Chapter 3
Construction-Site Survey and System Development

3.1 Introduction

This chapter presents construction-site survey and system development approach. Before the integrated system is developed, existing construction-site management and planning are first explored. Next, examples of construction-site management are presented to see how the conventional practices are performed in Thailand. Factors that affect construction duration and cost are also described. Moreover, problems of factory-construction planning are explored. The system development is described as follows: 1) input data, 2) methodology of system development, and 3) system outputs.

3.2 Existing Construction-Site Management and Planning

3.2.1 Construction-Site Survey

In this research, factory-construction projects are used as construction cases for Integrated System development. Construction-site surveys were performed in order to explore the existing methods that are used to prepare and generate construction-site planning of factory-construction and explore problems that may occur during planning processes. The construction-site surveys consist of three procedures as follows: 1) site observations, 2) direct interviews, and 3) expert's questionnaires.

1) Site observations

The objective of these walk-in observations is to capture the overview of some factory-construction activities that involve construction-site management and planning in order to explore and identify details and processes of construction-site management. A total five of construction projects were observed.

2) Direct interviews

After details of construction management are explored and identified, these issues are used in direct interviews with expert managers who involve construction-site planning and management. These experts consist of: 1) project managers or construction-site managers; 2) project engineers, and/or 3) planning team.

In this survey, five expert managers were interviewed about details of construction-site planning and management.

3) Expert's questionnaires

The questionnaire consists of five main parts as follows: Part A, Part B, Part C, Part D, and Part E (See Appendix 6). The questions in Part A are used for pre-screening. Part B involves the use of planning tools and importance, and Part C that is used for weighing the degree of problems of construction planning. Part D involves factors that affect planning errors. Part E is used to screen the factors that contribute to mistakes by the construction-site management. The questionnaires were sent to fifteen project managers who have extensive experience in three large construction companies.

3.2.2 Construction-Site Management Team

According to the direct interviews and responses from questionnaire (Part A), in construction-site management and planning, the construction management team usually consists of a project managers or project engineers and also site-engineers, sub-contractors. Sometimes, the construction management team includes material suppliers.

3.2.3 Planning Document, Tools and Techniques

According to direct interview and responses from questionnaire (Part B), the above planning team usually applies Critical Path Method (CPM) as a planning technique and usually uses drawings, Bill of Quantity (BOQ) and contract document as information in construction-site planning. However, other construction techniques such as PERT and simulation technique are never used. Bar chart is usually used to present the results of construction planning and to communicate among construction management teams. A network diagram is sometime used to present and communicate but simulation tools are never used for planning. Computer software such as spreadsheet applications are usually used to generate the construction planning, but other software are only occasionally used for planning.

3.2.4 Data and Information Requirement

According to questionnaire (Part B), the planning team usually requires productivity data of craftsmen, labor and construction machines. Other data and information used for planning are unit price of labor, machine rental price and sub-contractor cost. Productivity data usually comes from planners' experience and is sometime collected from historical records.

3.2.5 Problems in Planning

According to the responses from questionnaires (Part C), the following problems occur during the construction planning process:

1) Lack of personnel who have adequate experience
2) Lack of a good planning team
3) Lack of knowledge of planning technique such as CPM, PERT or Simulation techniques
4) Lack of effective planning tools
5) Lack of planning data such as labor productivity, construction machine productivity, sub-contractor productivity, labor cost, machine rental price, sub-contractor costs.

3.3 Examples of Existing Planning and Management

The following examples illustrate existing construction-site planning and management. These examples were collected from direct interviews with construction project planners.

3.3.1 Construction-Site Layout

Tools: 2D drawing plan (See Figure 3.1) and Site planning team (project manager, project engineers, site engineers, foreman, sub-contractors, material suppliers)

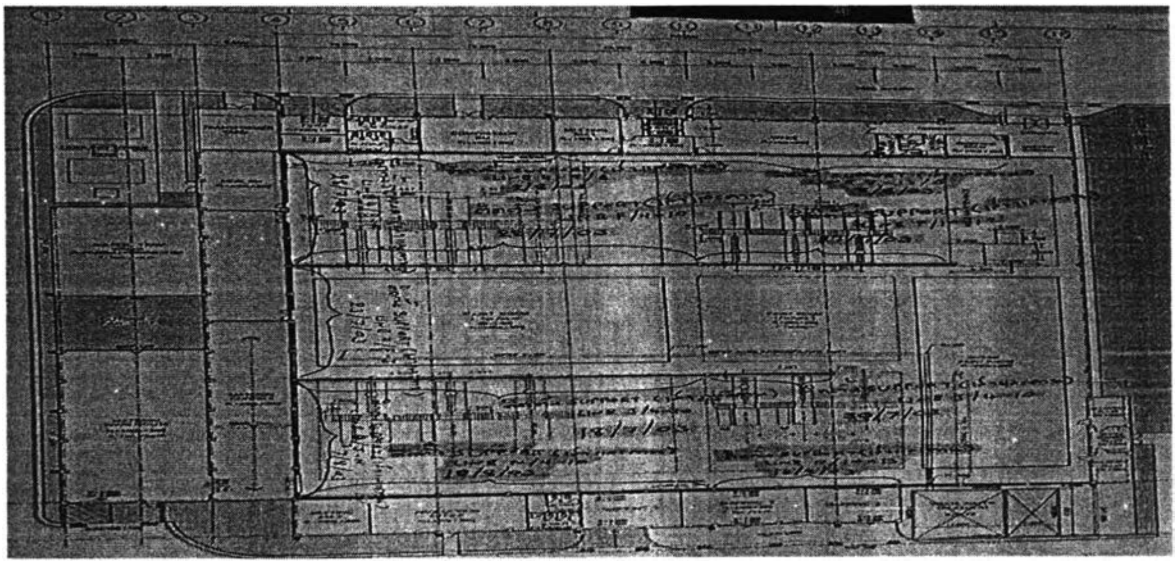

Figure 3.1: A 2D drawing plan used for construction-site layout

Criteria

The following criteria are criteria that are used for construction-site layout.

