

## **DEVELOPMENT OF 5D-CAD BASED WORK PROCESS MODEL FOR AGED-HOUSING REVAMP PROJECTS**

Hee-Sung Cha<sup>1</sup>, Kyungrai Kim<sup>2</sup>, Dong-Woo Shin<sup>3</sup>

1. Ph.D, Assistant Professor, Ajou University, South Korea

2. Ph.D, Associate Professor, Ajou University, South Korea

3. Professor, Ajou University, South Korea

### **ABSTRACT**

A growing number of aged-housing building projects have become a great concern in Korean building industry nowadays. Until 2010, over 20 year-old housing units are reported to exceed more than one million. The aged-housing units are required to upgrade the performance on both structural and service issues. Compared to new building projects, revamp projects are relatively under developed in terms of construction management. For example, there is few guidance or detailed procedure which addresses the management practice in dealing with revamp projects. Therefore, new technologies are reluctantly implemented in the revamp projects without in-depth analysis on constructability and/or economic efficiency. The objective of this study is to provide a new approach in dealing with aged-housing revamp projects. By developing 5D-CAD based work process model, project managers are effectively informed of various data, i.e., building elements, network scheduling, and cost items. The 5D-CAD based decision making can also enhance the accuracy and promptness during project execution. The authors developed a standardized work process model in dealing with 5D-CAD modeling via Virtual Construction<sup>TM</sup> software. In addition, the model has been implemented to pilot aged-housing project for the purpose of validating the feasibility and applicability in real future projects. The proposed WBS(Work Breakdown Structure) and CBS(Cost Breakdown Structure) have been proved as useful tools for contractors who deal with aged-housing revamp projects under circumstances that there is few historical projects and few experienced personnel. Also, the study identified potential benefits and limitations of the 5D-CAD based construction process for revamp projects. Key findings from this study are as follows.

- 5D-CAD modeling is no more optional strategy in maximizing the project value.
- The error-free construction planning is much more essential in revamp projects.
- Sharing the real-time project information can overcome communication barriers.
- Collaborative works are definitely can benefit from 5D-CAD modeling
- Full scale usage of 5D-CAD modeling can be achieved by partnering contract

### **KEYWORDS**

Aged-Housing, CBS(Cost Breakdown Structure), 5D-CAD, WBS(Work Breakdown Structure), Revamp Project.

### **1. INTRODUCTION**

The total monetary value of the Korean construction industry is approximately 140 billion dollars in 2007. Among the total amount, more than 60% comes from the multiple or high-rise residential projects. The residential building sector is the dominant area in the Korean construction industry. At present, a growing number of projects in this sector are related with revamping or upgrading works. For example, many of the aged-housing complex projects have been so deteriorated that the structural performance level has become lower than the average and the M/E/P facilities has become old-fashioned and even needed to be replaced. On the contrary, many project practitioners have paid little attention to the renovation or revamp projects compared to new construction projects. There are three main reasons in this reluctance. First of all, the revamp project is less profitable. Compared to the new projects, the contract amount of the revamp projects is small and the working condition is less favorable. Second, the work process for the revamp projects is ill-defined so many project practitioners are reluctant to participate in the risky projects. Thirdly, the existing building condition is hard to recognize in the renovation project so the traditional estimation approach is improper in forecasting the revamp project cost.

However, the growing number of revamp projects is continuously seeking the better-fit contractors. In these circumstances, the better approach in dealing with revamp projects is to maximize the usage of the computer integration system, i.e., 5D-CAD system, in earlier stage of the project delivery. The 5D-CAD is emerging

technology and has proven its effectiveness in the field of project management (Chen et al. 2004, Walley and Tharbet 2002). The computer-based 5D CAD system is still in the beginning stage and there is much room to be developed. Considering this, the revamp project can get much benefited by this new technology in the following areas as many researchers has already indentified.

- Effective communication among project participants
- Optimizing time-cost tradeoff in the planning stage
- Achieving the higher value for money by constructability review
- Coordinating the design and construction works by real-time updating process

In this study, the 5D CAD based design has been conducted during the development of the project planning phase for optimization in cost and schedule issues for high-rise residential revamp project. By doing this, this study provides project practitioners with a guidance in developing 5D-CAD based work process and proves the effectiveness of the computer based planning and design in comparison with the conventional approach.

