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Project Delivery Approaches for Modular Commercial Construction Focusing on The Relationships between Project Stakeholders: Case Studies

Joseph Grant* · Yong-Woo Kim**

Abstract

The objective of this research paper is to identify through case studies the relationships that exist between the key stakeholders on modular projects as opposed to conventional projects. Through case studies, we identified three types of relationships between key project stakeholders: (1) Full Integration, (2) Partial Integration, and (3) Weak Integration. The case study findings lead us to make three claims: (1) a direct contractual relationship and familiarity must exist between the general contractor and modular fabricator; (2) engaging an architect familiar with the modular system through a direct or indirect relationship is imperative; and (3) the more familiarity and relationships between the four major stakeholders that exist on modular projects, the better the outcome of the project.

Keywords : Modular Construction, Project Delivery, Case Study

1. Introduction

With construction costs rising faster than inflation, a declining labor availability rate, ageing of the construction workforce, more stringent cost and schedule demands from clients, and a measurably decreasing productivity rate, the construction industry is clearly in a state of crisis (Azhar et al., 2013). It is becoming ever more important to find efficiencies and explore innovations that can help to control costs and uncertainty. One such promising method is through the widespread adoption of modular construction technologies. Off-site construction involves the process of planning, fabricating, transporting and assembling building elements for rapid site assembly to a greater degree of finish than in traditional piecemeal on-site construction (Smith, 2015). Through the use of fully modular or prefabricated off-site modular components, it is potentially possible to reduce costs, schedule, uncertainty, and improve quality. Fig. 1 shows the difference of project delivery process in timeline between traditional stick-build method and modular construction method. Modular

*Project Manager, Commercial Real Estate Development, 1321 Seneca St. #2001, Seattle, WA 98101 (josephwgrant@gmail.com)

**Professor, Department of Construction Management, The University of Washington, 105 Arch Hall, Seattle, WA 98195 (Corresponding Author: yongkim@uw.edu)

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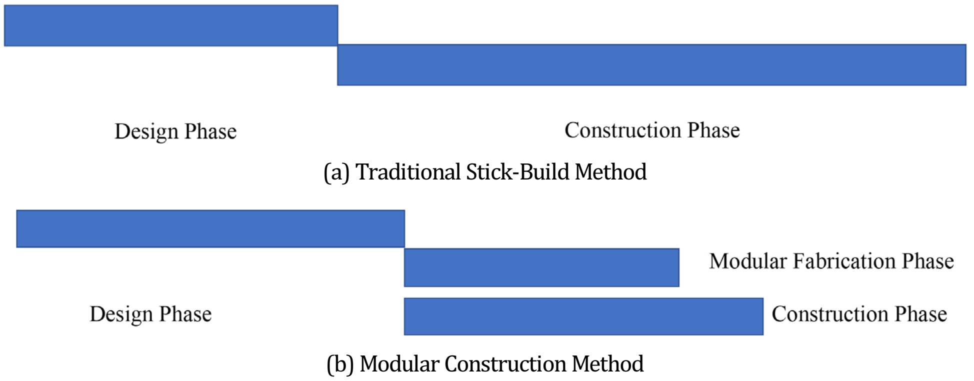

Fig. 1. Difference of Project Delivery Process

construction is gaining in prominence throughout the industry, estimated to comprise 2.93% of the value of new construction in North America as of 2014 and rapidly growing (Ramaji et al., 2017).

While the potential benefits of this technology are well understood, it remains unclear how the delivery of modular projects differs from that of conventional projects and how these differing delivery methods apply in practice. Since there are many elements of project delivery that will change when it is moved from an on-site to off-site construction method, stakeholders such as architects, engineers, and contractors must be aware of these changes and how the project will be affected (Griboff and Travelis, 2015). If modular construction represents a new delivery approach, then there are likely distinct project management characteristics that define this project type. This paper aims to fill this gap in understanding and provide through case studies a foundation upon which to explain how modular project delivery differs from that of conventional construction projects. If modular construction is to become a solution to tackle the difficulty of delivering successful and economical projects in today's environment, the unique characteristics of these modular projects must be clearly understood.

The objective of this research paper is to identify through case studies the relationships that exist between the key stakeholders on modular projects as opposed to conventional projects. By drawing on the experience of current practitioners on three contemporary modular projects within the Seattle market, actual example projects form a basis of understanding to address the objective. From this foundation, we discuss concrete observations on the unique characteristics of these relationships and present a potential framework for how to manage more effectively this emerging project type.

