TOWARD ADOPTION OF VIRTUAL CONSTRUCTION IN THE INFRASTRUCTURE DOMAIN

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***ABSTRACT*:** Building Information Modeling (BIM) has been attracting much attention in Architecture, Engineering, and Construction (AEC) for several years. Virtual Construction (VC) is a kind of BIM design, in which architectural, structural, and facility design, cost estimation, and construction planning are integrated and done in a short period, employing a standardized product model named Industry Foundation Classes (IFC). VC has already been adopted for actual design and construction of a number of building projects worldwide. On the other hand, VC has not been adopted in design and construction of infrastructures such as bridges, roads, tunnels, dams, river structures except some special cases. The 5th Asia Construction Information Technology (IT) Round Table Meeting was held in August 2009 in Tokyo by Japan Construction Information Center (JACIC) and the Committee on Civil Engineering Informatics of Japan Society of Civil Engineers (JSCE), and in a half-day special session, thirteen experts in IT in construction were invited from Asian countries and discussed the following agenda:

1. Why is the infrastructure domain slower in adopting VC than building industry?
2. Is VC necessary for the infrastructure domain, or not? Are there any merits?
3. What would hinder the promotion and adoption of VC in the infrastructure domain?
4. What is needed to promote and employ VC in the infrastructure domain in terms of research and practice?

Each participant gave short presentation for each agenda, followed by discussion. Although some differences were found from country to country, most participants agreed with the difficulty in adoption of VC for infrastructure domain because of its public characteristics and at the same time they confirmed the importance and necessity to promote and employ VC in the infrastructure domain.

KEYWORDS: Virtual construction, Building Information Modeling

1. INTRODUCTION

In Architecture, Engineering, and Construction (AEC), Building Information Modeling (BIM) (Eastman et al. 2008) has attracted much attention for several years. BIM is a new building design and construction process, in which architects, structural engineers, facility engineers, construction engineers, owners, and other participants have access to a three dimensional building model and collaboratively proceed the design tasks much faster, considering more alternative design cases. The 3D building model in BIM is an exchangeable digital file and is usually called product model. Product model is referred to ISO 10303 Standards for The Exchange of Product data model (STEP). In the building field, Industry Foundation Classes (IFC) of buildingSMART International (formally, International Alliance for Interoperability: IAI) (buildingSMART 2010) is the product model. Now, 3D CAD and other design, analysis, and simulation software packages are becoming more and more interoperable with IFC. Virtual Construction (VC) is a kind of BIM design, in which architectural, structural, and facility design, cost estimation, and construction planning are integrated and done in a short period, employing a standardized product model such as IFC. Since BIM is referred to as buildings, the word VC is used to include design and construction of infrastructures or civil engineering structures, such as roads, dams, bridges, tunnels, etc. BIM has already been adopted for actual design and construction of a number of building projects worldwide. On the other hand, VC in the infrastructure domain has not been so adopted as in the building industry, although some large general contractors have conducted earthwork and dam construction projects, employing 3D data. Note that the term Virtual Design and Construction (VDC) has been created and used at the Center for Integrated Facility Engineering, Stanford University for several years (Fischer and Kunz 2005). VDC is similar to BIM and has promoted BIM strongly.

The 5th Asia Construction Information Technology (IT) Round Table Meeting was held by Japan Construction Information Center (JACIC) and the Committee on Civil Engineering Informatics of Japan Society of Civil Engineers (JSCE) on August 6-7, 2009 in Tokyo (ACIT 2010). Thirteen experts in the field of IT in construction were invited from Asian countries and discussed various issues in the meeting. In the afternoon of the first day, a special session on Virtual Construction was organized on following agenda:

1. Is the infrastructure domain slower in adopting VC than building industry?
2. Is VC necessary for the infrastructure domain, or not? Are there any merits?
3. What would hinder the promotion and adoption of VC in the infrastructure domain?
4. What is needed to promote and employ VC in the infrastructure domain in terms of research and practice?

In the special session of the round table meeting, each participant gave short presentation for each agenda item, followed by discussion. The following sections describe the summary of the presentations and discussion in the special session with the author’s thoughts and comments.

2. LAGGING INFRASTRUCTURE DOMAIN

Most structures in the infrastructure domain are public. Although commercial buildings are required to be built rapidly with low cost due to the heavy competition, the public domain tends to be cost-blind and has low interest in improving efficiency. Many people in the infrastructure domain believe that civil engineering structures are designed and constructed without big problems currently in terms of the business process. In this circumstance, they do not dare to take risks of failing by introducing new technologies such as BIM and VC.