This paper consists of seven sections. Following this introduction, the background of this research is briefly described. In this section, the history of Korean building industry, the Center for Aged-Housing Remodeling Technology (CART), and the methodology of the research are elaborated. Next, the current status of the housing revamp projects is analyzed by studying both domestic and international case projects. In the following section, the merits and demerits in application of the 5D CAD system are discussed. To effectively use the 5D-CAD system in the revamp projects, a work-process model has been developed and the details of the model have been described in the subsequent section. The findings and path forward issues regarding the new process are discussed and finalized in the discussion and conclusion sections.

## 2. RESEARCH BACKGROUND AND METHODOLOGY

The dominant residential building type in Korea is a high-rise apartment or flat. More than half of the Koreans dwell in the apartment complex. In a very short period (less than two decades), most of the Korean residential buildings were constructed and their blocks, buildings, and the units of the facilities have been deteriorated and needed upgrading nowadays.

Table 1. Korean Aged-housing building stock statistics

ID	Years after its completion				
	0- 5 yrs	6- 10 yrs	11- 15 yrs	16- 20 yrs	Over 20 yrs
No. of Blocks	3,702	4,525	4,035	2,285	1,376
No. of Buildings	19,067	21,169	14,906	10,668	7,377
No. of units	1,525,152	1,748,173	1,093,182	534,917	360,861

As seen in table 1, there are numerous old building blocks that are more than 20 years old. Also, the number of old buildings is growing as time goes on. Recognizing this upgrading issue, the Korean government launched a 5-year, 10 million dollar, mega-research project that aims to develop efficient and effective technologies in renovating or revamping the old-aged apartment complex blocks. Four research organizations were involved in this research and the Center for Aged-Housing Remodeling Technology (CART) was established in 2005. As shown in Figure 1, there are three main objectives that CART is obliged to deliver, including standard revamp construction model, regulatory issues regarding revamp projects, and revamp technology development.



Figure 1. CART Research Roadmap

Standardizing the aged-housing apartment revamp projects is non-trivial because there are a variety of different types of the buildings and the residents' needs and requirements for upgraded facilities are difficult to identify and fit into the certain stereotype. Considering these constraints, the scope of this research is limited to a demonstration project and the final goal is to prove a "possibility" by developing a standardization model for the project. In detail, the study methodology is presented in figure 2.

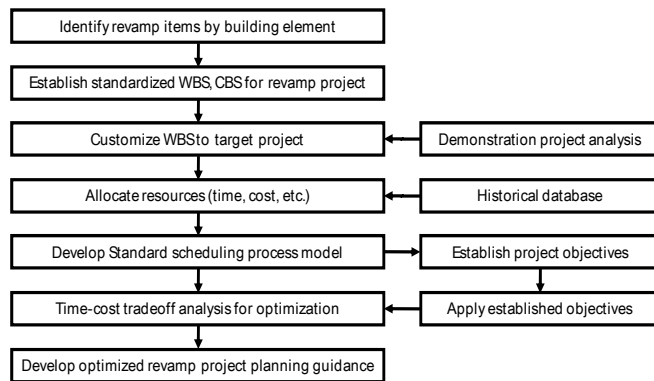


Figure 2. Research methodology

### 3. CURRENT STATUS ON AGED-HOUSING REVAMP PROJECTS

In Korea, the types of revamp projects are classified into three classes, i.e., extension, alteration, and renovation. In this study, extension and renovation are main targets. In figure 3, a brief summary of previous revamp projects completed in Korea are listed. These case projects were analyzed in detail through face-to-face interviews with project engineers and field construction managers.

This analysis showed that it took in average 24 months to complete the construction. It is also characterized that the entire building elements, i.e., finish materials, electrical/mechanical equipments, and supplies, are completely replaced while structural elements remains. The expansion of the existing plan and parking space is mandatory. A typical revamp construction process is summarized as follows.

- The horizontal plan expansion in building unit is important
- Total removal of non-structural elements is dominant
- More than expected structural reinforcement is inevitable
- In-the-wet construction method(i.e., concrete pouring) is commonly used

One of the meaningful findings from the case studies is that this type of revamp project is just on the beginning stage so that all of them are unprofitable resulting in a large amount of cost overrun.










