Chapter 1
Introduction

1.1 Background

1.1.1 Nature of Construction Operations

Construction is an important industry for developing countries. There are a lot of resources (material, man, machine or equipment, and money) used in construction projects. Thus, effectiveness of construction operations is essential. A project manager needs to meet the goal of completing construction projects within suitable time and cost. The nature of construction operations involves very complex processes, unlike processes in factories or other industries. These construction operations usually involve making decisions about, for example, selecting construction methods, choosing suitable machines and equipment, and determining crew sizes.

1.1.2 Decision-Making Tools for Solving Problems in Construction

There are several techniques or tools used to facilitate the complex construction operations. First, past construction experience is employed for solving complex construction operations but people who have such experience may not be always available. The second method is to experiment with the real situation, but this is expensive and sometimes impossible to perform. Mathematical modeling is the third method, sometimes requires a high degree of mathematical ability. And, sometimes the construction processes are too complex to solve. The forth method construction project planners may employ is using the scaled physical models and 2D drawings to experiment, analyze and manage the construction site. The operations of equipment and the conflict of working spaces are analyzed by construction managers to determine the suitable space management and method of work. This method is good for communication among the parties as to let them know their responsibilities and schedules. However, if there are many resources involved and the operations consist of several steps at different times, this approach is not practical, especially, when what-if analysis is required to repeat some certain steps over a period of time.

The simulation technique becomes a tool for solving problems of construction operations for over three decades. It is very convenient because it is realistic, inexpensive, fast and also flexible (Martinez and Ioannou, 1999). A simulation model is divided into continuous and discrete simulation models (Law and Kelton, 2000). Construction operations have been modeled for many years using discrete event simulation.

1.2 Statements of Problems

1.2.1 Fragmentation of Decision-Making and Planning

In traditional construction planning, construction planners usually make decisions involving several sequences of thinking such as construction methods, time or duration, and cost. However, usually they plan each part separately. For example, construction methods are assigned by expert planners while construction time or durations are calculated by scheduling tools and construction cost is estimated by cost estimators.

1.2.2 Limitations of Human Thinking

In general, most human managers have limitation in their thinking process. Decisions may be possibly made when they think in two dimensions (2D). Without any computation tool, their decision-making is ineffective when they make decision in several dimensions at the same time, e.g., x, y, z dimension, time and cost.

1.2.3 Limitations of Existing Simulation Modeling

Simulation is the process of building a mathematical or logical model of a system or a decision problem, and experimenting with the model to obtain insight into the system's behavior to assist in solving the decision problems. Simulation allows planners or analysts to experiment with and evaluate different scenarios during the planning phase. However, simulation has not been used to its maximum potential in planning construction operations (Huang and Halpin, 1994). Construction planners and analysts, who have more experience in actual construction operations, are reluctant in their decisions making by using the statistical text and graphical chart output which is provided by most simulation systems (Martinez, 1996). These is largely due to the fact that simulation tools provide the user with a large amount of numerical and statistical data but are not designed to illustrate the modeled operations graphically. The potential construction planners and analysts, who are typically well versed with the actual construction operations, thus perceive the use of simulation as being a black box not worthy of trust.

Simulation modeling can substantially help in designing complex construction operations and making optimal decisions where traditional methods prove ineffective or are unfeasible. However, there has been limited use of simulation in planning construction operations due to the unavailability of appropriate support tools that can provide users with a more realistic and comprehensible feedback from simulation analysis.

1.3 Motivation of Research

1.3.1 Needs of Integrated Decision-Making System

Due to fragmentation of decision-making tools (e.g., construction methods or processes are assigned by expert planners who have a lot of construction experiences while construction time or durations are calculated by scheduling tools, and construction cost is determined by cost estimators), motivation of this research is to propose an integrated system, which is able to enhance effective of decision-making by integrating construction processes, time, and cost.

1.3.2 Benefits of Virtual Reality for Simulation of Construction Operation

The capability to pictorially visualize the planned construction operations in 3D can greatly facilitate the usability of construction process simulation as an operation management tool in the construction industry. 3D visualization of the planned construction operations will provide easier accessibility for the planners by graphically conveying the physical configuration of system of interest in a very realistic but virtual format. This will allow users to easily and clearly comprehend the dynamic and interrelated behavior of the system model after each simulation run. 3D visualization will thus establish the credibility of the analyses by facilitating the validation and verification of complex simulation models. Besides, 3D visualizing of simulated construction operations can be of substantial help in describing the intricacies of simulation models and in obtaining valuable insight into the subtleties of construction operations that are otherwise non-quantifiable and presentable. (Kamat and Martinez, 2001).

