of the controversial features such as limited liability and joint decision-making. The benefits of design-assist delivery include reduced project schedule, improved value, fewer coordination issues, fewer RFIs and fewer change orders (Andre, 2012).

The design-assist concept is an evolving delivery "philosophy" (Andre, 2012). In general, it refers to contractors and subcontractors directly contributing to the development of design documents, most commonly the Mechanical, Electrical and Plumbing (MEP) documents. It is mostly implemented in conjunction with another delivery method (Hart, 2007). The design-assist delivery method is not rigidly defined and can be tailored to the needs of each project. As a result, the number of subcontractors involved and level of their participation can vary (Andre, 2012). Although there are varying intensities of design-services provided by the construction team in design-assist delivery it can range from design suggestions to arrangements more akin to the traditional fire sprinkler subcontractor who is responsible for all of their design.

Design-Assist Project Delivery and Prefabrication

The research on design-assist delivery for prefabrication is limited. We found some valuable information related to concrete precast applications. According to Precast Concrete Institute (2011), the precast contractor should play a major role in the design process of a design-assist project. During the schematic design phase, the precaster will identify criteria and options for the aesthetic, structural, size, count, schedule (coordination with other subcontractors), site features and composition factors relevant to the precast components. These options will be compared, reviewed and finalized during the design development phase. To ensure that everybody is on the same page, the owner and design team will visit the off-site manufacturing facility at the beginning of the prefabrication process to make minor changes if necessary (Precast Concrete Institute, 2011).

Target Value Design

Target value design (TVD) can be used in conjunction with other delivery methods, including IPD and design-assist projects. TVD allows for the design and construction team to set cost targets that direct their objectives during the design process. This allows the project team to design based on an estimate rather than estimate based on a design. The design is made for what is constructible and affordable. Working together as a group before the design rather than after will yield solutions to problems before they arise (Macomber and Barberio, 2007).

Going hand and hand with the principles of design-assist and IPD approaches, target value design emphasizes learning and innovation. It is a continual learning that is open and adaptive, facilitating retrospection throughout the process. Value and how value is produced is assessed and re-evaluated continuously (Macomber and Barberio, 2007).

Methodology

Qualitative research was used to investigate the impact of delivery methods on prefabrication feasibility and the practically of design-assist methodologies to facilitate prefabrication. Open-ended interviews allowed for a variety

of answers and perspectives. The interviews were analyzed to draw conclusions about the current and future direction of the industry.

Research Design

Three representatives from each of the following disciplines were interviewed in the study:

1. Prefabricators (one electrical contractor, one mechanical contractor and one multi-discipline prefabrication manufacturer)
2. General contractors
3. Designers (one architect, two consulting engineers)

The participants were specifically targeted for their exposure to and/or involvement with prefabrication. All of the interviewees were primary sources. Most of the professional experience of the nine primary sources was focused in the ******* United States. The participants were chosen through convenience sampling of acquaintances and referrals. While the sample does not reflect the views of the entire population of construction professionals, the result yield preliminary conclusions that can add to the understanding of prefabrication building processes and guide further research.

The professionals interviewed for the study had a wide range of experience within the construction industry with varying exposure to prefabrication. Included below are summaries of lengthy interviews

Results

Prefabricators
Interview 1

The interviewee had a negative experience using the design-assist process to facilitate prefabrication. However, the interviewee also understands what it takes to be successful using these methodologies. According to the interviewee, this process still adheres to the traditional system where the designer has complete control of the design and the contractors have to rework everything. The fact that these designs were constantly reworked indicates that in their experience the designer disregards the contractors input. In their opinion in order to successfully prefabricate, the subcontractor should have a defined design responsibility that takes away from the engineer's scope of work, and further the contractor should be compensated for this through additional overhead fees.

The participant consistently made references to the coordination difficulties that come with prefabrications. References are made to the difficulties and high costs of learning a new process, suggesting that it would be valuable to have an experienced team on a prefabrication project. Prefabrication projects should have the designers and major contractors collocated to facilitate collaboration in design. There should be less design contribution from the engineer and more from the contractor. However, one barrier to this is that it requires subcontractors to be on a project very early and does not allow for competitive bidding that works in the owner's favor.

Interview 2

Interviewee 2 defined design-assist delivery for prefabrication as a happy medium between design-build and design-bid-build delivery systems. It still allows the owner to have more control over a project, but still allows for contractor influence on design. One limitation of this, however, is that the architect wants to have control and has less concern for the contractors' constructability issues in this relationship. Another limitation of the design-assist system is that it does not always allow for the selection of the best prefabrication team members on the project. The bidding process for a design-assist project is at the mercy of the owner. Depending on the owner's selection criteria, the right contractor's for prefabrication may not be chosen for the project.