Project Summary	
<ul style="list-style-type: none"> <li>Completion Year: 1971</li> <li>Basement 1, 5story</li> <li>Balcony Extension &amp; Layout Alteration</li> <li>Structural Reinforcement</li> <li>Utilities Upgrading</li> </ul>	 
<ul style="list-style-type: none"> <li>Completion Year: 1983</li> <li>Basement 1, 14story</li> <li>Re-sale Type Remodeling</li> <li>Balcony Extension &amp; Unit Unification</li> <li>Structural Reinforcement &amp; Seismic Wall</li> <li>Utilities Upgrading</li> </ul>	 
<ul style="list-style-type: none"> <li>Completion Year: 1971</li> <li>Basement 2, 12story</li> <li>Balcony Extension &amp; U.G. Car Park</li> <li>Structural Reinforce &amp; Seismic Wall</li> <li>Utilities Upgrading</li> </ul>	   
<ul style="list-style-type: none"> <li>Completion Year: 1977</li> <li>Basement 1, 12story</li> <li>Balcony Extension &amp; U.G. Car Park</li> <li>Structural Reinforce &amp; Seismic Wall</li> <li>Utilities Upgrading</li> </ul>	

Figure 3. Selected aged-housing revamp projects in Korea

In other Asian countries including Singapore and Japan, the commonly used construction technology is prefabrication or offsite delivery system. In Singapore, as seen in figure 4, the staircases or space added items are produced in the offsite and then delivered to the site and assembled in a speedy way. In Japan as well, the revamping projects are designed and constructed based on Pre-cast Concrete (PC) method (see figure 5).

Compared to Korean cases, those examples are more productive in terms of both schedule and cost efficiency. However, there are some limitations in adopting the prefabrication system for Korean cases. The major issue on this comes from the availability and quality problems in concrete prefabrication market. Even if the revamp projects are planned based on the prefabrication system, the market cannot be sustainable without a steady amount of demand on PC products. Also, the dimensions of the aged-housing buildings are not quite in accord with “at that time” drawings and even the drawings are not appropriately maintained.

In summary, the aged-housing revamp projects should be planned in consideration of both design and construction issues well ahead of construction process.

Item	Contents	Pictures
Project Overview	<ul style="list-style-type: none"> <li>Project : Holland Oasis</li> <li>Contract Period : 2004. 06. 25 ~ 2006. 11. 24</li> <li>Contract Sum : US \$ 17.778 millions</li> <li>No. of Units : 1113 units</li> <li>Contractor : Top Global Limited</li> </ul>	
Method of Construction	<ul style="list-style-type: none"> <li>Program : MUP</li> <li>PC(Precast Construction)</li> <li>Unit Item : Utility room, Balcony Extension, Bedroom Extension, cum Toilet, Staircase Extension, Lift Shaft</li> </ul>	

Figure 4. Aged-housing revamp case project in Singapore (source: Singapore Housing Development Board (HDB))

Item	Contents	Picture
Project Overview	<ul style="list-style-type: none"> <li>Name : Murayasi APT Remodeling Project</li> <li>Size : 5 story, 97 buildings, 1940 units</li> <li>Completion Year : 1979</li> <li>Remodeling Period : 2001~2008</li> </ul>	
Method of Construction	<ul style="list-style-type: none"> <li>Attaching 26m2 PC unit</li> <li>PC(Precast Construction)</li> <li>Without residents' evacuation</li> <li>New Pc Unit Item : Utility room, Laundry room, Bedroom, Emergency Exit</li> </ul>	

Figure 5. Aged-housing revamp case project in Japan

#### 4. 5D CAD MODELING ISSUES

A few decades ago, the Computer Aided Drawing (CAD) was initially introduced in the construction industry for the purpose of facilitating the drawing work for designers and/or engineers (Sun and Howard 2004). Nowadays, the CAD system has been so developed that it has become an essential tool for not only designers but also construction practitioners who need a detail-level of information regarding construction execution, for example, an activity-level schedule and cost estimate (Pro IT News 2003). A more highly-developed computer software technology enables a 5D CAD modeling, which means an integration of 3D modeling with schedule data (4D) and resource data (5D) of a construction project. The 5D CAD modeling is also referred to as Building Information Modeling (BIM). In this modeling field, a *standardization* issue is the key element because the computerized CAD modeling can be a waste of time when every single data has to be generated in a project-by-project basis. To facilitate the international BIM system standardization, International Alliance for Interoperability (IAI) has been recently organized and they are developing Industry Foundation Classes (IFCs), which are a set of building product model or objects. When using the 5D CAD modeling, the main benefits are summarized as the followings (Gallelo 2005).

- Design and estimation are integrated.

