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Part 2: Theme Paper

Integration of Value Chain in the Construction Industry

Revisit Prework

Chul-Ki Chang
ckchang@cerik.re.kr

CERIK

Construction & Economy Research Institute of Korea

Executive Summary

The construction project is fragmented by nature. In most cases, planning, design, construction, and maintenance are separated by disciplines and executed in phases. To overcome fragmented process in construction project, both managerial and technical approaches have been attempted. As one of these approaches to integrate fragmented process, a prework has various advantages against traditional way of doing design and construction in terms of not only integrating design and construction process but also construction cost, time, quality, productivity and safety. However, some barriers exist. The main aim of this paper is to provide an overview of benefits, barriers, and application of prework in the construction industry. Through this paper, a case study of automatic digitalized rebar supply management system in Korea was introduced as an example of successful application of prework. At the end of this paper, several suggestions for successful application of prework are provided.

1. Introduction

1) Fragmented Construction Process

In most cases, planning, design, construction, and operation and maintenance are separated by disciplines and executed in phases, in an adversary environment and with little interaction between phases and disciplines. The vertical and horizontal fragmentation of the construction industry reduces quality of final product and increases the life cycle costs of the final product. Originally, the construction was not separated when the project was done by master builder. As technologies for construction developed, segregation between design and construction functions occurred slowly. The segregation was reinforced artificially through legislation that required separate contracts for design and construction services. In addition, these services were procured on a separate basis, again reinforcing segregation. Educational system reinforced the segregation through separate degree programs in architecture, engineering, construction management, etc. Industry associations also reinforced the artificial segregation by restricting membership to individuals with specific degrees or certifications, or employment with certain types of firms (FMI 2007).

2) Efforts to Bridge the Gap between Phase

Bridging the gap between phases through the use of design/build and program management techniques is occurring. Government allows using alternative-delivery-systems such as design-build, and construction management. Leaders of educational institutions are designing joint-degree programs to reflect and respond to industry drivers. In the past, IT systems have created "islands of automation" and are far from achieving an acceptable level of integration across disciplines and across the design and construction processes. It is recognized that greater benefits can be achieved if these systems are integrated. Thus, numerous studies have been carried out with the aim of integrating the various project life-cycle phases through IT solutions. There is an urgent need to transfer a major proportion of the assembly and fixing operation from the site to the more favorable environment of the factory where, subject to a substantial degree of standardization, automatic or semi-automatic numerically controlled machinery can be put into service to produce prefabricated assemblies for delivery on a first-in-time basis before simple installation in the structure.

3) Prework

Partly because modularization, prefabrication, and preassembly are ill-defined and mix-used, they are often collectively referred to in the industry as prework[3]. There is subtle difference among these terminologies. "*Prefabrication*" can be defined as "a

[3] Some countries use the term "off-site".

manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation" (Tatum 1987). These prefabricated components often only involve the work of a single craft. A common definition for *"Preassembly"* is "a process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a unit" (Tatum 1987). The preassembly may be completed at the job site in a location other than the place of final installation. A preassembly often contains only portions of systems, and work from a variety of crafts is typically necessary. *"Modularization"* is generally referred to as the preconstruction of a complete system away from the job site that is then transported to the site. The modules are large in size and possibly may need to be broken down into several smaller pieces for transport. Usually more than one trade is involved in the assembly of a module. "Off-site" and "Industrialization" is used to attempt to describe and encompass all three aspects of offsite construction work: modularization, prefabrication, and preassembly. The industrialization process can be defined as an investment in equipment, facilities, and technology with the intent of increasing output, decreasing manual labor, and improving quality (Warszawski 1990).

2. Why Prework

Prework has various advantages against traditional way of doing design and construction. There benefits for the use of prework have been recognized through several reports (Hass et al. (2000), Wong et al. The traditional project factors driving desired benefits also apply prominently when considering prework. Cost, schedule, quality, productivity and safety are main drivers. Prework has the potential to positively affect the project in each of these areas (Gibb 2001). Lack of availability of skilled, on-site labor may also play a factor into the decision to use prework. Shortages of skilled labor could be a strong driving force.

Productivity & Cost

The overall cost for a project that uses prework can be less than a traditional method. Cost savings can be caused by various factors. Cost savings mostly consist of the differences between fieldwork and shop fabrication productivity. Shop productivity is often better than field because of controlled conditions, closer supervision, and easier access to tools. Controlled conditions such as ground level work, climate control and consistent lighting directly impact productivity. Weather is less of a factor for prework, providing an additional advantage over stick-build sitework. The prework shops take advantage of controlled environments that are not affected by harsh weather. Work is not interrupted and productivity can remain at a high level. In addition cost savings from increased productivity, prework can decrease costs associated with fieldwork. Since some or all of the work is relocated to an offsite location, costs associated with site infrastructure and overhead can be reduced. Fewer workers on site translate into fewer costs for accommodations in remote locations, scheduling onsite work, and other onsite logistics.

