S10-1

WHEN CM AT RISK MEETS VIRTUAL DESIGN AND CONSTRUCTION (VDC) IN CONSTRUCTION PHASE: CASE STUDY OF PRACTICIES IN U.S.

Joo-Sung, Lee[1], Sung-Kon, Moon[2], Ju-Hyung, Kim[3], Jae-Jun, Kim[4]

[1]Graduate Student, Department of Architectural Engineering, Hanyang University, Seoul, Korea
[2]Graduate Student, Department of Architectural Engineering, Hanyang University, Seoul, Korea
[3]Associate Professor, Department of Architectural Engineering, Hanyang University, Seoul, Korea
[4]Professor, Department of Architectural Engineering, Hanyang University, Seoul, Korea
Correspond to neowings@naver.com

ABSTRACT: Turn-key and CMF(CM for Fee) have been selected as procurement paths of large public projects in Korea. However, recently, researches and discussions on CMR(CM at Risk) have been popular as the Korean government seeks for alternative procurement paths to enhance the performance. In the CMR projects, the part who is responsible for construction management should predict and control the potential risks for guaranteeing benefits. In this paper, CMR projects in which a general contractor plays the role as CMr is mainly analyzed. We give attentions to risk management during construction process given that subcontractors, main parts in this phase, work in various ways and thus more chances for faults exist. In this case, for the general contractor, to recognize potential risks in previous to start construction works of subcontractor by means of virtual design and construction (VDC) must be essential to this end. The case study of practices on VDC in U.S in which CMR has been introduced can provide considerable aspects to implement it in Korea.

Keywords: Risk Management, CMF(CM for Fee), CMR(CM at Risk), VDC(Virtual Design and Construction)

1. INTRODUCTION

Delivery methods introducing construction management can be classified as the two: CMF(CM for Fee) and CMR(CM at Risk). For CMF, the construction manager (CMr) provides service to the client as an agent to manage schedule, cost, and quality of project. In this procurement path, a CMr has limited responsibility for failures i.e. delay, over budget etc. according to the contract (Gee *et al.,* 2008). On the other hand, in CM at Risk (CMF), CMr has to complete the project within owner's guaranteed maximum price, by managing risk, schedule, and quality of project. The consequence of project failure belongs to construction manager. In order to reduce potential risks in these aspects, CMr should establish proper systems to manage the risks.

In January 2006, the Korean government enacts the 'Joint-Venture Contract Law' of General Contract Management System and it is likely to facilitate introducing CMR in public projects (Jang *et al.,* 2006). Regarding context in Korea, needs for developing practical methods to support managing risks in projects introducing CMR have been raised.

Advanced technologies in design and construction management have been mentioned as a tool for managing risks. Virtual Design and Construction (VDC) is one of those as it can provide tools for acknowledging design errors and poor constructability in previous. So, VDC can be defined as the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives (John *et al.*, 2009).

We aim to initiate discussions by clarifying activities for risk management and providing considerable aspects of practical applications to manage those by means of case study of CMR projects using VDC in US.

2. RISK MANAGEMENT IN CONSTRUCTION PHASE OF CM AT RISK PROJECTS

2.1 Conflicts in the Construction Phase

The risks that occur during construction phase would cause negative results relevant to schedule, cost and productivity. Jung *et al.,* (2004) presented risks and responsibility through project life cycle and those for construction phases are selected and modified in Table 1.

Table 1. Risks Which Can be Caused by General Contractor's Fault in Construction Phase