- Construction-site area and its boundaries
- Building areas and locations
- Size and dimensions of facilities such as site office, labor camp, entry & exit door (See Figure 3.2 (a))

- Space area for material storage and prefabricated area (See Figure 3.2 (b))
- Construction-machine paths (See Figure 3.2 (c))

Figure 3.2 (a): Facilities (site office, labor camp, site entrance)

Figure 3.2 (b): Areas for material storage and prefabrication

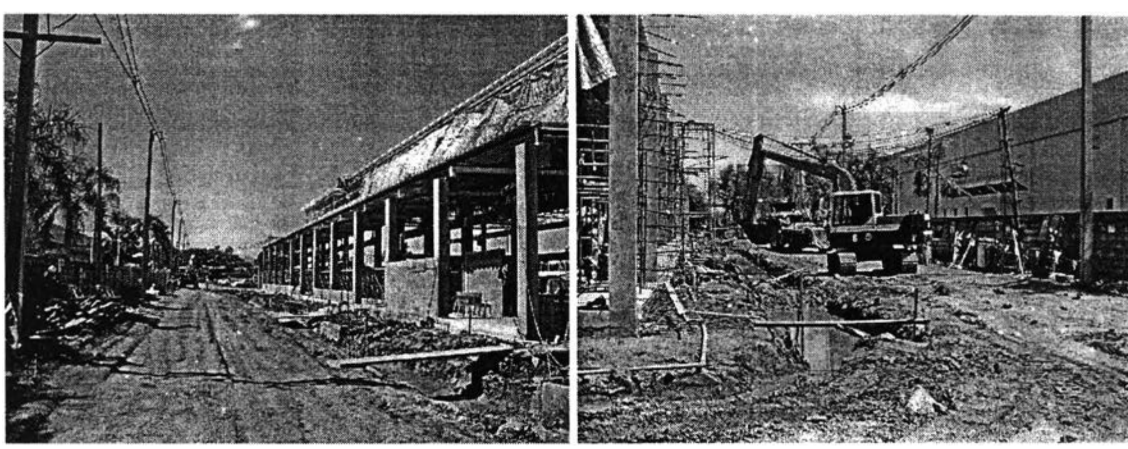

Figure 3.2 (c): Construction-machine paths

Figure 3.2: Examples of constraints for construction-site layout

<u>Methods</u>

1) Identify construction site boundaries and areas by using a 2D drawing plane.
2) Identify the position and area of construction building.
3) Locate facilities into the site plan using priority management as follows.

Entry and Exit door → Site office → Material storage → Material-Transportation path → Prefabricated area → Labor camps

4) If there are adequate space-areas for locating all facilities, the project planners will locate by using following criteria:
   - *Shortest transportation paths*
   - *Safety conditions*
   - *Ability to comfortably operate construction work*
5) If there are not adequate space-areas for locating all facilities, the project planners will locate the lower priority facilities into the outside of construction-site area as follows:
   - *Labor camp*
   - *Prefabricated area*

Problems

There are construction-work extensions that are requested by the owner. Those works need some space areas for construction. Thus, the positions of some facilities must be changed, which affect the existing layout.

3.3.2 Space Conflict and Safely Analysis

Space conflicts and constraints

During construction of buildings, several materials, labors, equipment including permanent structures and temporary facilities require their space within construction-site. But under the limitations of space and boundaries of construction-site, project managers should manage the available space in order to minimize space conflicts, since space conflicts and constraints may affect productivity, critical path of construction work and project duration delays. Conflicts of space often occur when some construction work obstruct the following construction operation. Those obstacles and conflicts often occur, due to the mistakes in the construction sequence assignment and lack of appropriate methodology and procedures to organize the overall space.

From construction-site survey of factory-building construction, some examples of space conflicts and obstacles are illustrated as follows:

1) Pile transportation obstructs pile-driving machine operation (See Figure 3.3).

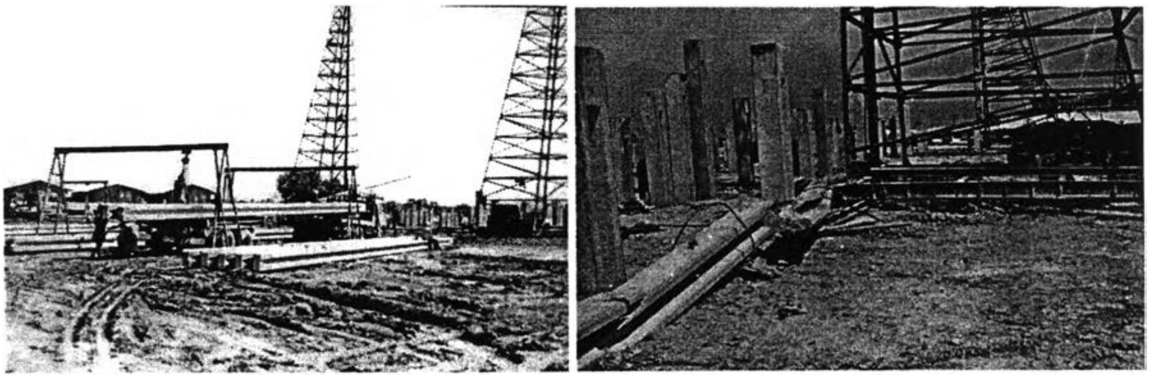

Figure 3.3: Activity of pile transportation obstructs pile-driving machine operation

2) Driven piles obstruct earth excavation by excavator (See Figure 3.4).
3) There is not enough space for pile driving machine paths (See Figure 3.5).
4) Steel fixing of first floor slab obstruct concrete placing and roof-truss installation (See Figure 3.6).

Figure 3.4: Driven piles obstruct operation of an excavator.