- Cost calculations are automatically created.
- Schedule is automatically created and optimized.
- Constructability analysis is facilitated.
- Design to build/build to design processes are enabled.
- Project risks can be identified and mitigated
- Subcontractor costs are reduced
- Contractual issues and claims are effectively managed.

Recently, Vico Software Inc. developed the 5D CAD software package titled as Virtual Construction™. In this package, there are six software programs, including Constructor™, Estimator™, Control™, 5D Presenter™, Cost Manger™, and Change Manager™. Each program is useful tool in representing the 5D-CAD modeling for a construction project. Although the system is relatively new, many projects have already proved the potential benefits described earlier. The project participants can effectively deliver 5D CAD modeling using this system. In revamp projects, the software is also helpful in developing detail-level Construction Execution Plan (PEP) in association with various project objectives, i.e., time, cost, safety, and quality issues.

However, despite the global efforts on computer integration in the construction industry, the 5D CAD modeling has many disadvantages compared to the conventional approach as follows.

- The CAD software programs are incompatible with each other.
- Too much skill is needed to take a full advantage of the CAD system.
- The different levels of detail are not acceptable in the system.
- Too much unnecessary input data needed to operate the system.
- All of the user groups should be well aware of the full context of the system.
- Only a few CAD system operators/users are available in the industry.

Furthermore, in revamping projects, there is no guidance in dealing with the 5D CAD modeling. Compared with the green-field residential projects, the revamp projects are difficult to manage due to the residing home owners and the deficient space for construction. The purpose of this study is to develop a work process model for 5D CAD modeling in executing revamp projects for high-rise residential buildings.

## 5. DEVELOPMENT OF 5D CAD-BASED WORK PROCESS MODEL

Recognizing the merits and demerits of the 5D-CAD system, we developed a 5D-CAD work process model as depicted in figure 6.

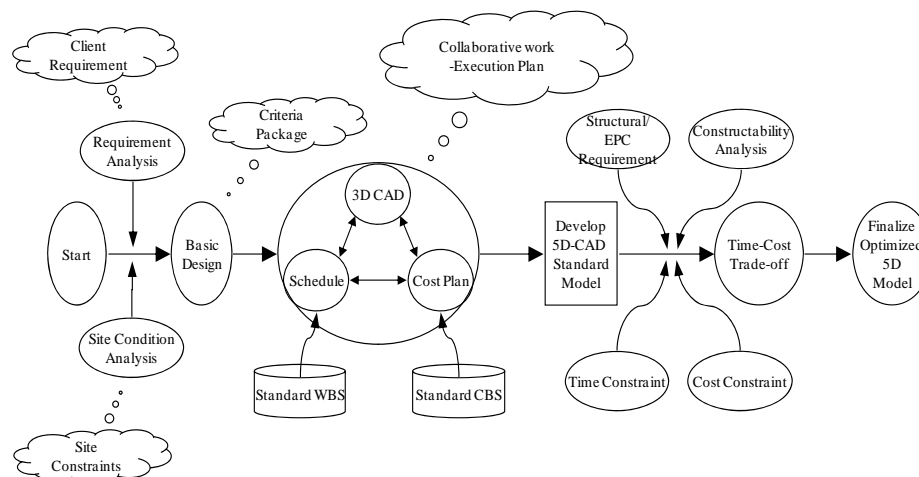


Figure 6. 5D-CAD work process model for aged-housing revamp project

In the first step, analyzing both residents' requirements and site conditions, the basic design is completed. In this stage, no collaborative work is required. The chief architect or designer can only be involved in this preliminary design phase. After this, 5D-CAD modeling is conducted using standard Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS) databases. In this stage, the standard WBS and CBS are the key elements. Also, this modeling work is conducted in collaboration with all project participants, including designers, estimators, schedulers, and construction managers. After developing the standard 5D-CAD model, the structural and Mechanical/Electrical/Piping works are analyzed and incorporated in the system. In this stage, detail-level constructability items can also be effectively identified and reflected to the model. By designating the target project cost and schedule, the time-cost tradeoff analysis is conducted in this stage. Once the optimization of the time and cost is completed, the final version of the 5D CAD model is produced.

This work process model has been developed to effectively apply to the pilot project in aged-housing revamp project. Since the final goal of our research center (CART) has not been achieved, this work process model is still in progress at the time of this writing. The following section provides the case project the work process model has been applied during the development of the 5D CAD model.