Kamat and Martinez (2001) also concluded that planning, scheduling, and controlling complex construction projects could benefit greatly by integrating traditional project management technique with construction operations simulation and visualization. 3D visualization of the planned and simulated construction operation can greatly enhance the process of constructing facilities as follows:

1) Visualization of future construction operation allows decision-makers to make prudent decisions without relying on their intuition, instincts, and opinions.

2) Visualization facilitates greater awareness and understanding about the project among the management and the site personnel by providing them with virtual experience of how and what should be constructed.

3) Improved and easier detection of errors in scheduling, flaws in design, and constructability problems are facilitated before the actual commencement of the construction operations.

4) Construction personnel, management and workers can comprehend the construction process better allowing them to visualize precisely how activities relate

to one another, thus reducing conflicting interpretations and communication problems.

5) Organizing the resources for maximum productivity can better plan sequencing of interrelated activities in an operation.

6) Problems with equipment positioning and manpower congestion in certain areas can be visualized prior to the actual operation, thus preventing accident and safety problems such as collision between two machines and losses in productivity.

7) Visualization of construction operations can serve as a tool in the evaluation of construction claims by providing an improved method for documenting construction activities.

8) If necessary, quick adjustments and revisions, to the construction schedule are possible by allowing the project management personnel to precisely determine the state of the project by visualizing and comparing the planned and actual construction progress.

9) Construction operation designers and planners can take full advantage of advanced process simulation capabilities by first simulating and then visualizing numerous possible "what if" scenarios, thus eliminating costly and risky trial and error techniques.

10) Construction activities can easily be viewed on the computer screen using 3D CAD models, thus eliminating the cumbersome and costly physical models that might be needed to reconstruct certain scenarios.

11) 3D visualization can be used very effectively for educational training in construction process design and execution.

1.4 Research Objectives

The objective of this research is to **propose the new innovation of decision-making system for construction planning**. This system is the integration of construction process in 3D, time, and construction process cost. This system was developed by using Virtual Reality (VR) technology to enhance effective decision-making. Accordingly, sub-objectives of this dissertation are:

1) To develop a system which integrates 3D process simulation time and cost. It will be useful to display construction methods, construction sequences and resources used and assist project planners to prepare construction project planning.

2) To investigate the advantages of simulation modeling that are able to provide suitable construction duration and productivity, and cost of construction processes via 3D visualization software or virtual reality language.

3) To obtain a tool that can enhance effective decision-making for project planers and managers.

4) To obtain a tool that can enhance effective communication among project planning team and construction operators.

1.5 Research Methodology

The research methodology employed in this research will be as the steps below:

1) Review previous literature and research studies, which involve integrated system in construction, computer simulation, and simulation modeling by focusing on state of the art of such technology in construction. And also recommend the advantages and limitations of the technology.

2) Review previous literature and research studies in 3-dimension CAD animation and virtual reality by focusing on state of the art of such in construction. And recommend the advantages and limitations of these approaches.

3) Survey factory-construction sites to collect data and study construction operation processes including construction methods and sequences, resources used for construction, productivities, movement of construction-machines for their operations, operation time in each construction sequence, construction process cost, and also constraints involved.

4) Study and select the suitable methodology to integrate simulation techniques and virtual reality technology to visualize construction processes and resources used and also determine operation time, productivity, and construction cost.

5) Develop a prototype of an integrated system designed for simulating and visualizing the real construction to enhance effective decision-making for factory construction, and describe the methodologies of this system development.

6) Create a system database, which will be linked to the integrated system. The system database is created from computer database language by using data from construction site survey and field collection.

7) Verify and validate the system by comparing the system output and actual time and cost from real construction data and identify the system limitations.

8) Present results, conclusions, and future research.

1.6 Scope of Study

In general, factory construction involves large volumes of work because there are a lot of structure members to be fabricated in each activity such as, piling work, column installation and roof truss installation. Besides, factory construction activities are more complex than earthmoving activities. Consequently, it becomes an interesting construction operation that is worth enough to be simulated and concentrated its construction processes.

According to the focus on factory-construction operations, the scope of this research is concentrated in some activities of factory-building construction, which are listed below:

1) Piling work
2) Sub structure work
   2.1 Pile cutting work
   2.2 Footing work
   2.3 RC column work
3) Super structure work
   3.1 Steel column installation
   3.2 Roof-truss and bracing installation
   3.3 Purlin and roof-material installation
   3.4 RC slab work
4) Wall and siding installation

1.7 Research Contributions

1) The research outcome will propose the new innovation of decision-making system, which is able to deal with construction processes, resources used, time, and cost simultaneously.

2) The product of this research will be a prototype of an integrated system that is designed for the realistic visualization of factory construction. It will be a tool for assisting construction planners to make decisions about selecting suitable equipment set, operating logic, construction method, operation time, productivities, and construction process cost.