2. Literature Review

There is a small but growing body of literature covering modern commercial modular construction. Common topics range from investigations of the effectiveness and promise of modular technology to its applications. What is lacking from this literature is any clear investigation of the project delivery methods of modular construction projects. This is not surprising given that in this nascent stage of development, the focus is more on studying the potential of this method rather than any wide-spread contemporary application of the technology. However, there is still valuable information one can glean from the existing research.

The terms *prefabrication, modular, and off-site production* are all used somewhat interchangeably to describe the process whereby construction work is completed for a given project somewhere else than the project site itself. Modular construction is often divided into what can be termed 3-D systems versus panelized modules. The difference here is that 3-D approaches consist of entire cubic modules which are produced to be stacked in place while panelized modules are planar assemblies that comprise the floors/walls/ceilings of spaces (Ramaji et al., 2017). Prefabrication is a broader term that encompasses a wider range of off-site production such as prefabricated steel stairs or curtain wall units; although prefabrication in the context of this paper is meant to mean a kit-of-parts approach whereby the majority of building systems are produced in a controlled off-site environment then assembles on-site similar to full modules. All of these activities fall under the umbrella of off-site production.

The existing literature is primarily divided into two themes: benefits/drawbacks of modular construction and studies of the application of such technology. The benefits of such a project approach tend to be as follows: a shortened construction schedule, greater quality and precision, lower cost, greater productivity, less labor demand, centralized process, and less waste (Blismas, 2006). In terms of schedule, contractors can deliver modular projects with an average duration 40% lower than that of conventional projects (Kamali and Hewage, 2016). Unique to modular construction, building construction and site preparation activities can take place concurrently (Na, 2007; Hass et al., 2000). In addition, the risk of delays due to unexpected weather conditions can be greatly minimized by using modular construction (Celine, 2009).

In terms of cost, estimates range from a 10% savings in overall project cost to a 25% savings in labor (Kamali and Hewage, 2016). However, owners must balance labor cost savings with the additional cost of the transportation when considering modular construction (Velamati, 2012). If there is sufficient economy of scale, the larger volume of modules will actually reduce the total transportation cost, allowing additional cost savings (Carlo, 2007). Multiple case studies also have reported that modular buildings are more effective in embodied energy and CO_2 emission through life-cycle assessment (Al-Hussein et al., 2009; Quale et al., 2012). Other metrics such as better on-site safety, higher quality, fewer defects, and less waste are more subjective measures and are inevitably more project-specific; however, these factors all additionally play a role in reinforcing the promise of modular construction approaches. Essentially, modular construction is a manufacturing process versus a more conventional custom build on site. These benefits are commonly offset by a set of challenges to the widespread implementation of modular building approaches. Such challenges tend to include difficulties or unfamiliarity in planning such projects, difficulties in transportation of off-site elements, negative perceptions of the field due to inaccurate conflations of the technology, high initial costs, and difficulties in coordination (Kamali and Hewage, 2016). It is notable that many of these challenges could be alleviated through a better understanding of the unique project management demands and characteristics of this approach as compared to conventional construction, including the project delivery approach—the focus of this paper.

In addition to a study of the benefits/drawbacks of modular construction, numerous papers cover specific instances of its applications and the suitability of prefabricated or modular construction in various circumstances. Multiple studies have been conducted to help identify the cases in which modular approaches make most sense. These resulting tools are not widely applicable to all project types, nor are their conclusions and recommendations consistent across all studies (Azhar et al., 2013). The applicability of modular technology is generally assumed most efficient in such sectors as multifamily, educational facilities, office buildings, and healthcare facilities given their repetitive and standardized unit components (Ramaji et al., 2017).

In a study of the potential applications of modular technology, market participants in a survey identified many building components and project types that had little receptivity towards modular approaches whereas items such as façade, finishes, and structure or the project types listed above had a higher likelihood of adopting such approaches (Tam et al., 2007). Implementation of modular construction technology in high-rise applications has proven particularly difficult, as evidenced by difficulties such as those encountered at the Atlantic Yards B2 tower project recently built by Skanska and developed by Forest City in New York City. In this example, small dimensional discrepancies in the modules compounded over the multiple levels of the building and exceeded acceptable tolerances, thus limiting the proper interactions between the building components. With several entities involved in the fabrication and installation of modular projects, it can prove difficult to determine who is responsible when issues arise on site (Oder, 2015).