## 6. CASE STUDY

The pilot test project is located in the southernmost part of Korea, Jeju-island. In figure 7, both the existing and revamp plans of the cast project are depicted. This small aged-housing building has five stories and eight units per story. The area of each unit is only 350 square feet. There are two staircases with no elevator shaft. In the revamp planning, two elevators have been added and barrier-free access ramp between the ground level and the first floor has been installed. All of the units have been expanded to the maximum allowance (30% of the gross area). As seen in figure 7(b), the units are expanded to either northern or southern direction.

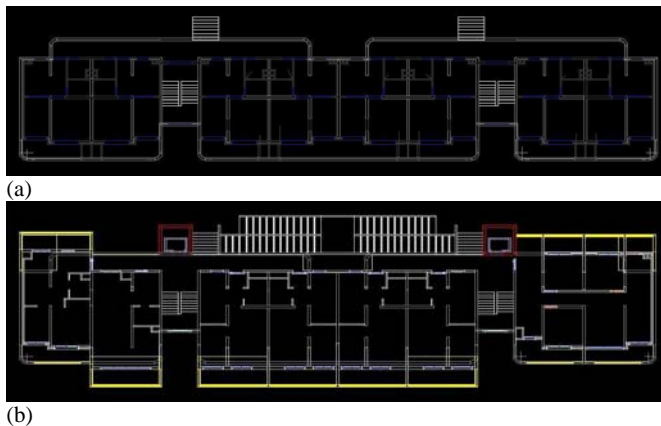


Figure 7. Aged-housing revamp project for pilot study (a. before revamping, b. after revamping)

Once completing the basic drawings, the 5D CAD modeling work can be accomplished. First of all, the standard WBS and CBS have been developed as shown in figure 8. The breakdown system has been established in cooperation with the experienced revamp construction experts. The characteristics for revamp project should be included in the WBS and CBS. For example, the activities regarding dismantling and reinforcing the structural elements play important roles in revamp projects. In addition, the recycling construction debris and wastes should be considered prior to the construction execution phase.

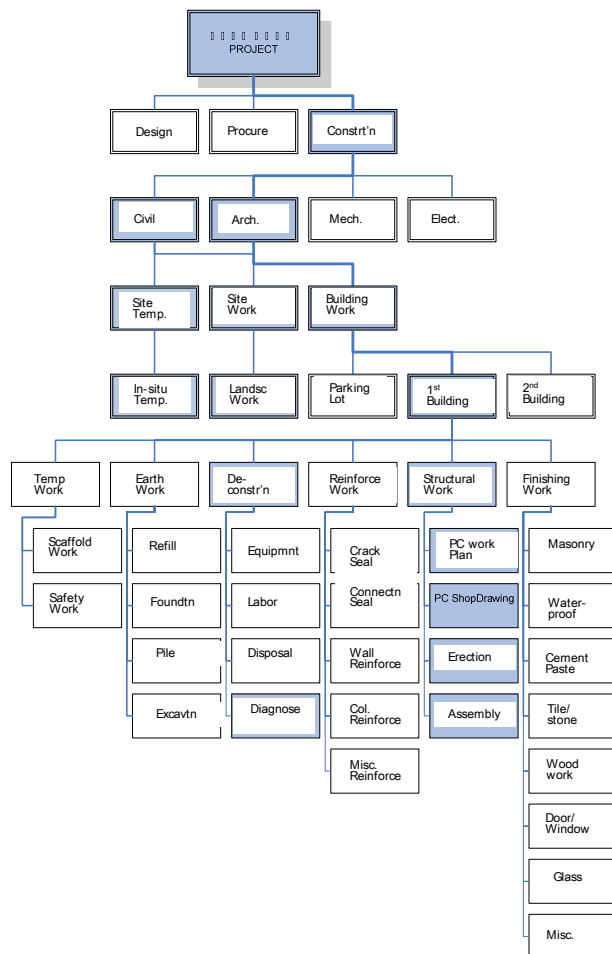


Figure 8. Work Breakdown Structure (WBS) for Aged-housing revamp projects

Using the standard WBS, each building element could be coded based on the databases which the Virtual Construction<sup>TM</sup> provides. The program has a unique methodology where the cost and schedule data can be effectively incorporated into the 3D model. First, each building object in the CAD model is connected to data element, called *Recipe*. The Recipe lists the activities and ingredients needed to construct the building object. Therefore, different columns can have different recipes. For example, some column can have a Recipe of in-situ concrete pouring with re-bar inside of wood form while others can have a Recipe of Precast Concrete fabricated in offsite. In more detail, the recipe is broken down into a set of *Methods*. The list of activities required to complete the building object is referred to as Method. The cost items such as material, labor, equipment, etc. are then linked to the Method to further identify the specific resources. In developing project schedule, the Methods are categorized into a task and the complete duration of the project can be obtained using the scheduling application program. Figure 9 shows the in-progress 5D CAD modeling screen shot via Virtual Construction<sup>TM</sup> Software.