Time

The construction duration can be shortened through the use of prework. Activity desequencing along with increased productivity is a typical way of improving schedule with prework. Instead of performing tasks in a strictly linear sequence onsite, construction activities can be broken up and completed simultaneously at multiple locations. Fabrication may continue offsite while permitting delays activities at the project location. More work for a project can be completed before going to the site so that the construction schedule is decreased.

Safety

Overall project safety can be improved through the use of offsite work. With prework, workers face less exposure and companies receive more opportunities for decreasing safety risk. Prework may reduce exposure to weather, heights, hazardous operations and neighboring construction activities. Workers at a fabrication shop are not affected as much as workers on site by temperature, wind and precipitation extremes. Since much of the prework is done at ground level, fewer safety harnesses are required and workers can focus more on the work.

Quality

Quality can also be improved through the use of prework. Controlled factory and production conditions and repetitive procedures and activities, along with automated machinery can lead to a higher level of quality than can be attained onsite.

Environmental Impact

Environmental impact of the project can be potentially decreased by use of prework. This is partly due to reduced amount of work on jobsite and jobsite construction duration and a decrease in field labor requirements. Additionally, prework may reduce material waste, pollution associated with dust and noise.

3. Barriers

While the benefits of prework help to enhance the use of prework, the decision to implement is influenced by the balance between the potential benefits and barriers. Common challenges faced by projects include increased engineering requirements, extensive transportation planning, decreased flexibility of scope, and high use of advanced technologies.

Increased Engineering Effort

Design work and extensive planning must be completed before prework can begin. Depending on the extent of prework, it may be necessary to complete 90% of engineering design prior to construction, as opposed to the 40% generally necessary for conventionally built projects (Tatum et al.. 1987). Interference analysis is required and lift planning must be completed well in advance. Interface management and transportation requirements may not only increase degree of completion requirements, but also account for a large portion of the estimated 15% increase in design cost. Since components are fabricated in the shop and shipped to the installation location, additional engineering is required to insure compliance. Due to increased engineering and planning effort engineering costs can increase as much as 15% and home office costs 5-15% per unit of prework.

High Use of Advanced Technologies

Prework requires various advanced technologies. 3D modeling is widely used to check interferences, to connect to component information, and to improve visualization. Prework also requires information technologies to aid in the coordination efforts required for prework projects. Advances in computer-controlled equipment have also provided enablers for the prework industry. Prework facilitates the application of productivity enhancing automation such as robotics much easier than site work. Prework may also benefit from advances in tracking technologies. Prework should make materials management easier and make applications such as radio frequency tagging and bar coding more economical, since fewer expensive tags would be required.

Extensive Transportation Planning

Transportation logistics play a large role in determining prework feasibility. Size and weight limitations, route restrictions, permitting and the availability of lifting equipment are among the considerations to be made for the coordination of construction. This is especially true for large modularized sections that must be transported over a long distance. Size constraints and limitations exist, based on the method of travel, which directly leads into cost and schedule considerations. Roadways, railroads and water transport all have limitations. The availability of these methods may dictate the type of prework selected.

Once the components reach the site, additional lift planning may be required, especially for heavier lifts. Key considerations for heavy lifting include lifting points, rigging and early involvement of the lift contractor (Gibb 2001).

Decreased Flexibility of Scope

Since prework requires a well-defined scope early in the project planning stages, scope flexibility may decrease. This is due to the increased engineering and transportation requirements. The scope must be set early to insure adequate design and integration upon construction and final assembly.

Extensive Coordination

It is necessary to understand the extensive coordination required prior to and during construction operations. In addition to the transportation and design issues, scheduling may also have to be coordinated (Tatum et al.. 1987). Further coordination may be required for materials management and supply chain scheduling. The complexity of assemblies, integration, and delivery provide opportunities for computer control.

Given the increases in coordination for projects utilizing prework, effective communication is necessary. Effective communication between project participants includes distribution of information regarding decisions, designs, transportation requirements, and schedules. In order to coordinate between multiple sites with critical scheduling, open communication must exist between owners, engineers, suppliers and contractors.

Local Economy and Condition

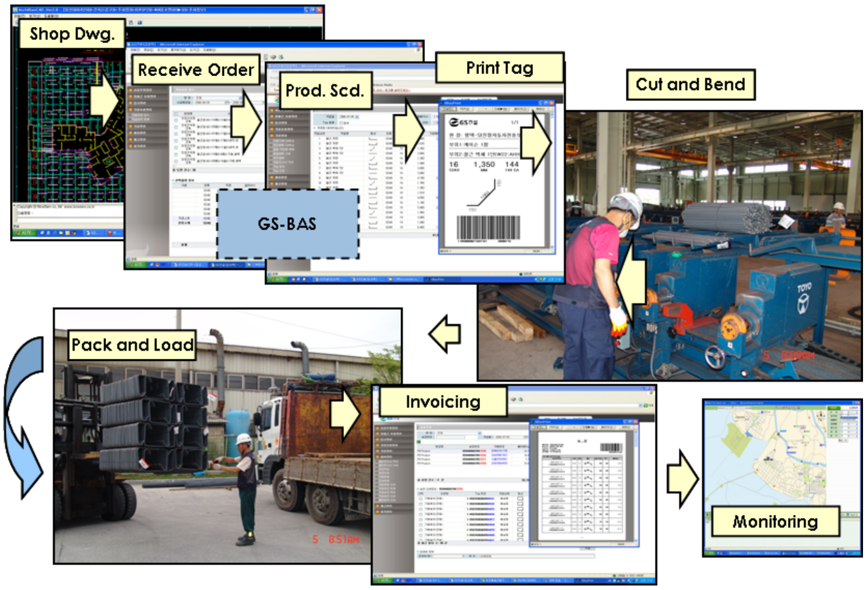
Other factors affecting the use of prework include the local economy. In areas where the cost of labor is low, prework may not provide an economic advantage. Another concern is the knowledge base of designers concerning prework components. Engineers may not have experience with such construction projects and therefore prefer traditional methods.