Furthermore, modular construction varies in its prevalence depending upon the country under consideration. In China, modular approaches have become commonplace, with significant capacity for domestic applications as well as export of modular components to international markets, as evidenced in the Company A case study below. The industry is so well-developed that plans are in place by an established modular firm to erect a 202-story modular kit-of-parts building in a planned 90-day period (Generalova, 2016). There are significantly fewer notable modular projects in the United States, although the industry is rapidly evolving as demonstrated by the case studies herein.

This research helps to emphasize the idea that modular construction demands a unique approach to project delivery. There is a developing understanding that modular building approaches need to be differentiated from more conventional projects. One paper builds on this idea by suggesting that a modular approach to building use a Product

Breakdown Schedule (PBS) rather than the typical WBS (work breakdown structure) approach to project planning. Whereas a WBS views a project through the breakdown of major components—typically CSI (construction specification institute) Masterformat or Uniformat divisions—into sub-components, the PBS approach breaks a project down into physical chunks that comprise distinct systems such as MEP clusters or envelope modules. By viewing a project in terms of the end user's requirements consisting of the systems and modules that make up a building rather than the trade-based WBS (Isaac et al., 2014), this methodology would help to make buildings more adaptable and maintainable by allowing the deconstruction of buildings as needed through complete modular components rather than piece by piece. Viewing a project through this lens suggests that a modular project delivery approach may fundamentally differ in its conception of a building as a whole. This paper aims to address some of the validity of such alternative approaches and to establish whether there is a prevailing project delivery approach within modular construction and if not what the elements of such an approach might look like.

3. Research Method

We had a series of semi-structured interviews with multiple stakeholders in different projects. The respondents for each case included at least a company or project manager and a middle manager who was in charge of processes working with other stakeholders. The respondents also included project managers who are not in the three companies but working on similar modular projects. In most cases, an email follow-up was made to clarify the contents. The duration of the interviews ranged from one hour to two hours. In total, there were 12 interviews carried out and 4 email follow-ups was made. A list of interviews is found in Table 1.

Below are the interview questions used in the semi-structured interviews.

- Describe the type of modular technology used

Table 1. List of Interviewees

Type of Company	Project	Interview Duration	Interviewees
Developer, Modular Manufacturer	Inhabit Belltown, Inhabit Burwell	1 hour per interview, email follow up	1 President, 1 COO
Developer, Architect	General view (no specific project)	1 hour per interview	1 CEO 1 Architect
Contractor	CitizenM Hotel, Seattle, WA	40 min -1 hour per interview	1 Chief Estimator 2 Project Engineers
Architect	CitizenM Hotel, Seattle, WA	40 min-1 hour per interview	2 Architects
Developer, Modular Designer	47+7 Apartment, Seattle, WA	1 hour per interview, email follow up	1 Vice-President, 1 Associate Architect
Architect, Modular Fabricator, Contractor	General view (no specific project)	2 hour per interview	1 Project Manager

on your project.

- What was the contract type on your project?
- What were some advantages to the chosen project delivery method?
- What were some drawbacks to the chosen project delivery method?
- What would you perceive as potential improvements to the project delivery method?
- What is an ideal project delivery method for your project type?
- Does the selection of project delivery method play a major role in the success or failure of your project type?

4. Case Studies

The case studies shown herein provide a representative look at some of the different prevalent modular approaches currently on the market in the United States. The companies profiled do not represent the entire industry, nor do they represent a significant portion of market share—of note, there are no clear market leaders in this fragmented, nascent industry. Specific names were removed from this paper to allow for an honest evaluation of the project results. Other modular approaches to those studies in this paper include wood-frame pre-fabrication as employed by such firms as Katerra and Guerden, concrete prefabrication as commonly found in parking and highway structures, unitized façade systems, prefabricated structural components, and others.

4.1 Company A (onebuild)

Company A is a small modular fabricator and developer based in Seattle, WA. Their projects entail the more traditional idea of modular construction involving the stacking of module boxes in the form of living units to form a structure as explained in the Literature Review above. Company A first entered the modular space with a small multi-family project in Seattle, WA. They acted as the modular fabricator within the project team. This project consisted of timber-frame modules built by Company A in their proprietary factory located several hundred miles from the project site. On this project, a local contractor was engaged to oversee site work, build the retail podium, and oversee the installation of modules.

The project developer engaged the contractor under a GMP (guaranteed-maximum-price). The contract covered the full cost of construction, including the modules. The modules were purchased directly from Company A based on precise shop drawings that were developed based on an overall design provided by an unaffiliated architect. This project was successful to the extent that the building opened in an extremely accelerated timeframe; however, various issues with waterproofing created major impediments to deeming the project a pure success.