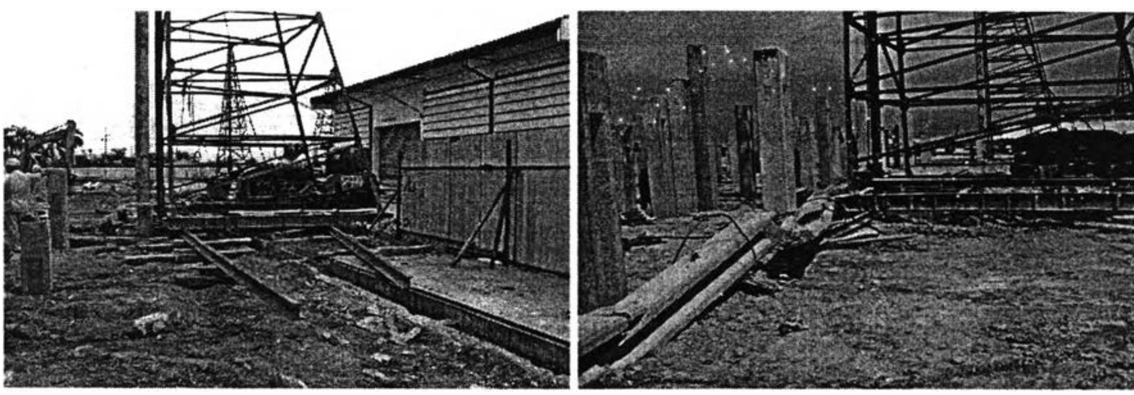

Figure 3.5: Inadequate space for pile driving machine paths.

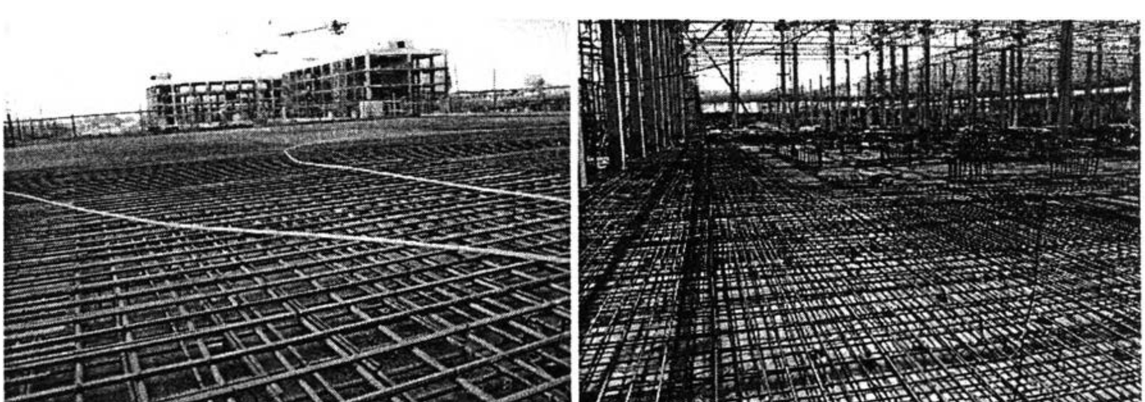

Figure 3.6: Steel fixing of slab obstructs concrete placing and roof-truss installation.

<u>Safely analysis</u>

During construction, safety-conditions are considered by project engineers. If the factory building consists of more than 2 stories, safety problems will occur since planners do not prudently look at vertical direction. They cannot look at all dimensions in the same time when the planners used 2D drawing as a tool for planning.

3.3.3 Construction Method Assignment

According to construction-site surveys and direct interviews, a construction method refers to steps and sequences of construction operation, construction techniques and resource assignment (labor gang and construction machine set).

The construction management team usually brainstorms to select and assign an appropriate construction method to each construction activity by using their experience. However, construction methods are sometimes assigned by using formal construction method statements that are generated and prepared in text and flowchart form. But those method statement forms are sometimes difficult to understand, and some steps and sequences in those method statements are often remised or neglected. Moreover, sometimes, planning problems occur during construction method assignment due to the construction planners' lack of experience. The following examples are construction method assignments for factory-building construction.

In Figure 3.7, one mobile crane and bucket is used as equipment to place concrete into RC column of the second floor. However, construction planners use their experience to assign a concrete pump for placing concrete to second floor slab instead of using a mobile crane and bucket since from their experiences when a large quantity of concrete must be placed, a concrete pump becomes more effective machine for placing a lot of concrete at high levels of building structure than a mobile crane and bucket (see Figure 3.8).

The construction planners assign one mobile to install the roof structure of the first floor of the factory building. This mobile crane is assigned to be able to stand inside the building and move through the building to install one by one of the roof-trusses until the installation is complete. The Figure 3.9 shows the path of a mobile crane used for roof-truss installation inside a factory building.

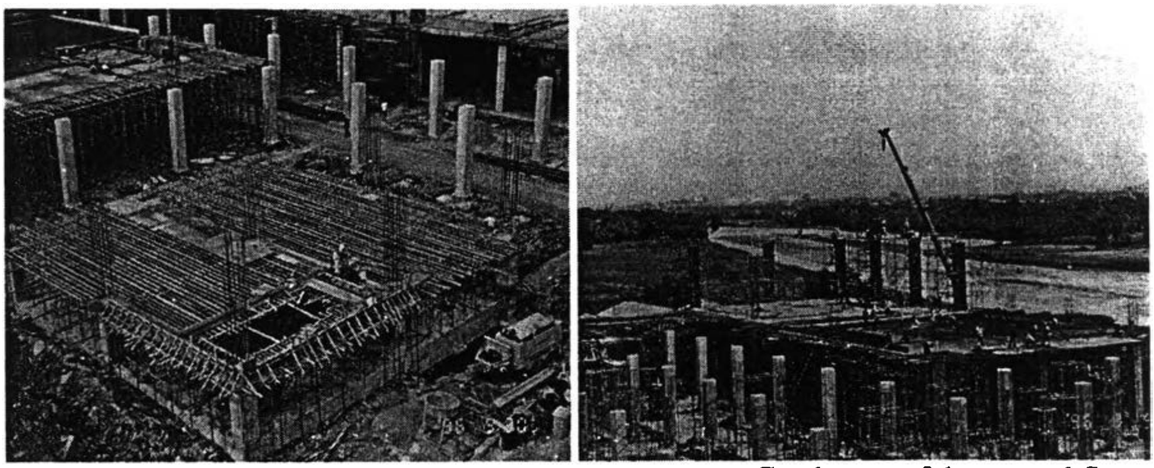

Figure 3.7: A mobile crane is used to place concrete to RC columns of the second floor.

