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Study on BIM utilization for design improvement of infrastructure project

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Abstract

Virtual construction could be done by using Building Information Modelling technology. But, to do that, information and knowledge on construction phase or fabrication phase should be available in design stage. In Japan, MLIT had been taking the leadership in the CALS/EC project which was just partially successful. We have to learn from "the experiences of CALS/EC" to get the fruit from BIM introduction to infrastructure projects. In the case of design-bid-build contract, since data sharing should be restricted based on the contract, consultants or engineers for designing are to become more capable of utilizing information relevant to construction of fabrication. The mobility of personnel is to be promoted in construction industry. In the case of design-bid-build contract, since data sharing should be restricted based on the contract, public sectors have to be more positive overcome contract related issues with their own leadership. If public sectors in Japan would not notice the similarity of issues of CALS/EC and BIM, Japanese construction industry may experience the same kind of frustration as one they had while executing CALS/EC projects.

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Keywords: Building Information Modelling; CALS/EC; design-bid-build contract

1. Introduction

Serious schedule delay is normally caused by unpredictable condition change in construction process. As a result of the delay, contractors might face serious risk of productivity reduction. Owner side also may have to take steps to meet critical situation. Frontloading is effective to decrease such risk caused by design change, and can improve the

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productivity. Virtual construction in design process must be the powerful method to precisely predict what would happen in the construction process. Virtual construction could be done by using Building Information Modelling technology. But, to do that, information and knowledge on construction phase or fabrication phase should be available in design stage. In Japan, MLIT had been taking the leadership in the CALS/EC project which was just partially successful. We have to learn from "the experiences of CALS/EC" to get the fruit from BIM introduction to infrastructure projects.

2. What we have learned from CALS/EC projects

2.1. What is CALS/EC?

CALS/EC is defined as "Continuous Acquisition, Lifecycle Support and Electronic Commerce" and used as the word expressing a series of activities to innovate construction projects by using the technologies of networking, electronic data and data sharing in Japan and Korea. Fig. 1 illustrates the image of CALS/EC set at the beginning of the project. A series of database is used for sharing information among public sectors, construction related companies and other organization or persons such as overseas companies, general public and other institutions. The number of organizations and persons involved in any civil project is not a few. Also, during the life cycle of facilities, the information can be utilized and recycled as well. From planning to maintenance, all the information produced during a project can be accumulated and used for various purposes. Fig. 2 illustrates possible information gap among each phase of planning, design, construction and maintenance. For example, from design phase to construction phase, some quantity of information with some quality is transmitted from one organization (or person) to another organization (or person) and used for the sake of construction or fabrication. But the rest of the information obtained in the design phase is not used anymore because of the insufficiency of the information for that sake. In that case, the information can be disposed and additional information is produced by the contractor or the fabricator, which might lead to the reduction of productivity. At the end of each phase, this kind of information deterioration occurs.