Infrastructures are less complex and have less number of kinds of members than buildings. On the other hand, there are many kinds of infrastructures such as roads, bridges, tunnels, dams, river banks, harbors, etc. Furthermore, due to the nature of single part production and non-standardized members, it takes more time and efforts to create 3D CAD models of infrastructures. Created models cannot be recycled at other projects. However, as for the complexity of infrastructures, the opposite opinion was mentioned.

Owners of buildings are usually private

companies while infrastructures are public. As for private buildings, architects, structural engineers, facility engineers, contractors can make up a team for design. The way the project is done by this way is called the Design-Build (DB) method. In principle, on the other hand, the process of public work projects is Design-Bid-Build (DBB), in which design is done by design consultants and then, general contractors tender bids and perform construction if they win. In the DBB method, design and construction are separately contracted and performed by different companies. A firm which has designed the project is not allowed to join the project for construction. Since no official standards for representing 3D product data models of public infrastructures exist, it is very difficult for owners to treat 3D model data. They say they cannot receive particular commercial CAD files from design consultants because the owners are public. On the other hand, in the DB method, which is popular in commercial building projects, participants do not have to worry about the standardization but they can use de facto standard commercial CAD format.

Since there is no official standard for 3D model data in the public infrastructure domain, there is no common 3D CAD software for infrastructures. Thus, few people would use 3D CAD in this domain.

Public infrastructures tend to be horizontally long, and thus, multiple coordinates systems may be necessary, which is cumbersome for the use of 3D CAD. Since most infrastructures are built in the natural environment, modeling of very wide and spacious natural areas is necessary and the structural models are to be inserted and molded into the natural 3D model. This task takes time and effort. Furthermore, even if detailed design is done, the design usually must be changed according to the condition of nature. Especially, the geotechnical conditions cannot be fully surveyed before construction. On the other hand, buildings can be designed just like machines using 3D CAD.

In the commercial building domain, design is divided into architectural design, structural design, facility design, production design, and many different kinds of designers and engineers have to collaborate and exchange design information frequently. On the other hand, there are not so many different kinds of engineers participate in public infrastructure design.

In the commercial building design, cost of design is usually from 7 to 10% of construction cost, while it is only 3 to 4% in the public infrastructure domain, and thus, reduction of design cost and return on investment (ROI) by introducing VC technology may be small.

Many people in the infrastructure domain do not know even words such as BIM, product models, virtual reality, and they are not so familiar with IT and they are not so interested in it. On the other hand, people in the building domain are much more familiar with 3D CAD and VR because they use computer graphics more often for presentation to owners and citizens.

Not so much research has been done about BIM or VC in the infrastructure domain. There are few professors majoring in IT in construction or civil engineering informatics in civil engineering departments of universities. Not much research funds are provided to this area.

3. NECESSITY AND MERIT OF VC

Most participants to this special session agreed that VC would be necessary in the infrastructure domai.

However, the amount and degree of the merit is uncertain and it depends on how and for what objective VC will be used. Common merits of VC are described as follows.

3D models made in the design phase will be used for visual presentation, which will be effective in improving design and construction as well as negotiation and consensus building with citizens, other stakeholders, and activists. 3D models are expected to improve the efficiency and safety of construction and quality with clash detection, 4D and 5D CAD capabilities. With the design process improvement, the number and scale of design changes are expected to be decreased. It is also expected to promote "ICT construction" by applying 3D model data to construction machine control, work progress control, and inspection, which can lead to reducing cost, shortening the construction period, and improving quality.

The other perspective is that VC will be useful and effective for only complex structures and should not be used for simple structures. Those who gave this kind of comments had disclosed the opinion that public infrastructures are simpler than buildings. Some participants gave more negative impression that VC may not be so necessary because the design cost of public infrastructures is not as big as buildings and thus the effect of using VC would be limited. And they argued that design change would not decrease in the infrastructure domain because of many uncertainty factors. Therefore, VC will be applicable to only large-scale and monumental projects.

Intermediate perspective was that it would depend on benefit-cost ratio (B/C). It was also implied that large-scale projects would have better B/C than small projects.

New idea was that the public domain should consider shifting from the DBB method to the DB method so that VC would be more applicable, the value of VC would be maximized, and the knowledge of general contractors would be utilized in the design phase.

4. OBSTACLES FOR ADOPTION OF VC

Since VC will change the business model, flow, and method of public infrastructure design and construction, conservativeness of those who are engaged in the public construction domain will be a big obstacle for adoption of VC. On the other hand, if the government or the public owner decides to adopt VC, they tend to do it completely even if commercial sectors are reluctant.