Risks which can be caused by general contractor's fault	Responsibility			
	O	D	GC	SC
Inadequate setting of project organization			√	
Delay of Shop Drawing preparation and submission	√	√	√	
Lack of case project DB			√	
Lack of schedule and resource DB			√	
Communication problem between owner, designer, and general contractor	√	√	√	
Communication problem between general contractor and subcontractor			√	√
Unreasonable subcontracting relation			√	√
Countermove against change-order		√	√	√
Safety accident			√	√
Lack of resource utilization plan / selection of inadequate resource			√	
Delay of resource delivery / badness of resource			√	√
Lack or damage of resource			√	√
Lack of resource storage in field			√	
Lack of labor utilization plan and communication with laborer			√	√
Insufficiency of laborer's skill			√	√
Delay and badness of equipment delivery			√	√
Interference and delay between work items			√	√
Lack of skill managing sub-contractor			√	√
Delay of subcontractor delivery			√	√
Subcontractor's contract breach			√	√
Lack of subcontractor's experience			√	√
Subcontractor's inadequate work			√	√
Delay of payment for subcontractor's work	√	√	√	
Approving diverse order / complicated preparation process	√		√	
Subcontractor's inadequate management process and lack of experience			√	√
Shortage of construction manager			√	√

(O : Owner, D : Designer, GC : General Contractor, SC : Subcontractor)

2.2 CM at Risk Service in Construction Phase

In CMR project in which a general contract (GC) plays the role as a CMr, it takes the responsibility for controlling all events that happen in the construction site. Given that activities at the level of execution are conducted by sub-contractors, proper communication between GC and SC is essential for the success of the project. If this is the case, most of all, aspects that can cause the poor communication between them should be considered as a primary risk management factor. Activities to prevent risks relevant to project coordination and management of subcontractors are clarified as follows (Young *et al.*, 2004):

1. Establish site organization, including work and storage areas
2. Establish job site management organization and job site procedures
3. Maintain daily log for job site record and maintain as-built drawings and records
4. Provide general conditions work to meet project requirements
5. Monitor and maintain quality control
6. Shop drawing control
7. Equipment and material control
8. Provide and monitor overall progress and short interval scheduling
9. Prepare billings and progress payments
10. Conduct Subcontractor Coordination Meeting
11. Provide coordination between Subcontractors
12. Prepare and receive requests for information
13. Establish, monitor and maintain safety program and procedures
14. Prepare agendas and conduct weekly safety and progress meetings
15. Prepare and distribute weekly safety and progress meeting minutes

2.3 Communication between GC and SC

In construction phase of CMR projects, the general contractor takes the responsibilities for managing risks. In the previous part, the conflicts between GC and SC can cause various problematic situations during this phase. Regarding risks management scope, the primary activity for GC must be management of subcontractors. A challenge is that subcontractors have various professional background i.e. building, electrical, mechanical, plumbing and fire protection, etc and a systematic approach should be introduced to handle all of them.

All these subcontractors have to produce their own shop drawings. This shop drawings might be illustrated by 2D drafting tools (i.e. AutoCAD) or 3D modeling tools (i.e. Revit MEP, ArchiCAD, PD3D, etc.). Then sub-contractors submit it to the general contractor. After the general contractor collect shop drawings, the GC has to unify each of models into single one to enhance understanding and manage the project in a consistent manner by using viewing tools such as Navisworks or Innovaya. This unified 3D model contains geometrical data of all parts in shop drawings, so it can be used as a communication tool between SC and GC when they meet at stated periods to discuss and deal with the status of construction operating. For this reason, 3D has been widely introduced.

But actually, this model is not created based on objects that include information about properties or attributes. So, this 3D model has limit to be used as a communication tool in detail. In project briefing or meeting, the VDC modeling which is object-oriented is needed to simulate all of events that can happened in project lifecycle.

3. VDC TO REDUCE RISKS IN CMR

Virtual Design and Construction (VDC) can provide a tool to predict potential problematic situations and resolve the conflicts in previous. In this paper, VDC means the object-based information handling through the project life cycle. The term BIM (Building Information Modeling) can be used instead of VDC but it includes all phases of projects and means the collaborative environment rather than specific activities.

Risks which can be caused by general contractor's fault in construction phase mentioned in the previous section can be managed by introducing VDC. Its advantages are as follows (Howard, 2008):

- Single Data Entry, Multiple Uses
- Design Efficiency
- Consistent Design Bases
- 3D Modeling and Conflict Resolution
- Conflict Identification and Resolution
- Take-off and Estimating
- Shop and Fabrication Drawing
- Visualization of Alternative Solutions and Options
- Energy Optimization
- Constructability Reviews and 4D Simulations
- Reduced Fabrication Costs and Errors
- Facilities Management
- Functional Simulations

4D models in which components in a 3D object-based model are linked to activities can enable CMr to manage schedule as well as product information (Zhang, 2008). The 4D model permits the participants to simulate the construction process in a sequential order and to analyze the current status.