Due to the various issues faced with this timber module approach, Company A made the decision to focus instead on production of steel-framed modules for its next project: a small multifamily building near Seattle. However, the expertise and infrastructure to produce such steel-framed modules is not so prevalent or available in the United States. Therefore, Company A is outsourcing this production to a Chinese firm more familiar with this technology and instead transitioned into a more direct developer role given the additional risk of outsourcing modular production overseas. In addition, Company A decided to act as its own GC (general contractor) in order to better coordinate the traditional site work with the less predictable international procurement of modules. This decision allowed for maximum flexibility in terms of cost control, schedule, and project management. The current project is still underway and, as such, the success of this new approach is still unknown.

4.2 Company B (CitizenM)

Company B is an established European hotel brand that operates with a model to provide convenience in small-sized modules with a focus on amenities rather than large personal spaces. As such, they embrace modular as the core of their business model with their hotel units prefabricated off site and stacked in place at their various developments. They have established a strategic relationship with a modular fabricator that provides standardized modules for all of their modular development projects. This relationship has followed them to the United States with their latest expansion. The modules employed on all projects are steel-framed and arrive entirely finished including all interior fixtures. Mechanical and plumbing chases extend between units for use as risers, and the finished modules need only to have their MEP connections made in the field for them to be fully functional.

On the project in question, Company B has contracted with a major American contractor and a notable architecture firm that both provide oversight of their growing program. The contractor was engaged on this project through a GC/CM (general contractor/ construction management) arrangement. Given the close relationship between Company B and its modular fabricator, and given the standardized nature of the modules to be installed, it was decided that transferring the risk and oversight of the module production to the contractor was the best option for this project. Accordingly, the entire job was contracted through a standard GMP arrangement. Company B procured the architect directly, and while the architect is not affiliated with the modular fabricator, they are familiar with the modular technology employed by Company B.

Whereas Company B is delivering this first project through a GC/CM arrangement with a GMP, the contractor is discussing the potential of delivering these projects through a design-build approach in the future. Given the extensive amount of design and entitlement responsibility that the contractor assumes by procuring the modules, there could be a significant benefit to a design-build approach whereby the full shop drawing design process of the modules need not be a duplicate of the preliminary design led by Company B and its architect. If a standard unit can be sufficiently described by Company B in the form of an RFP (request for proposal), the delivery of a full project can be streamlined.

4.3 Company C (SLI)

Company C is engaged in another type of modular approach. This approach consists of a panelized type of modular system. The company was founded by an architecture firm with the goal of designing an adaptable modular panelized system for high-rise applications. The system consists of panelized wall and floor modules that are manufactured off-site then erected floor-by-floor on-site and lifted into place within a steel exoskeleton. As opposed to the more traditional modular approaches mentioned above, this system allows for more efficient transport as instead of transporting what is essentially an empty box, stacks of panels can be transported. There is also the advantage that, as opposed to the more strictly defined 3-D modular approach, the panelized sections can be built into a more flexible arrangement of layouts. The architecture firm acts as the design architect for Company C in partnership with other local design consultants. As initially envisioned, Company C was to act as the modular designer carrying the project design through the shop drawing phase for execution by a separate general contractor.

Their first project was a collaboration between a local developer, Company C, and an experienced local contractor. The approach to this project was not unlike the typical GC/CM project delivery approach for most multi-family projects in the Seattle market. Early involvement from the GC in the design led to a series of estimates to establish cost in advance of construction start. Due to the innovative nature of this project, there was an outsized commitment of resources on the part of the GC leading up to construction both to address the unique code implications of this system as well as the constructability challenges facing the team. As initially envisioned, the contractor would take on the role of both on-site contractor and off-site fabricator of the panelized modules; however, initial cost estimates came in excessively high for this approach. When analyzing the cost figures, it became clear to the project team that the unfamiliarity of both the contractor and the subcontractor market with this technology was leading to inflated cost estimates, leading Company C to take the modular fabrication on internally.

After the completion of this first project, Company C used this initial experience to settle into a desired approach for how to implement their system on future projects. Instead of acting solely as a designer with a general contractor taking on a traditional role to manufacture and assemble the modules, they realized that the contractor is best suited to build the site-specific components and assemble the modules in the field. The upfront work to manufacture the modules themselves is best managed by the modular designer in order to control cost and keep control over quality and execution. On current projects, Company C assumes a role most similar to that of a design-builder. An Owner contracts with Company C to both be the designer of record, through their affiliation with the local architecture firm, and either directly or indirectly to build the project. On the construction side, Company C contracts with a company that fabricates the panelized modules and arranges for on-site work to take place through direct or indirect contracts with a preferred general contractor.