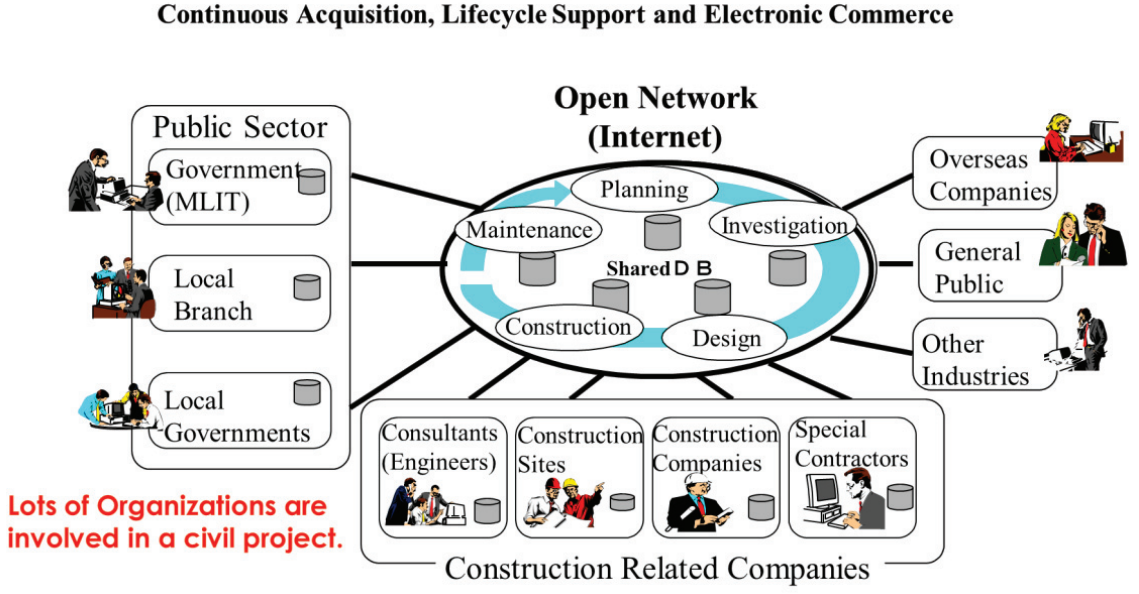

Fig. 1. Image of CALS/EC (Curtsey of JACIC).

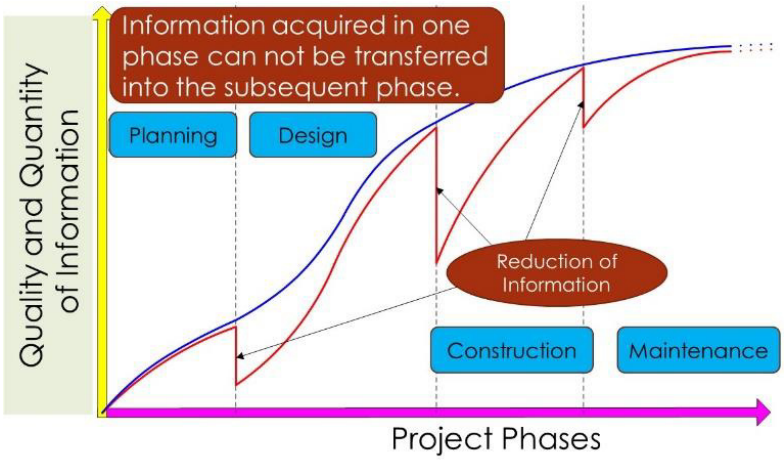

Fig. 2. Information Gap between each project phase (Curtsey of JACIC).

2.2. CALS/EC Utilization based on design-bid-build contract.

In the case of projects based on design-bid-build contract, data sharing or information sharing is prohibited based on the contract between the designer and the contractor or the fabricator. Table 1 summarizes four types of CALS/EC utilization in that case. First two are information sharing between design phase and construction/fabrication phase. The first type shows the case if the designer does not have sufficient information or knowledge on construction/fabrication, it would not be essential for the designer to try to produce construction or fabrication related information. He may have better to concentrate more on the quality of basic design concept. However, if he concentrates to the kind of task, reduction of his business opportunity would occur. Such a situation is not acceptable for the designer. Second one is so-called frontloading. If the designer succeeds to get enough information for the sake of construction or fabrication at design stage and put that information into delivered documents, the contractor do not encounter unpredictable condition change after commencement of the work. However, the contract does not allow share information in design process with any contractor. Also, for designers, it is serious issue to be capable of acquiring construction related information during designing if he does not have much experience to construct on sites. Third type shows the case of information sharing among the engineer, the contractor and the owner sides during construction. Various kinds of software to assist that sort of activity were developed and used in various projects, and unfortunately project-by-project utilization of specific software caused another problem. For example, engineers of the owner side were forced to use several different systems for simultaneously handling different projects. The last type shows the case of maintenance phase. Since civil facility has to be operated for some decades, cost reduction and adequate decision making by using information acquired from design to construction processes. Main issue is in this case identification of information needed for long-term maintenance.

2.3. Has CALS/EC Succeeded?

Table 2 summarizes the results of the CAL/EC project in Japan. An idea of information sharing is precedent, and nobody did not sufficiently grasp the merit of knowledge sharing for each organizations. Electronic bidding succeeded and as a result transparency and equality of bidding chance was enhanced dramatically. Knowledge transfer from design phase to construction/fabrication phase was supposed to be done by using 2D CAD format was standardization. Though the compatibility of the standard format for 2D drawing was insufficient, the use of the forced. As mentioned above, information sharing during construction execution among related organizations or persons did not succeed. Other activities of electronic delivery, usage of delivered data and data acquisition for maintenance did only partially succeed.

Table 1. CALS/EC Utilization based on design-bid-build contract.