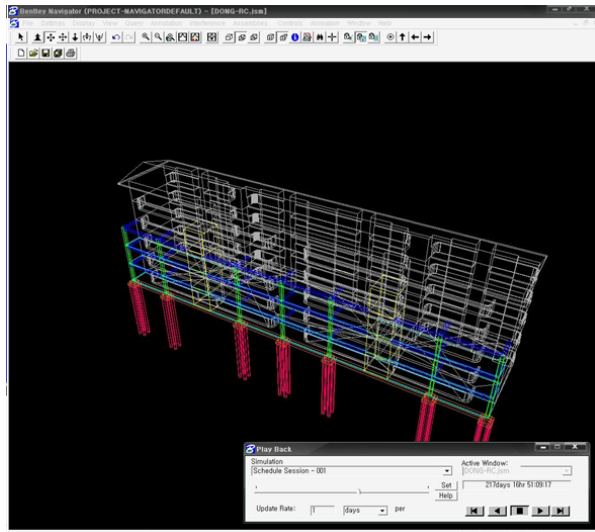


Figure 9. 5D-CAD Modeling (in progress)

## 7. DISCUSSIONS

Although the 5D CAD modeling has many benefits in project planning and construction, there are still many areas for further development. By introducing the 5D CAD modeling to the aged-housing revamp project, the following shortcomings have been identified.

- The software may be unnecessary during basic design development. So, the different versions of the software program may be helpful when developed in consideration of the level of detail on the information.
- The 5D CAD modeling work is time-consuming that the standardized databases or models are required to be pre-developed and embedded in the system.
- A number of project stakeholders and participants are involved during the modeling phase. It may be useful to enable the uses to track record of the decision- making history linked to significant building objects.
- Not all the electronic files are exchangeable to the CAD system. The interoperability issue still required to be overcome.

## 8. CONCLUSIONS

The revamp project for aged-housing residential buildings has been a growing market in the Korean building industry. The industry-proven 5D CAD modeling has got benefited in many ways from the project management's perspective. Since there is no standardized 5D CAD modeling work process, this study, although it is premature, provided a step-by-step approach in application of the system. The findings from this study are summarized as follows.

- 5D-CAD modeling is no more optional strategy in maximizing the project value.
- The error-free construction planning is much more essential in revamp projects.
- Sharing the real-time project information can overcome communication barriers.
- Collaborative works are definitely can benefit from 5D-CAD modeling
- Full scale usage of 5D-CAD modeling can be achieved by partnering contract
- Information-driven construction projects should get much benefited from 5D-CAD.
- The project type, including revamp projects, has to be considered in developing the diverse versions of the 5D CAD system.

- Developing 5D-CAD software companies should take the “maintenance and revamp issues” into consideration. If so, the software can be much powerful.

#### **ACKNOWLEDGEMENT**

This study is part of a research project (Grant no. C105A1050001-05A0505-00110), sponsored by Korea Institute of Construction & Transportation Technology Evaluation and Planning (KICTTEP). The financial support is gratefully acknowledged.

#### **REFERENCES**

- Chen, P., Cui, L., Wan, C., Yang, Q, Ting, S.K., and Tiong, R.L. (2004). “*Implementation of IFC-based web server for collaborative building design between architects and structural engineers,*” Automation in Construction 14, 115-128.
- Gallelo, D. (2005). Virtual Construction Benefits, White papers, Vico software, Boulder, Colo.
- Koo, B., and Fischer, M. (2000). “*Feasibility Study of 4D CAD in Commercial Construction,*” Journal of Const. and Engr. 126(4), 251-260.
- Pro IT News (2003). Product Model Data in the Construction process, Confederation of Finnish Construction Industries, Finland.
- Sun, M and Howard, R. (2004). Understanding IT in Construction, Spon Press, London.
- Waly, A. F. and Thabet, W. Y. (2002). “*A Virtual Construction Environment for preconstruction planning,*” Automation in Construction 12, 139-154.