VDC based on 4D model serves plenty of uses at various types of projects for supporting proper schedule/cost management and productivity control. In comparison with the conventional schedule management methods such as a critical path method (CPM) network diagram and a bar chart, 4D system support not only simple product information, but also status of project process simulation. Moreover, based on this function, this supports the decision making of project participants. That is to say, construction manager defines the process of construction work items, and he/she can understand the all risks of schedule plan in early stage.

A 4D model enables GC to acknowledge potential risks derived from errors in plan in the early stage when change-order occurs. In addition, validating constructability and work efficiency is possible by checking 4D simulation. Given that a 4D model shows the 3D space configuration which is almost same to the as-built real building, it prevents the faults of works and possible reconstruction parts by supporting the decision making process among participants i.e. owner, designer, general contractor and subcontractor.

Regarding discussions so far, benefits for introducing 4D in terms of risk management can be summarized as follows (Brian, 2007):

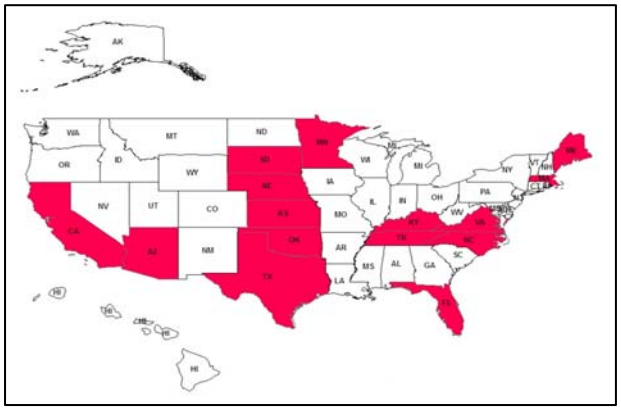
- Offering the documents for supporting decision making of general contractor and subcontractor in construction phase
- Revitalization of communication between general contractor and subcontractor in construction phase
- Establishing the optimum schedule management planning through checking at pre-construction phase
- Visualization and optimization of construction process

4. CURRENT STATUS OF CMR IN U.S.

One of countries that develops and get settle down the CMR is United States. In U.S., there have been continuous endeavors to legislate the law supporting the alternative delivery system over the last 30 years (Tulacz, 2003). There have been many states that enact the law about CMR. For instance, for a decade, New York, California, Florida, Texas and Arizona establish a code to introduce the CM at Risk on the public construction project (Jang, 2006). The map in Figures 1 shows the states which adopt the CMR system.

Figure 1. States Introducing CMR as a Compulsory Delivery Method in US (Jang, 2006)

As illustrated in map given above, 15 states permit the CMR delivery method, and the number of states that introduce the CMR tends has been increased.



5. CASE STUDY: VDC USED IN CMR PROJECTS

As mentioned in previous section, CMR delivery method will occupy the majority in the public construction project, and in this trend, VDC will play an important role of risk management especially in construction phase.

In this section, six projects out of seven projects which are analyzed in 'VDC Use in 2007: Significant Value, Dramatic Growth, and Apparent Business Opportunity' (Gilligan *et al.*, 2007) are used to explain the advantages of VDC during construction phase. VDC technologies enable general contractor and subcontractor discuss the issues or problems which is originated at construction field by using nD models (i.e. 3D, 4D, and 5D). And nD models are created by using 3D simulation tools such as Navisworks or Innovaya. Table 3 shows the level of VDC implementation according to process and participants who take part in.