Type	Merits	Issues
Design-to-Construction Limited design work	Consultant can concentrate to the task essentially needed in the subsequent phase.	Consultant cannot accept reduction of business opportunity.
Design-to-Construction Frontloading	Contractor does not encounter unpredictable condition change after commencement of the work.	Contract does not allow share information in design process.
Construction or fabrication Phase	Productivity improvement with cooperative activities among owner, contractor, and engineer	Project-by-project utilization of software for information sharing
Maintenance Phase	Cost reduction and adequate decision making with information acquisition	Owners did not identify Information needed for long-term maintenance.

Table 2. Has CALS/EC succeeded?

Activity	Success or Failure?	Cause of Failure
Electronic Bidding	Success	Transparency and Equality of Bidding Chance (Applicable for other countries)
Knowledge sharing between	Partial	2D CAD Standardization is insufficient.
Design and Construction	Success	Insufficient knowledge on fabrication or construction execution is available.
Data sharing during Construction Execution Among Organizations	Partial Success	Compatibility of ASP software is insufficient.
Electronic Delivery	Partial Success	Additional delivery of paper documents may be required together with E-documents.
Usage of Delivered Data	Partial Success	Acquired data is stored in each closed system
Data Acquisition for Maintenance	Partial Success	Required Information has not been identified.

3. How should we overcome issues related to data sharing?

3.1. What is BIM?

BIM technology is power to realize the virtual construction and information sharing among phases. Fig. 3 shows how BIM heighten the efficiency of construction projects. Design change in construction phase or insufficient design of existing structure decrease drastically the efficiency of operation and maintenance. In the case of 2D design process, unpredictable design change causes schedule delay and productivity reduction. If we use BIM design process, the cost for the design increase somehow but the impact for total cost reduction is larger than the cost increase in designing.

Fig. 4 illustrates virtual construction by using BIM technology. The 3D model is combined with scheduling data and cost data and then some virtual components such as construction machines and labors are installed to simulate all the construction process virtually.

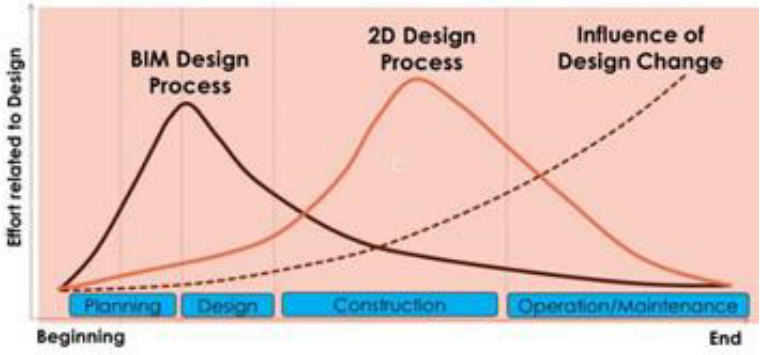

Fig. 3. Efficiency of the whole construction project with BIM Technology (Curtsey of JACIC).

Fig. 4. Virtual construction by using BIM technology (Curtsey of Taesung S&I).

3.2. BIM Utilization based on design-bid-build contract.

In the case of projects based on design-bid-build contract, data sharing or information sharing is prohibited based on the contract stated above. Table 3 summarizes the four types of BIM utilization in this case. First one is information sharing construction/fabrication. In this case, contractors could do anything based on their own decision for productivity improvement. Issue related to technology is not critical. If the designer has sufficient information or knowledge on construction/fabrication, it would not be essential for the designer to try to produce construction or fabrication related information. Second one is so-called frontloading. As mentioned above related to CALS/EC, the contractor do not encounter unpredictable condition change. In the case of maintenance phase, cost reduction for maintenance can be reached with BIM together with essential information acquired, since duration of maintenance is about 50years to 100years for infrastructures.

Table 4 summarizes merits and issues to be overcome in the case of utilization of BIM from the design phase based on design-bit-build contract. For the merits for all participants, owner sides has responsibility to overcome contract-related issues. For example, Integrated Project Delivery (IPD) has used in the case of the World Trade Center re-development project. Also, it is essential for designers to be capable of being familiar to construction or fabrication related information or knowledge.