5. Case Study Findings

From the case studies above, we identified four key stakeholders as integral to modular projects:

Owner, Architect, General Contractor, and Modular Fabricator. The stakeholders are similar to those found on conventional projects with the addition of the modular fabricator. In these cases, the owner can be better understood to be the developer creating the project for the end user—whether this is the same entity or not—while the architect can be better understood as the designer of record for the site-specific structure. The contractor fills a conventional role as being responsible for on-site work and the coordination of the module install. The modular designer or entity creating the shop drawings is integrated into the Modular Fabricator category; while the modular designer and modular fabricator may not be the same company, their close coordination is integral and neither can effectively operate independent of the other.

Three types of relationships have been identified below as found in the case studies. The different relationships are shown by lines between each stakeholder with solid lines representing direct contractual relationships in the delivery of the projects and dashed lines representing indirect relationships consisting of strong coordination between parties.

5.1 Type 1: Full Integration

This relationship was found in Company C's initial case study project. This was the ultimate project delivery approach after it was found that the contractor was not well-suited to carry the modular fabrication themselves. The contractor instead contracted with the modular fabricator to provide the modules as part of the construction of the project. The future iterations of Company C's projects will continue this relationship whereby regardless of the exact delivery method, there will always be direct contractual ties between contractor, modular fabricator, and architect.

In this type of relationship, the owner designs the project through a direct relationship with the architect based on the parameters of the modular system in question. These parameters are clearly discernible due to the direct relationship between the architect and modular fabricator who essentially details the architect's design for them. This prevents

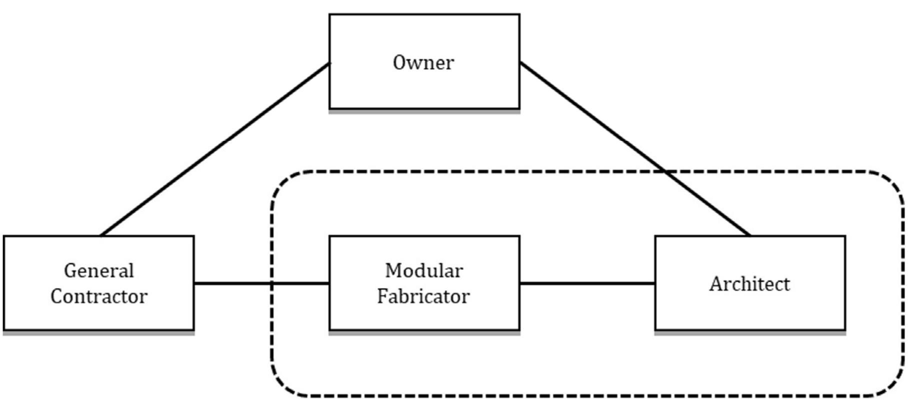

Fig. 2. Full Integration (Type 1)

any disconnect between the intended design of the project and the constraints of modularity. The owner then engages the general contractor to carry the full construction scope including installation of the modules within their contract. As the contractor is best suited to address the site-specific needs of the project, they delegate the production of the modules to the modular fabricator while maintaining control of schedule and logistics as it relates to the installation of the modules. While it is desirable that the contractor has strong experience and knowledge of the modular system in question, the ability for the modular fabricator to bridge any ambiguity in the design and execution between the architect and contractor helps to mitigate any issues that may arise. Keeping the module scope under the general contractor's main contract prevents the inefficient bifurcation of construction scope between multiple parties, which would be difficult, if not impossible to delineate if these scopes were split. While the modular fabricator does not hold any direct contractual relationship with the Owner, the architect and general contractor are directly affiliated with the modular fabricator, which leads to a seamless interchange of design feedback between the all parties.

5.2 Type 2: Partial Integration

This relationship was found in Company B's modular hotel project. Through the existing relationship between the Owner and modular fabricator based on their previous project collaboration, the modular fabricator understood the needs of the Owner. The modular fabricator was able to work with the architect through an indirect relationship to ensure that the design adhered to their modular system parameters. Through the direct relationship with the modular fabricator, the contractor was able to ensure a seamless process of module procurement, shipping, and installation. The weaker tie between the architect and fabricator does present certain risks as discussed below.