The characteristics that the owners are usually public will make it difficult to change the project method from DBB to DB. Thus, the official standardized product model is needed and the public owners will not adopt VC until the standard becomes effective. Equality and fairness in bidding will be an obstacle for adopting new technologies such as VC because weak companies which may not be able to utilize the new technology are considered patiently.

Other obstacles include slow development of VC tools for infrastructure domain, bad communication and different motivations between construction engineers and IT professionals, the mindset that efficiency would come last and the commercial sectors rely on the government unnecessarily.

More obstacles include lack of success stories and insufficient education and training of VC to engineers in the infrastructure domain, and lack of B/C ratio.

5. REQUISITE FOR PROMOTION OF VC

In order to promote VC in the infrastructure domain, relaxing the current relatively rigid contract methods and project systems are expected so that DB method can be more adopted instead of DBB method. At the same time, since it will take time for the public sectors to shift from DBB to DB method, relaxing the current rigid electronic data submission is expected. For example, the rule that electronic data must be conformance with the ISO standards is too strict. For better performance of construction projects, de facto standards or commercial CAD files may be added to design drawings by design consultants. And the CAD files may be handed from the public owner to general contractors.

Interoperable product models are necessary to share and exchange data. Many various tools which are interchangeable to the product model data are necessary as well. In addition, new tools such as an integrated system of Geographic Information System (GIS) and CAD would be important in the infrastructure domain from a standpoint of coordinate systems.

In order to develop such product data models and tools, a lot of research and development would be necessary at universities and research institutes as well as companies. Government should consider raising funds for those tasks. R&D and standardization should be done collaborating with international organizations, universities, research institutes, companies in foreign countries instead of doing alone (Yabuki et al. 2006) (Arthaud and Lebegue 2007).

Fundamentally, a new vision with a strong strategy would be necessary to change the business model and process in the infrastructure domain, which is very conservative and which tends to resist change. The government should have a policy toward changes to improve the efficiency, quality, safety, etc. by adopting VC, inventing new schemes such as giving incentives to those who challenge the changes. Success stories are necessary to promote changes. And education of IT, CAD, VC, BIM, etc. to not only students but also practitioners and engineers is necessary. Government’s support is important in these fields.

As a new support business, a VC information manager or a VC information management company will be needed to promote and facilitate the new business process of VC. VC managers will collect various data and information related with the design and construction of the project, covert to some particular data format, distribute them to the related engineers and team members and support all participants to the project in terms of data and information they treat. This kind of work is currently done by the owner or public agencies. Just like design consultants were spun off from the owners some decades ago, VC information managers will be born, raised up and spun off from the owners in the near future.

6. CONCLUSION

In this paper, based on the discussion at the Special Session on Virtual Construction (VC) in the 5th Asia Construction IT (ACIT) Round Table Meeting held on August 6, 2009, four issues of VC were discussed. First, the reason why the infrastructure domain is slower in adoption of VC than building industry was identified as the following: the cost-blind tendency and conservativeness of the public domain, less complex structure than buildings, difficulty in shifting from Design-Bid-Build (DBB) method to

Design-Build (DB) method, lack of official standards of product models in the infrastructure domain, coordinate system problems, less complex organization than building design industry, smaller ratio of design cost in the total construction cost than buildings, lack of IT familiarity and research of IT in civil engineering.

The second issue was the necessity merit of VC. Necessity of VC was agreed, but the level of necessity and merit varied. Many agreed that VC would improve the efficiency, safety, quality of design and construction of infrastructures. However, some pointed out the merit would be limited to complex and large scale structures. Overall, it depends on B/C or ROI.

The third issue was obstacles for adoption of VC. Potential obstacles include conservative mindset, rigid DBB contract method, lack of standard product data models, lack of communication between civil engineers and IT specialists, etc.

The final issue was requisite for promotion of VC. In order to promote VC in the infrastructure domain, shifting from DBB to DB method or relaxing the need of rigid officially standardized product model would be necessary. However, some standards are apparently necessary and various interoperable tools are required. VC information managers, a new task, will be needed in the near future to promote VC. Finally, government's support including strong vision, strategy, education, research and development is necessary.

The knowledge and thoughts unveiled and discussed by the thirteen experts in the half-day special session of VC at the occasion of 5th ACIT Round Table Meeting were valuable and important. Thus, the author decided to compile the statements and discussion and wrote this paper. For future work, more thoughts and other experts' comments should be added and the author would like to make a strategy for the infrastructure domain to adopt VC.

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