The interviewee emphasized the need for the right team to be successful on a prefabrication project. This includes other MEP contractors and a general contractor with knowledge and experience on the subject. The best delivery method to facilitate this would be design-build as it allows for the contractor to work as an equal to the designer in the design phase. In order for a prefabrication project to be successful, there must be involvement by the time that

the design is 20% complete. Creating a strong model is essential to facilitate prefabrication adaptations. According to the interviewee, additional compensation for design work is not needed, as the competitive advantages of prefabrication and cost control implications make up for these expenses.

Interview 3

Interviewee 3 offers a different perspective on prefabrication. The participants experience with prefabrication involves multi-trade hospital bathrooms and walls. These components entail 13 trades and in turn require a significant amount of integration. Instead of controlling this work through traditional means, the contractor assembles all of the features through one entity under one contract. This requires involvement on a project before design.

According to the participant, all common delivery methods, including design-assist, place limitations on prefabrication through compartmentalization, which causes contractual constraints and conflicts of interests. For prefabrication to be effective, the trades need to be combined into one entity. Another barrier to design-assist prefabrication is the lack of experts on the subject in the industry. In order for the participant's company to bid on prefabrication work that was laid out through design-assist procedures, there would have to be an industry professional knowledgeable of everything that their prefabrication work entails.

Under interviewee 3's system, the contractor essentially is the designer and must be involved from the beginning. This suggests that there must be a team that has a lot of experience with the processes prefabrication. The participant suggests that BIM is a good tool for prefabrication design, but is not what drives effective coordination in the process.

General Contractors

Interview 4

The interviewee indicates a need for early contractor involvement in the design phase to facilitate prefabrication. One problem with using design-assist prefabrication is the fact that the prefabricator's scope of work cannot be bid out to other prefabricators. In other words in order to get them to contribute their ideas for the design they want to be sole sourced for the work in return. This makes it difficult to implement cost control measures. One solution to this would be to have a prefabrication consultant designer work in the design-assist role without bidding the construction work. This, however, is not a very feasible solution and by definition is not the intent of design assist.

According to the participant, the driving factor for prefabrication is the owner of a project. While there are a lot of unknown cost variables, it remains valuable to the general contractor to work through them and prefabricate if it is something the owner wants.

The participant refers to technology and BIM as tools that can help improve the prefabrication process. It is essential that prefabricators are allowed to use the software that they are already competent using in order to maintain efficiency. Considering the notion that modeling is an efficient tool for prefabrication, it can be concluded that it is important to have a prefabrication team well versed in this technology.

Interview 5

The contractor had been exposed to IPD, design-build and design assist delivery methods on prefabrication projects. The IPD and design-build arrangements are beneficial because they allow the contractor to collaborate more with the architect during design. The participant implies that these two deliveries facilitate a better coordination relationship between the contractor and designer than design-assist. Design-assist is limited by the fact that the owner still employs the architect. In this system, the ability to prefab is dependent on the design team that is on the project. This design team may not be open to considering constructability issues in their design. However, interviewee 5 also indicated that they are seeing some structural engineers giving up some of their design scope to subcontractors in order to mitigate risk. This could potentially be an avenue for a greater prefabricator design role.

Another limitation of design-assist for prefabrication is that it limits the owner's ability to have a competitive bid process for the work. One possible solution to this would be to allow the owner to select from multiple subcontractors who he/she wanted to work in the design-assist role.

Effective prefabrication is reliant on early contractor involvement. In order for this to happen, there needs to be an owner who trusts the contractor. It is also essential to have the right team with prefabrication and modeling experience. Team members need to have experience defining critical issues in their design and scope of work.

Interview 6

Interviewee 6 expressed that he had never used design-assist methodologies on prefabrication projects. He explained that it could work if a contractor saw value in doing it. In order for it to be a success, however, it is necessary to have an experienced team with modeling capabilities. The best delivery method for prefabrication would be IPD as it allows the contractor to share the risk. Design-build allows for some risk sharing. The traditional delivery method, however, entails too much risk and the contractor leaves it up to the subcontractors to prefabricate.

In the participant's experience, all the contractor needs is a one line program or diagram from the designer in order to prefabricate. This indicates a decrease in design work for the architect and an increase in design work for the contractor. The components that are going to be prefabbed need to be clearly defined before the work is bid to a subcontractor. This suggests that the design contribution should be entirely made from the general contractor rather than the prefabricator.