In this type of relationship, the owner's familiarity with the modular system is key to defining the design with the architect from the outset. The owner must play a greater role in informing the design team of the constraints of the particular modular system due to a lack of direct relationship between

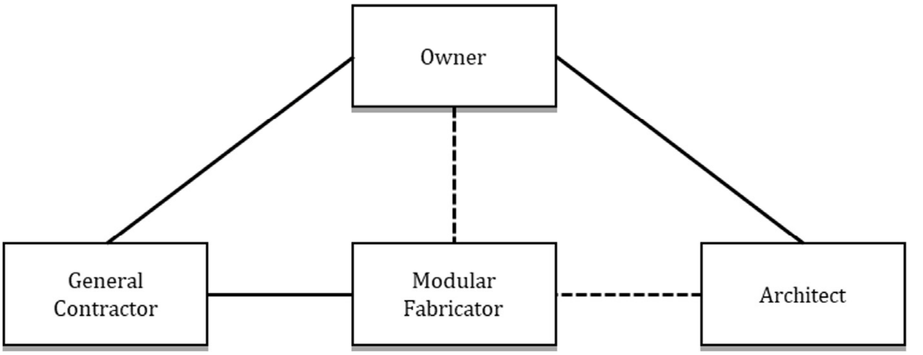

Fig. 3. Partial Integration (Type 2)

the modular fabricator and architect. The owner must rely on the familiarization and close coordination between the former two parties in the creation of the overall design—this is the indirect relationship shown between architect and modular fabricator. Similar to Type 1 discussed above, the modular fabricator essentially details out and completes the architect's design as part of the project delivery process. If this collaboration is successful, the architect and modular fabricator can convey a cohesive design to the general contractor for execution. Similar to the other relationship types defined herein, the owner contracts with the general contractor to carry the full construction scope. This direct contractual relationship ensures an organized and efficient delivery in the field. The successful delivery of a project of this type depends largely upon the success of the upfront design effort, as there are no longer direct contractual links between the modular fabricator and architect. The feedback loop between the construction and design team present in the first relationship is no longer evident here as the design team is less able to react to constructability issues due to the lack of direct relationship with the modular fabricator.

5.3 Type 3: Weak Integration

This relationship was found in the case of Company A's first project. In this case, the owner designed a project with modularity in mind but no clear relationship with the modular fabricator to help guide their design direction. When engaging the architect, the lack of a clear relationship with the modular fabricator (Company A) meant that not all modular parameters and design constraints were taken into account in the design that was ultimately conveyed to the general contractor. While the general contractor was engaged with the modular scope within their overall contract, constructability issues were not addressed up front, leading to more inefficient and costly correction in the field. There did seem to be some degree of alignment between the owner and modular fabricator based on the initial conception of the project, but this relationship did not ultimately continue throughout the course of the project. While it is important for an owner to understand

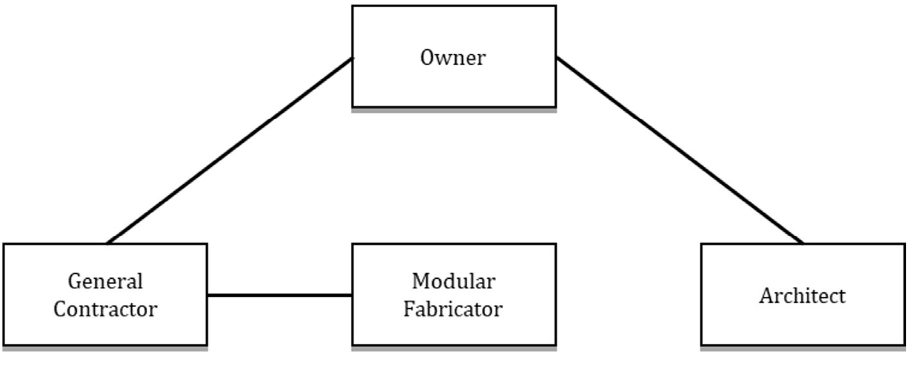

Fig. 4. Weak Integration (Type 3)

the limitations and opportunities of a given modular system, a lack of deep coordination between the architect, modular fabricator, and contractor led to gaps in knowledge that made the implementation of the modular system on this project less than ideal.

In this type of relationship, there is no clear familiarity with the modular system either on the part of the Owner or the architect. As a result, it becomes difficult to ensure that the parameters of the modular system are accounted for in the overall design. With no direct or indirect relationships between these parties, the onus is on the contractor to ensure that the modular installation occurs successfully in the field. When engaging the general contractor, it is possible for the Owner to direct that they play a greater role from the outset in coordination of the modular fabrication in the context of the overall design. However, this would entail the general contractor becoming generally accountable for the modular fabrication, which proved difficult in the case of Company C's initial project delivery approach. The modular fabricator must remain a distinct entity in order to allow for efficiency in the delivery of multiple projects. If integrated within a general contractor's business model, such modular projects would essentially become design-build projects where the contractor would need a very high volume of standardized projects in order to remain financially viable—a situation that has not yet manifested itself within the market.