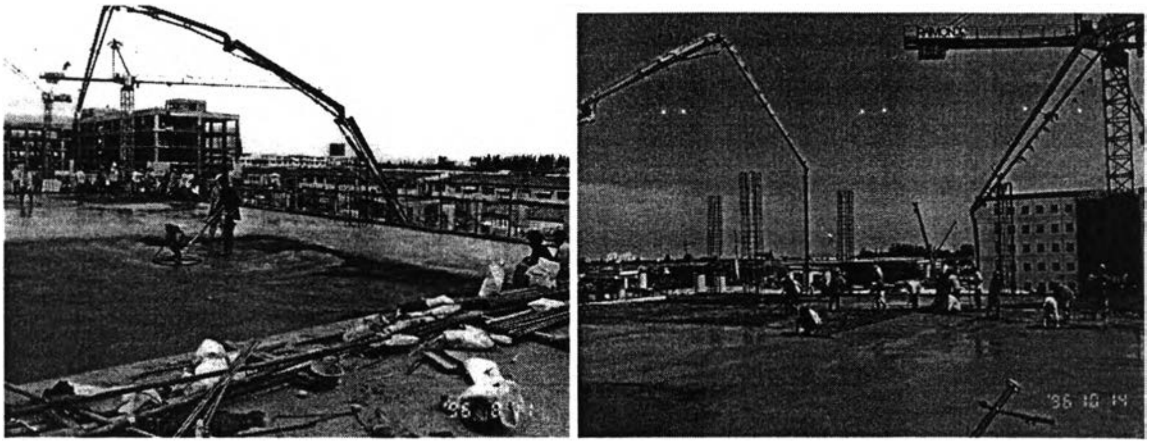

Figure 3.8: A concrete pump is an effective machine for concrete placing on second floor.

In order to install the roof structures of the second floor, the mobile crane cannot be assigned to stand inside the building. Therefore, the mobile crane is assigned to stand outside of the building instead of inside the building as shown in Figure 3.10.

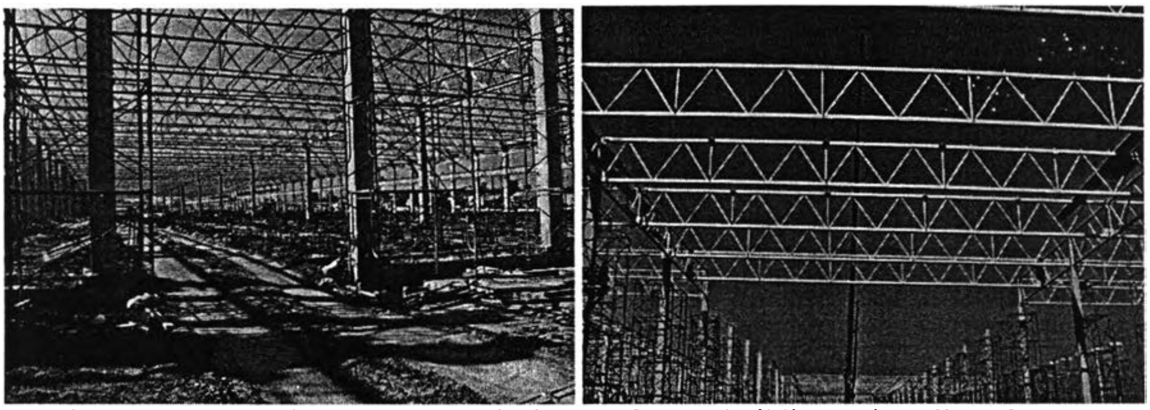

Figure 3.9: A mobile crane stands inside the factory building to install roof-trusses.

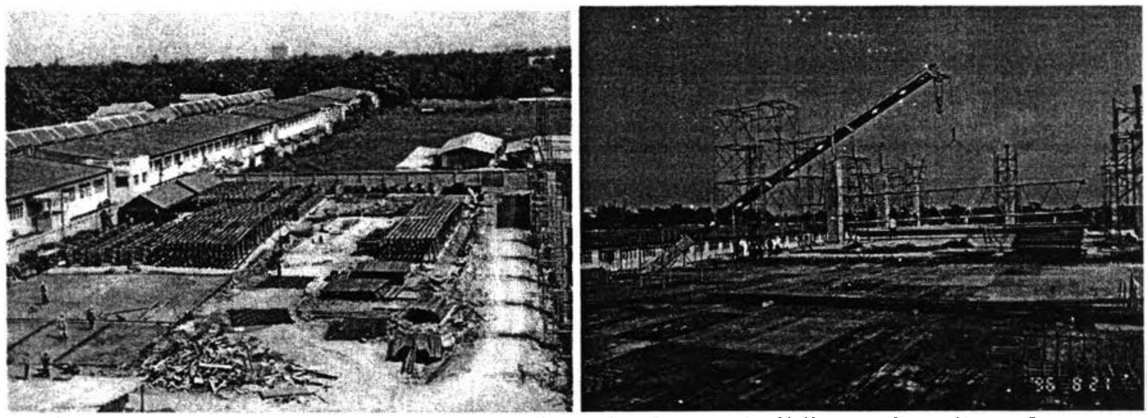

Figure 3.10: A mobile crane stands besides the factory building to install roof-trusses.