According to interviewee 6, there are many different scenarios for prefabrication. Single-trade applications can be left to the subcontractor and require little collaboration in design. Large multi-trade applications, however, require early planning and involvement. Each project is different and some projects are more suited for prefabrication than others. The most important factor is having the right team on the project.

Designers

Interview 7

According to the architect, the traditional delivery method is not suited for prefabrication because there is no team member who wants to pay for the additional design rework that would allow for prefab. There is value in design-assist delivery methods to facilitate prefabrication, but this comes with some major limitations. If a prefabricator wants to have a greater design role, they would need to be licensed and have experience. In the participant's experience, subcontractors do not want to do this because they do not want to take on additional liability. In order to achieve prefabrication, contractors need to be in a good financial position to tackle performance and payment bonds as well as design liabilities.

The designer's motivation to use prefabrication on a project would have to be owner driven. Early involvement and planning in design is key to prefabrication. Furthermore, right team with good experience needs to be on the project. Each team member's scope needs to be planned out and accounted for ahead of time. BIM technology is an important tool for collaboration.

Interview 8

The engineer expresses some major limitations for design-assist methodologies to facilitate prefabrication. Subcontractors should not have a major role in design because they would produce a lower design quality and not do a good job with constructability analysis. If prefabricators were to influence the design, the engineer should still be responsible to specifying system proportions and evaluating performance. This would give a subcontractor limited input on design. In addition, subcontractor design integration is not beneficial for general contractors because it does not allow for competitive bidding.

The participant claims that collaboration early on is essential for prefabrication. This can only be done with a competent, experienced team. BIM is a good tool for seeing things virtually but is not the primary means to facilitate collaboration and planning.

Interview 9

All of the engineer's exposure to prefabrication is on the single-trade level where subcontractors can take a design and adapt it for prefabrication without changing any of the original design work. There are some scenarios for multi-trade prefabrication where it would be advantageous for the prefabricator to be involved early. This involvement, however, would be limited to providing installation criteria for the prefabricated components and would have no impact on the building design. One major limitation to design-assist roles is that the contractor does not want to take on additional design liability. The only solution to this would be an integrated project delivery with joint liability. This integrated design process allows the contractor to make input on constructability issues that will save money on a project.

The participant also mentions that the architect does not want to account for constructability issues during the design process. In the design-assist role, this could be a major limitation, as the architect still maintains primary responsibility for the design and has the ability to place his objectives over the objectives of the prefabricator.

Conclusions

Advantages for prefabrication include decreased project schedule, decreased waste, improved quality, improved efficiency and improved safety. Some disadvantages for prefabrication include increased design costs, increased transportation costs and installation complication issues. Coordination and collaboration between the designers and contractors is essential for the successful implementation of prefabrication on a project. The delivery method of a project can have a significant impact on the feasibility of this collaboration.

As it relates specifically to the design-assist delivery method and its suitability for prefabrication the interviewees had mixed opinions. All of the prefabricators and contractors expressed a need for strong coordination during the design phase of construction. This entails influence and collaboration with the design team, preferably in a common location. The contractors and prefabricators felt there should be a greater design contribution from the prefabricator and a decrease in design contribution from the designer. This view was not shared by the designers.

Other concerns were raised related to cost, competiveness and value as it relates to design-assist. All parties seemed to acknowledge that design-assist would decrease the competiveness for the prefabricated scope of work. This is reflected in the need to incentivize the prefabricator's design contribution by promising the opportunity to execute the work. This loss of competitive environment could be mitigated by the use of strategies such as target value design, but the question still remains as to whether the owner is getting the best value.

The majority of the interviewees also mentioned that under the design-assist methodology the architect would still retain ultimate authority over the design and thus might minimize the potential for true collaboration. Some interviewees were of the view that design-build and IPD created a tighter team and thus the designer might be more prone to listen to and implement the prefabricator's ideas.

All of the prefabricators, contractors and designers emphasized the importance of having a strong, experienced team on a prefab project. The prefabricators indicated a high use of BIM in their prefabrication practices. While BIM is seen as only a tool, it can be concluded that competency in BIM is extremely important for a successful project team.

The interviewees all expressed very different and diverse opinions about the potential for design-assist delivery to improve the prefabrication process. By in large all interviewees saw value in design-assist to aid prefabrication, but did not believe it was the key missing ingredient that has prevented prefabrication from flourishing.

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