6. Discussions

Whereas a conventional project delivery consists of relationships between three key stakeholders —Owner, Architect, and General Contractor— modular projects have an additional key stakeholder to account for: the Modular Fabricator. In

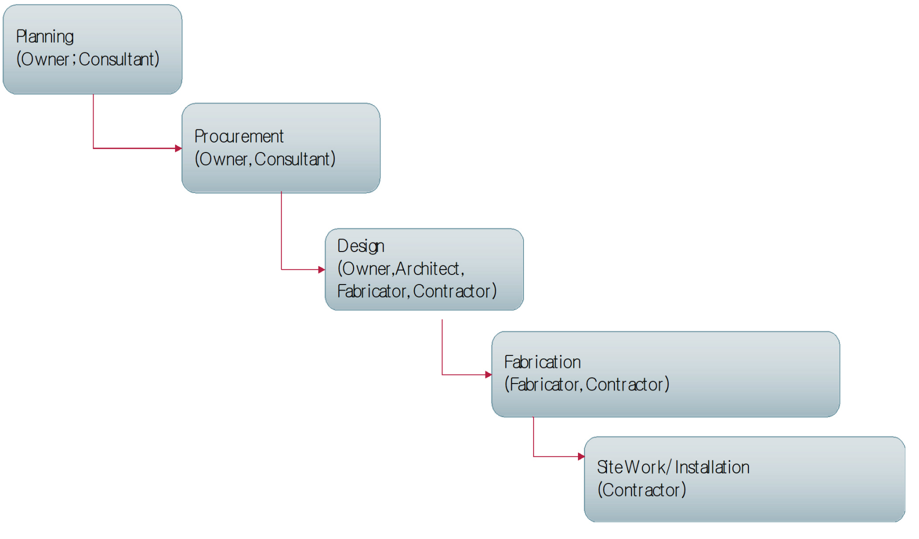

Fig. 5. Project Phases with Major Stakeholders

modular commercial projects, the project consists of five phases: planning, procurement, design, fabrication and site work/installation. As seen in Fig. 5, a modular fabricator and a general contractor should be actively involved in the design and fabrication process working closely with an architect. Depending on the relationship between stakeholders, the role of each stakeholder can be expanded or reduced.

The early iterations for each business investigated herein have demonstrated the ineffectiveness of approaching these modular projects in a fashion similar to that of a conventional project. Given the large portion of the project encompassed by the modular component, both in cost and quantity of work, the modules are difficult to procure in a standard fashion as a subcontract of the main contract with the general contractor. The design of the building and the design of the modules need to be coordinated, but occur under different frameworks. The design for site-specific components can proceed in a normal fashion, whereas the design of the modules must be integrated with the ultimate manufacturing process in which precise shop drawings, not standard design documents, will form the basis for their fabrication. Given the close coordination necessary between the modular fabrication and both the construction and overall design of a given project, relationships—either direct or indirect—must exist between the modular fabricator and both of these other stakeholders. Based on the case studies, relationship types defined above, and associated research herein, we have formulated three claims to be proposed as necessary elements of a successful modular project delivery in terms of performance and risk distributions.

6.1 A direct contractual relationship and familiarity must exist between the general contractor and modular fabricator

When approaching the construction of a given project, there is a distinction between site-specific components and modular installation. Given the complex interconnections between both components and the infeasibility of dividing a construction project contractually between on-site and modular scopes, one general contractor must be responsible for both components. In order to successfully deliver both of these scopes, there must be a keen understanding by the general contractor of the modular technology employed on a given project. The site-specific components are not a difficulty for most any contractor given the level of familiarity both at the general contractor and subcontractor levels of any given project. What is more difficult is ensuring a level of familiarity and the removal of uncertainty related to the installation of the modules. The contractor must both be able to assemble the modules in a well-built manner as well as in a cost-effective manner. If a modular technology is not well understood, costs can easily spiral out of control as each project participant in the value chain will assign contingency to cover the risk of the unknown.