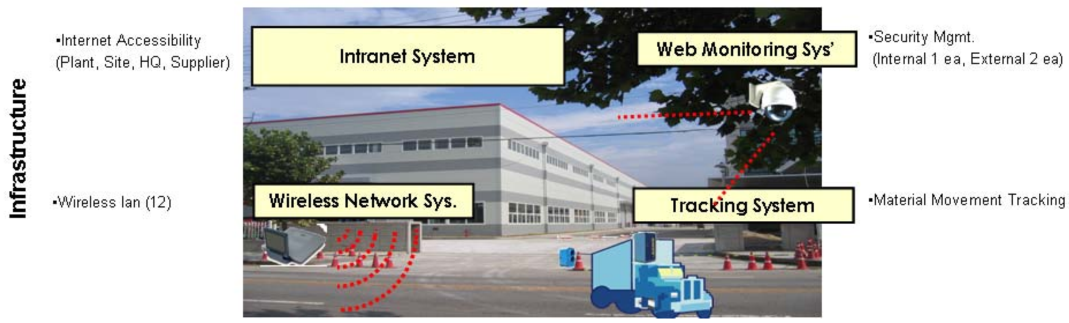
4. Case study

Previously, in Korea, it was impossible for a construction company accurately estimate the quantity of rebar needed on-site work using only manual work and experience. Additionally cutting and bending rebar on-site left the excessive rebar stock and needed extensive area for fabricating and storing rebar causing inefficient use of on-site space. To resolve these problems, GS Engineering and Construction, Korea’s premier construction company, developed automatic digitalized rebar design system (GS BAS[4]) that can integrate management bar bending design and installation. Through successful application of this system, the company can integrate entire rebar design, shop drawing, output calculation, supply chain, transportation, and installation process.

Through successful use of this system, the company could save 9.7M compared to on site fabrication resulted from reduced production loss from 8~10% to 3%. Construction duration was also reduced by 2 weeks, unnecessary relocation and movement was reduced and material inventory also could be minimized.

[4] Bar Banding Automation System





5. Suggestions for Successful Implementation

Early Decision during Pre-planning

The companies involved in prework stress the importance of early decisions during pre-planning when using prework. In cases with a lesser degree of prework, decisions could often be delayed until later in the project during detailed design. Regardless of the type of prework, the importance of coordination of all involved parties through regular meetings to coordinate various design disciplines should be stressed.

Careful Analysis of Labor Differentials

Careful analysis of labor differentials is a common factor in determining prework feasibility. Moving work off-site takes advantage of lower wages available in shops and potentially lower costs related to equipment and overhead. The company which wants to employ prework should carefully evaluate the differences in wage rates, productivity, overall risks, equipments and overhead costs associated with labor.

Extensive Transportation Planning and Expediting

For adequate use of prework, extensive transportation planning is required. Careful analysis of shipping options and routes often dictated size and extent of prework.

Integrate Project Team

There does not seem to be much leadership for prework in design company. Many architects appear to reject prework out of hand, often referring to the limitations of previous generation's applications. Many current construction processes do not encourage more innovation from designers. There are some good examples where project teams have stimulated and encouraged the increased use of prework. However, it is important that the whole project team must be committed for effective implementation and this is made easier in vertically integrated teams.

Enhance Information and Communications Technology Use

Because of the way that much of the prework supply chain is organized, ICT play an important role in prework to control supply chain information flows and to enhance the visualization of design alternatives.

6. Conclusion

Prework can not only integrate design and construction process but also can provide various benefits in term of cost, time, qualify, and worker’s safety. One of the key principles of prework is that the benefits are often realized elsewhere in the construction process. In other words the actual elements being preworked may be more expensive than the site assembled alternative. However, issues such as reduced site labor, less disruption and better quality control can produce savings that outweigh the additional first cost of the items. What this means is that the client and their advisors need to recognize this aspect in order to promote the increased use of prework. Overcoming lack of industry knowledge is another key factor in successful use of prework. Along with various benefits of prework, sustainability will be a good driver for increased prework, in particular less waste, noise, disruption etc resulting from factory-based activities.

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