3.3.4 Construction Time and Cost Analysis

<u>Construction time analysis</u>

The duration of each construction activity should be analyzed and forecasted because it is necessary for project managers to manage all construction activities completely within the constraints of construction project duration and cost specified in the contract. The duration of each construction activity is used to determine type and quantity of construction resources such as labors and construction machine. According to direct interview with construction project managers, the duration of construction activities are analyzed and forecasted as follows:

<u>Tools</u>:

1) 2D drawing

2) Bill of Quantity (BOQ)

3) Master Scheduling

4) Productivity Rate (field record)

4.1 Manpower

4.2 Machines

<u>Planners Team</u>

1) Project manager

2) Sub-contractors

<u>Method:</u>

1) Breakdown construction activities follow master scheduling.
2) Define total quantity of each construction activity based on BOQ.
3) Determine quantity of manpower and machine used by:

$$\text{Duration of construction activity} = \left(\frac{\text{Total quantity of work}}{\text{Productivity}} \right)$$

However, the duration of construction activity is controlled by duration of activities in the master schedule.

In order to prevent unseen events that can affect the duration of construction activity, the productivity of the manpower and machines that are used to calculate the duration in the above equation should be discounted from the average productivity that is recorded from the field. The discount rate of this productivity depends on the experience of the planners. The average productivities are averaged from productivity data recorded from the field or construction site.

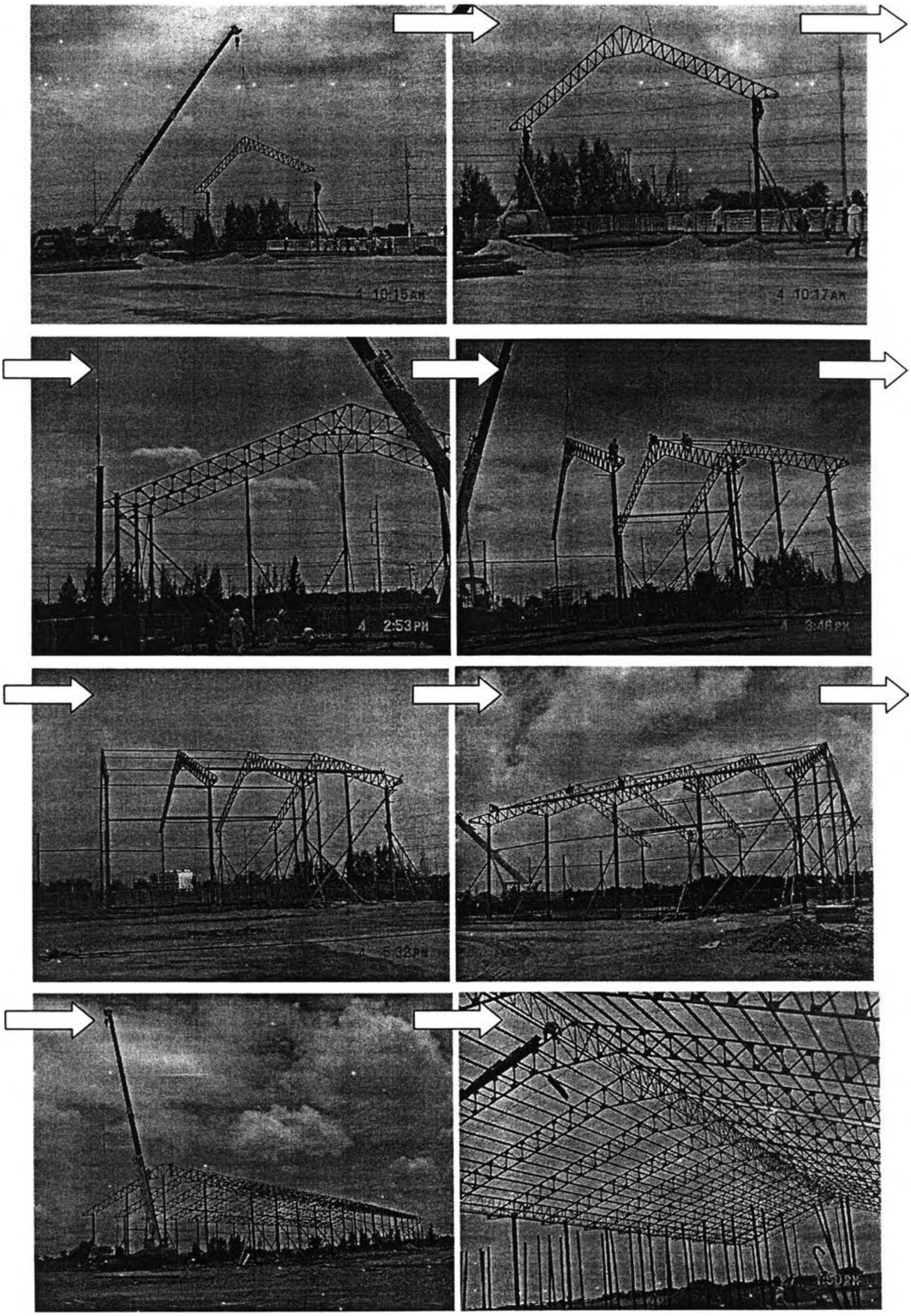

Figure 3.11: Roof-truss installation recorded at different times in order to record productivity of mobile crane and steel workers.

The following example is the field record of productivity of mobile cranes and steel workers that are used to install steel-column and roof-truss. These productivities are directly recorded from factory-construction sites.

In this activity, one mobile crane and three steel workers are used to install thirty steel columns and sixteen roof-trusses. The construction methods of this installation are assigned as following steps: (See Figure 3.11).

1) Steel-columns and roof-trusses are moved from prefabricated area to installation positions.
2) First and second column in the first line are lifted for installation by mobile crane and braced by steel workers, respectively.
3) First roof-truss is lifted and installed by a mobile crane and fixed by steel workers
4) Next the steel-columns and roof-trusses in the next line are continuously installed until all columns and roof-trusses are completely installed.

The time for the installation of each steel column and roof-truss is recorded as soon as that steel-column or roof-truss is completely installed as shown in Table 3.1.