Successful project delivery for a modular project will rely on having a general contractor engaged who is familiar with the modular system and able to familiarize all other project team members such that costs are contained and the efficiencies of modular construction can be realized. This truth is evident even in the estimating approach: one cannot logically understand the schedule of values for a modular project given the bifurcation between standard divisions and the modules themselves, which often reside on the Division 13: Special Construction line. If a builder cannot be in control of this line item, they are only in control of a small portion of the overall project budget; this is a recipe for disaster on any given project. The first alliance between the general contractor and a given modular fabricator will be a difficult one, but a concerted effort to build a strong relationship will allow for future successful project deliveries.

6.2 Engaging an architect familiar with the modular system through a direct or indirect relationship is imperative

Similar to the reasoning in the first point above, a keen understanding by the architect of the modular system being employed on a given project is crucial. Modularity constrains the flexibility that a project has in terms of design. As such, an architect must clearly know and a modular fabricator must clearly define these constraints. While it is not necessary to have a formal relationship between these two parties, coordination and the exchange of information must occur earnestly. Providing a cohesive design to the general contractor is the best method to ensure a successful project delivery as this will minimize the difficult coordination that must occur in the field between the on-site construction and modular installation.

6.3 The more familiarity and relationships between the four stakeholders, the better the outcome of the project

From the cases and relationship types defined above, it is clear that scenarios with greater amounts of relationships, either direct or indirect, between the four stakeholders on a modular project lead to better results. In the Full Integration relationship type, the benefit of having each stakeholder formally or informally linked to the others is clear: there is no gap in information between the design stakeholders or the construction stakeholders on the project. When combining a complex manufacturing process—modular fabrication —with conventional on-site construction, it is crucial that communication be maintained between all parties. The strict tolerances inherent in modular construction must be met by the general contractor, but their feedback is also critical in advising a modular and overall project design that will be constructible in the field.

The case study findings suggest that it would be effective to assign a single point of responsibility to one entity for the overall delivery of the project. Design flexibility and modularity are not compatible characteristics given that standardization and efficiency in repeatable manufacturing processes is key to realizing the benefits of modular. In the case of a single point of responsibility, however, an owner should be willing to forego significant design control in order to allow for the successful delivery of a modular approach. The selection of the modular system will be the owner's main decision, followed by delegation of the detailing to the architect in coordination with the modular fabricator. The general contractor will participate intensely in the design process to ensure that their input is accounted for and that they are familiar with the eventual construction documents and coordination issues. Whether a single responsibility is used or not, strong coordination between major stakeholders is not optional, but rather mandatory in modular construction.

7. Conclusions

Through the representative case studies and interviews, it is clear that there is a different approach to project delivery for modular projects versus conventional. Through case studies, we identified three types of relationship between project key stakeholders: (1) Full Integration, (2) Partial Integration, and (3) Weak Integration. The case study findings lead us to make three claims: (1) A direct contractual relationship and familiarity must exist between the general contractor and modular fabricator, (2) Engaging an architect familiar with the modular system through a direct or indirect relationship is imperative, and (3) The more familiarity and relationships between the four stakeholders, the better the outcome of the project.

Modular technology has the potential to transform our built environment. Through the efficient production and delivery of modular projects, we can see lower costs, faster delivery, higher quality, less waste, and a transformation of the construction industry in general. Modularization, as opposed to conventional stick-built approaches, is the only route forward in the construction industry. Without a notable increase in efficiency, we will be unable to build the cities of the future and accommodate a growing and urbanizing global population. To better implement the necessary modular technology, we need to better understand how to implement it. This paper has attempted to investigate what would be better project delivery approaches to effectively manage modular construction projects. As the industry evolves, standard practices will emerge that can be adopted by market participants such that modular construction will become the new conventional construction.

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요 약

본 연구의 목적은 모듈러 건설사업의 주요 참여자들간의 다양한 관계(Relationship)를 살펴보고 몇 가지 정형화된 유형을 정의하는 것이다. 사례연구를 통해 (1) 강한 통합 관계, (2) 부분 통합 관계, 그리고 (3) 약한 통합 관계로 나누고 각 관계의 특성에 대해 조사하였다. 또한 사례연구를 기반으로 다음 세가지 명제를 도출하였다. (1) 시공사와 모듈러제작사간의 직접적인 계약관계가 필요하며, 서로간의 이해가 필요하다. (2) 건축설계사는 모듈러제작사가 제공하는 모듈러시스템에 대한 충분한 이해와 경험을 가지고 있어야 한다. (3) 주요사업참여자(시공사, 모듈러제작사, 건축설계사, 발주자) 간의 관계가 좋을 수록 모듈러사업의 성과도 좋다.

주제어 : 모듈러 건축, 프로젝트 발주, 사례연구