Table 3. BIM utilization based on design-bid-build contract

Type	Merits	Issues
Construction Phase	Productivity Improvement by Contractor	(Issue related to Technology is not Critical.)
	Contractors could do anything based on their own decision.	
Design-to-Construction Phase	Risk reduction of Change in Construction Condition	How to Contract?
	Virtual Construction during Design Phase is essential for productivity improvement.	In the case of separate contract, Data sharing is restricted.
		How to implement IPD for public works?
Maintenance Phase	Cost Reduction during Maintenance	Merit of Contractor and Consultant is insufficient.
	Duration of maintenance is about 50years to 100years.	Information needed for long-term maintenance should be identified.

Table 4. Merits and issues of data sharing between design and construction/fabrication

Organization	Merits	Issues to overcome
Owner	Improvement of	Contract Improvement
	Productivity	New Contract Method such as Integrated Project Delivery should be implemented.
	Productivity of Project Improves, and Benefit/Cost Ratios Increases.	
Contractor	Risk Reduction caused by	Knowledge Sharing with Consultant
	Design Change	Knowledge on Construction should be shared with Consultant and Owner.
	Decrease in Uncertainty Leads to Risk Reduction by Design Change in Construction Phase.	
	Merits and Issues of Data Sharing between Design and Construction(Fabrication	
Consultant	Higher Dependency on	Improvement of
	Design Quality	Design Ability
	Success of Project depend on the quality of design more than before.	Knowledge on Construction or Fabrication Phase should be acquired and used wisely in Design Phase.

3.3. Three options of contract for BIM utilization.

Table 5 compares the issues of three types of contract from the viewpoint of BIM utilization. In the case of design-bid-build contract, since data sharing should be restricted based on the contract, consultants or engineers for designing are to become more capable of utilizing information relevant to construction of fabrication. One method to realize this for consultants is to hire more engineers who have rich experiences on construction or fabrication, which means that the mobility of personnel is to be promoted in construction industry. Since most of civil engineering projects are executed on this type of contract, overcome of this issue is crucial. Accepting design-build contract is a good strategy for effectively utilize BIM technique from design phase to construction phase seamlessly. At this moment, technological issues are not crucial any more. Toe executives of contractors should be positive for utilizing BIM technology as the motor for the innovation. Integrated project delivery is a new possibility for the breakthrough. When IPD as shown by Fig. 5 is adopted, all the stakeholders should collaborate beyond the constraints of contract.

Table 5. Three options of contract for BIM utilization

Type	Issues	How to Overcome?
Design-Bid-Build Contract	Data sharing should be restricted based on Contract.	Consultants are to be more capable of utilizing information related to Construction and Fabrication.
Design-Build Contract	Just Technological (not Critical)	Top executives of Contractors should be positive (not conservative).
Integrated Project Delivery	Difficulty to collaborate beyond the range of Contract	Public sectors should be more positive to change the social system. (Issue on the roles of Contractor, Consultants and Owners.)

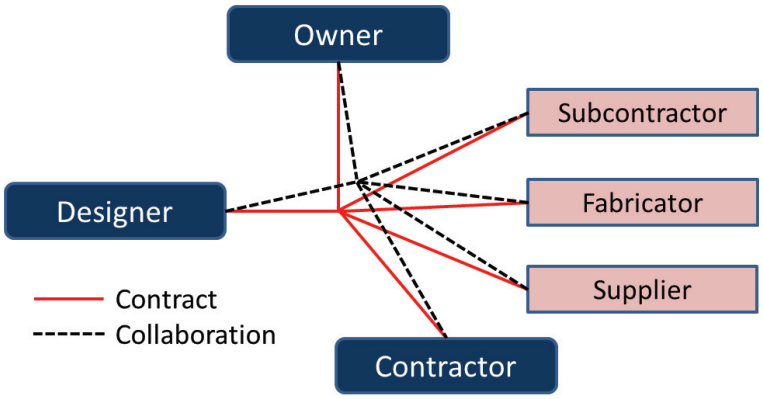

Fig. 5. Integrated project delivery.

4. Conclusions

In this paper, the authors discussed what we can learn from the "failure" of CALS/EC for the future successful utilization of BIM technology in Japanese construction industry. In the case of design-bid-build contract, since data sharing should be restricted based on the contract, consultants or engineers for designing are to become more capable of utilizing information relevant to construction of fabrication. The mobility of personnel is to be promoted in construction industry. In the case of design-bid-build contract, since data sharing should be restricted based on the contract, public sectors have to be more positive overcome contract related issues with their own leadership. If public sectors in Japan would not notice the similarity of issues of CALS/EC and BIM, Japanese construction industry may experience the same kind of frustration as one they had while executing CALS/EC projects.

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