Table 3.1: Examples of field data record of steel-column and roof-truss installation

Line No.	Col. Line A	Installation Time	Col. Line B	Installation Time	Truss T1	Installation Time	Total Time
1	C_{1A}	28	C_{1B}	28	Line1	45	45
2	C_{2A}	34	C_{2B}	62	Line2	34	79
3	C_{3A}	38	C_{3B}	100	Line3	56	135
4	C_{4A}	40	C_{4B}	140	Line4	50	185
5	C_{5A}	35	C_{5B}	175	Line5	67	252
6	C_{6A}	35	C_{6B}	110	Line6	40	290
7	C_{7A}	36	C_{7B}	146	Line7	35	325
8	C_{8A}	30	C_{8B}	176	Line8	30	355
9	C_{9A}	34	C_{9B}	210	Line9	28	383
10	C_{10A}	28	C_{10B}	238	Line10	34	417
11	C_{11A}	34	C_{11B}	272	Line11	38	455
12	C_{12A}	38	C_{12B}	310	Line12	40	495
13	C_{13A}	30	C_{13B}	340	Line13	35	530
14	C_{14A}	28	C_{14B}	368	Line14	36	566
15	C_{15A}	34	C_{15B}	402	Line15	30	596
16	C_{16A}	38	C_{16B}	440	Line16	34	603
	Average		Average		Average		

** Installed by using 1 mobile crane and 3 steel workers.

Cost Analysis

The project planners analyze construction cost by using data from the Bill Of Quantity (BOQ), such as quantity of work, unit price, and operation cost. Construction cost is controlled by the budget in the BOQ. Construction planners also employ construction methods and time to determine construction cost. The different construction methods can vary construction time and the varied construction time affect construction cost.

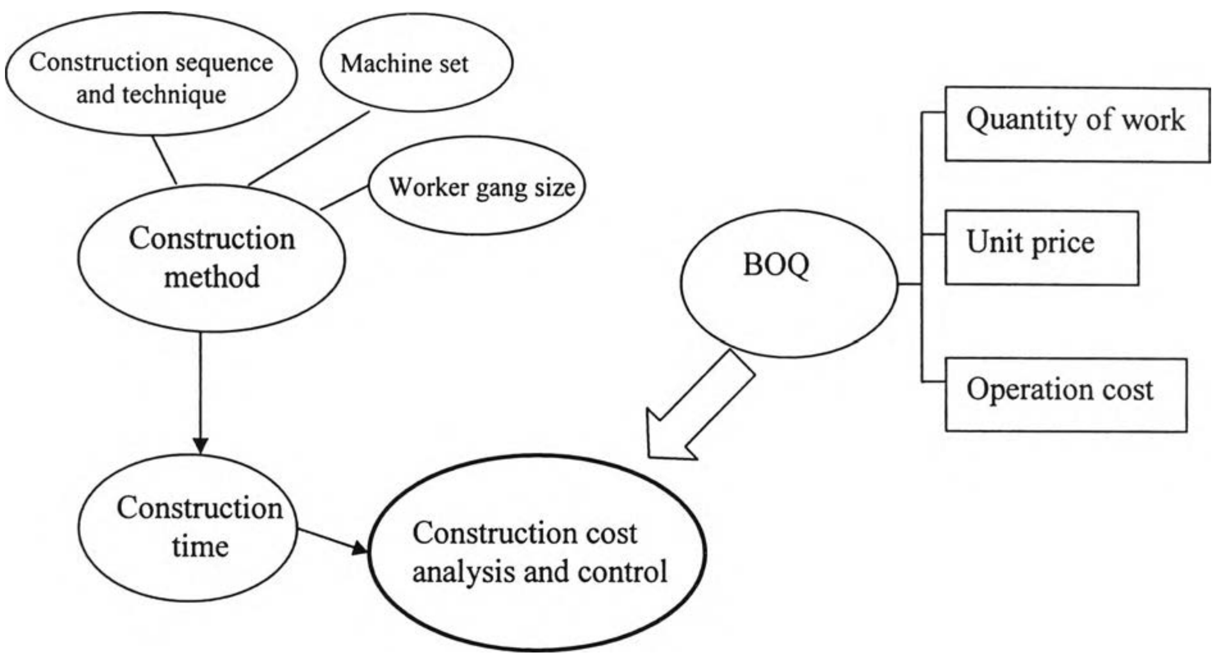

Figure 3.12: Construction cost analysis and control

3.4 Factors That Affect Construction Processes, Time, and Cost

According to direct interviews and questionnaires, the following factors affect construction processes, time and cost:

1. Labor Productivity lost
2. Material supplying delay
3. Machine downtime
4. Rainfall

3.5 Problems of Construction Planning

According to direct interviews and questionnaires, the problems usually occur during planning operation such as:

1. Not enough experience
2. Lack of data
3. Limit of ability to decision making in all dimensions

During the planning operation, construction planners make decisions about construction methods, space-conflicts, safety, time and cost. However, they cannot make decisions about all dimensions due to the limitations of the thinking ability of humans. The thinking ability of a construction planner will decrease when he must make decisions involving in more than one planning criteria as shown in Figure 3.13.