Table 3. Case Study: Level of VDC and Participants to Implement it According to Project Phases
(Gilligan and Kunz, 2007)

Level of VDC Implemented		Programming & Schematic Design	Design Definition & Pre-construction	Construction & Coordination	As-Built / O&M Documentation
Salisbury Fire Station & Head quarters	Automation	O	O	O	
	Technical Integration	O	O	O	
	Automated Prediction	O	O	O	

	Visualization	O	D	GC	O	D	GC	S	O	D	GC	S			
Atlanta Hilton Aquarium	Automation														
	Technical Integration														
	Automated Prediction						GC	S			GC	S			
	Visualization				O	D	GC	S	O	D	GC	S	O	D	GC	S
Camino Medical Office Building	Automation										GC	S*			
	Technical Integration										GC	S*			
	Automated Prediction						GC	S			GC	S			
	Visualization				O	D	GC	S	O	D	GC	S			

(continued)

Level of VDC Implemented		Programming & Schematic Design		Design Definition & Pre-construction				Field Construction & Coordination				As-Built / O&M Documentation			
Mills Peninsula Hospital	Automation										GC	S*			
	Technical Integration										GC	S*			
	Automated Prediction						GC	S			GC	S			
	Visualization				O	D	GC	S	O	D	GC	S			
Honda Data Center	Automation										GC	S*			
	Technical Integration										GC	S*			
	Automated Prediction					D	GC	S		D	GC	S	O	D	GC	S
	Visualization	O	D		O	D	GC	S	O	D	GC	S	O	D	GC	S
Texas & Ohio Data Centers	Automation											S*			
	Technical Integration											S*			
	Automated Prediction									D	GC	S	O	D	GC	S
	Visualization	O	D		O	D	GC	S	O	D	GC	S	O	D	GC	S

In Table 3, general contractors and subcontractors involve in automation, technical integration, automated prediction and visualization in the construction and coordination phase. They use VDC technologies in communication and discussion by means of visualized 4D model in which subcontractor's shop drawings are integrated. In the sample projects, subcontractor's shop drawings are designed by using AutoCAD, CADMEP, CADDuct, Revit Structure, PD3D, etc. Some of these softwares support just only 2D drafting, and others support both 2D drafting and 3D modeling. To make an integrated 3D model from data with different formats graphic tools (i.e. Navisworks Viewer or Jetstream) are used.

Creation of models earlier in project process allows general contractor and subcontractor to avoid problems which can be originated from poor communication in construction phase. Given that the responsibility to establish communication system belongs to the GC, in the case projects, it creates integrated 3D model in the pre-construction stages to analyze the construction schedule. By doing this, GCs can modify the initial construction plan or specific detail in previous.

In addition, GC who operated the Mills Peninsula Hospital construction project, held weekly collaboration

meetings with SCs in a large "***i-room***" presenting issues using the 3D model on smart boards. By using this i-room, GC and SC could optimize the use of 4D based integrated models which consist of electrical, mechanical/plumbing, structural concrete/steel, fire protection drawings (Gilligan and Kunz, 2007).

These exercises and endeavors could make general contractor manage and reduce the risks which can become serious obstacles to project.

6. Conclusion

Korean government has prepared to establish regulations and codes to introduce CMR in the projects over certain amount of budget in the public sector. Private construction companies and research institutes have conducted various researches supporting the introduction of CMR. This becomes an urgent issue which can change traditional practice and systems in the construction industry.

Like other procurement methods, for successful delivery of CMR projects, participants should understand projects in detail and collaborate systematically. Given that the sequence of project success or failure influence upon the status of the part who play the role as CMr, in general GC, this part has tried to establish a new environment in which potential risks can be predicted in previous and resolve it in the earlier phase of project.

Focusing on the construction and coordination phase, a major role of the GC as the CMr is to facilitate proper communication and decision making with SC. VDC seems to provide a tool to this end. Using VDC technology, GC can create 4D model, and leads the discussion with SC. Furthermore, all participants of a project can cooperate each other at all stages.

A challenge could be the diversity of organization and thus format of digital data provided by SC vary. This can be partly resolved by means of introducing relevant techniques in the field BIM. However, business process among participants who play the role as GC and SC should be discussed and consensus should be made to magnify the benefits of VDC in CMR.

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