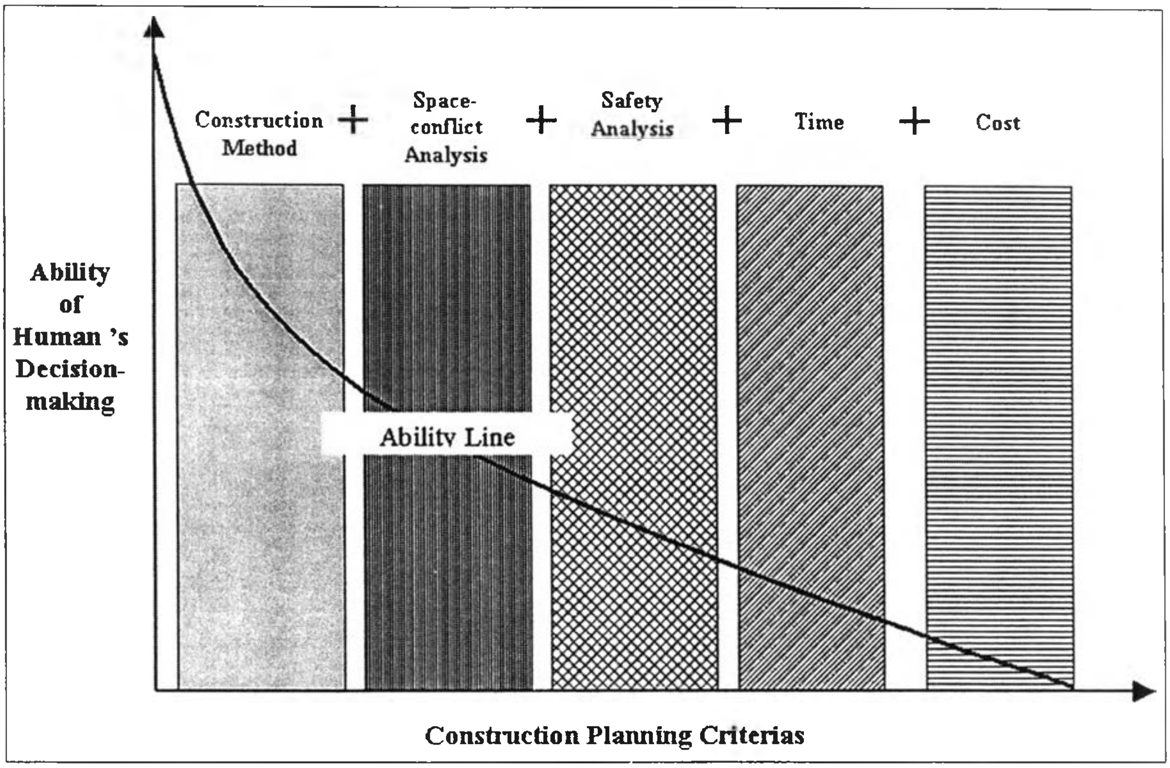

Figure 3.13: Ability of human's decision making under many planning criteria

3.6 Summary of Construction-Site Survey

From the construction-site surveys by site investigation, direct interviews, and expert's questionnaires, it can be summarized that construction planners usually prepare their construction plan by using drawing and their experience. The tools used in construction planning are included 2D drawings, BOQ, and the construction contracts and sometimes, planning software. The activities involved in construction-site planning usually consist of construction-site layout, space conflict and safely analysis, and construction activity time and cost analysis. Problems that commonly occur in construction planning include a lack of planner's experience, lack of data, and the limitation of ability to make decisions in all dimensions. In order to enhance the effectiveness of construction-site planning and the decision-making of construction planners, an effective system will be developed.

3.7 Integrated System Development Approach

In order to enhance decision-making and reduce problems in construction planning operations, a new construction-planning approach should be developed by using new technology. In this research, Virtual Reality (VR) technology is an appropriate technology to develop the system due to its capability to visualize the virtual construction processes.

3.7.1 System Descriptions

The general system components should consist of three parts: 1) input component; 2) system processing component and 3) output component. Similar to the general system, the Integrated System in this research also consists of three components.

3.7.2 System Design Approach

The input component of the Integrated System can be classified into three phases such as: 1) 3D Dynamic models generated by CAD (described in chapter 4), 2) construction database (described in chapter 5); and 3) interactive floater or direct input (See appendix 16).

The processing component consists of system process operation such as variable defining, mathematical factions, controlling system flow (If-cause operation, loop-operation), and so on. This processing component will be generated and programmed by using MAX Script language (described in chapter 5).

The outputs of this integrated system should illustrate the building-construction process and methods, time and cost. The building-construction process is illustrated by using virtual scene in 3DS MAX. The floating windows created by MAX scripts are used to illustrate simulation time. Moreover, the construction costs for different construction methods and resources are summarized by using spreadsheet.

3.7.3 System Input

The system inputs are assigned as below:

<u>CAD data and 3D models</u>

The AutoCAD version 2000, which is a well-known CAD software package for creating construction drawing nowadays, was selected for preparing system input. The components of data input are prepared by using AutoCAD as below:

- Grid lines
- Dimensions

- 3D Structure members of factory
- Colors
- 3D Equipment models

System Database

System development requires the following information, which is used to calculate output data (time and cost):

- Equipment productivity
- Labor productivity
- Equipment cost
- Labor cost

Construction process and sequence

Construction processes and sequences are simulated or animated by using 3D software as follows:

- 3D MAX Studio (distributed by AutoDesk Inc.)
- MAXscrip (Scripting language for 3D Studio MAX) (See chapter 10)

3.7.4 System Development Processes

The system development process consists of:

1) Dividing the construction process

In this research, the researcher has divided the factory construction process into sub-activities as follows:

- Piling work
- Pile cutting work
- Footing construction
- Concrete column construction
- Steel column installation
- Roof-truss installation
- Purlin installation
- Roof material installation
- Wall and siding installation

2) Developing each sub-activities

The method of development for each sub-activity is focused on selecting appropriate construction sequences, construction-machine sets, machine paths, and operation cost. All of these activities will be displayed in the 3D environment.

In this step, "What if " analysis, optimization methods, statistics and probability are applied to develop and analyze each sub-activity.

3) Integrating sub-activities

After each sub-activity is completed, it will be integrated and become a tool for enhancing effective decision making for factory construction.

The System development chart is presented in Figure 3.14.

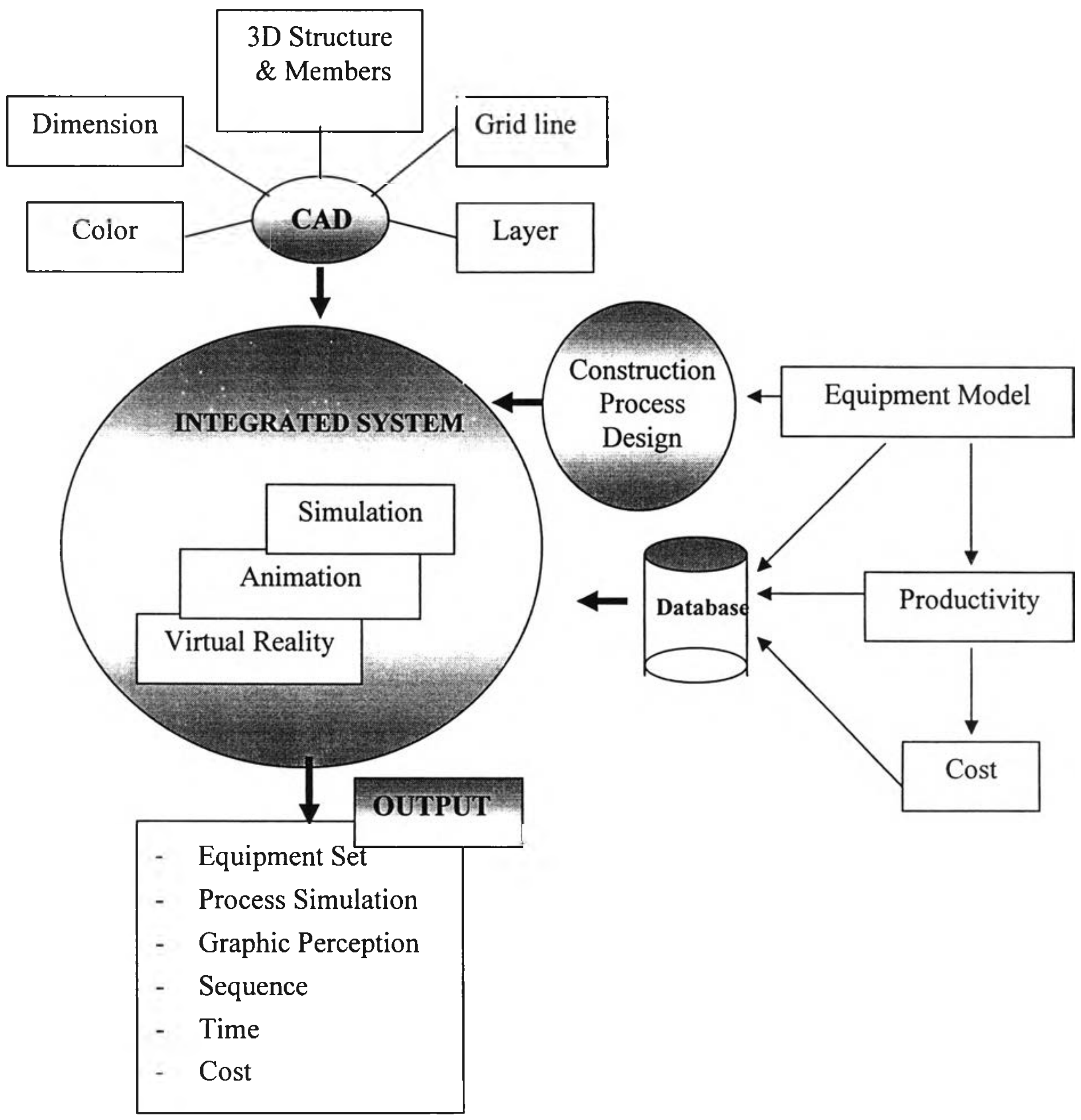

Figure 3.14: System development chart

3.7.5 System Output

The system will construct outputs as follows:

- Equipment Set
- Process Simulation
- Graphic Perception
- Construction sequence
- Construction time
- Operation cost

3.8 Software Development Platforms and Tools

3.8.1 Operating system

The Microsoft Windows operation system was chosen to use as the development platform for this research. It was chosen because of its stability, portability and popularity.

3.8.2 The Visualization Software

AutoCAD Version 2000 and 3D Studio MAX Version 5.0 were chosen to use as tools in this research. This software is distributed by AutoDesk Inc.

3.8.3 Simulation Programming

MAX Script is the built-in script language for 3D Studio MAX. MAX Script provides 3DS MAX users with the ability to:

- script most aspects of the program's use, such as modeling, animation, materials, rendering, and so on.
- control the program interactively through the command-line Listener window.
- package scripts as a macro, and install these Macro Scripts as buttons in the 3DS MAX toolbars.
- extend or replace the user interface for objects, modifiers, material, texture, render effects, and atmospheric effects.
- build scripted plug-ins for custom mesh objects, modifiers, and render effects.
- build custom import/export tools using the built-in file I/O.
- write procedural controllers that can access the entire state of the scene.
- build batch-processing tools, such as batch-rendering scripts.
- set up live interfaces to external systems through OLE Automation.
- record actions in 3DS MAX as MAX Script commands.

- store in scene files the scripts to run for each of the notification events supported by 3D Studio MAX, such as pre- and post-scene file open, new, reset, scene file save, pre- and post-render, selection change, and so on.
(Source: MAX Script Reference)

3.8.4 Database Software

In this research, the software packages used to generate the database of Integrated System are: 1) Microsoft Access and 2) Microsoft Visual Basic.

3.9 Conclusion

In this chapter the construction-site survey is performed. Walkthroughs of construction sites, direct interviews, and experts' questionnaires were selected as approach in this survey. Construction planners or project managers usually prepare construction plans by using their experiences. Tools and documents employed in construction planning including 2D drawings, BOQ, construction contracts and sometimes planning software. The activities in construction-site planning usually consist of construction-site layout, space conflict and safely analysis, and construction activity time and cost analysis. The problems that usually occur in construction planning are inadequate planner's experience, lack of data, and limited ability to make decisions in all dimensions. In order to enhance the effectiveness of construction-site planning and decision-making of construction planners, an effective system will be developed.

In order to enhance decision-making in construction planning and reduce problems in planning operations, the new approach by using new technology has been proposed. In this research, Virtual Reality (VR) technology is an appropriate technology to develop the system due to its ability to visualize the virtual construction processes, time, and construction process costs.