Abstract

Conceptual Cost Estimating System Development for Public Housing Projects

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At the conceptual phase of a construction project, estimated construction cost is very important as it significantly influences the owner's decision-making. Accurate cost estimating; in the early stage of a public construction project; serves as a critical factor because initial decision-making affects the final cost of a construction projects.

However in cases of Korean public housing construction projects, excluding a few of the public institutions there is a problem in properly estimating construction cost due to the lack of a construction cost estimating system at the early stage. Moreover, most public institutions have a few engineers for reviewing the adequacy of estimated construction cost.

Thus this research developed a conceptual cost estimating system for

public housing projects using a case-based reasoning that proposed by Park et al (2010) with 66 cases of Korean public housing projects. Based on system experiment involving 19 officers (engineers) in public institutions and 9 cases of Korean public housing projects that are not included in the system database, the effectiveness of the system in terms of estimation accuracy and user-friendly was confirmed.

As a result, the developed system has an error range of -0.49% to 13.88% and mean of 4.61%. In addition, the developed system was evaluated that it could greatly improve current cost estimation tasks of public officers.

Consequently, the results of this research can be used a foundation for technological advance in estimating construction cost and improving accuracy and consistency of construction cost estimation.

Keywords: Cost Estimating System, Case-Based Reasoning, Public housing, Conceptual Design Phase

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Chapter 1. Introduction

1.1 Research Background and Objectives

In the early stages of a construction project, the estimated construction cost effects chiefly owner’s decision-making and the cost serves as a crucial element to success of a construction project (Trost and Oberlender 2003; Lee et al. 2011). Because of this, even though the importance of the cost estimating is getting highlighted, especially in the case of public housing construction projects in Korea, there are difficulties in predicting the proper construction cost due to the insufficient information of a construction project and the uncertainty of main factors related to the construction cost.

Looking at the cost management practices of public construction projects in Korea, the cost estimating condition in the early stage of construction projects is very poor and weak because the relevant regulations and standards are concentrated on the detailed design phase. The core purpose of cost estimating in the initial stage is to provide an owner proper total cost of a construction project by taking into account a variety of cost variables and gradually confirm the total construction cost as the project progresses. However, when public institutions estimate construction cost of a new project, if they don't have historical cost data they have difficulties in estimating construction cost because they generally use cost data of previously conducted projects and estimator's experience.

In practice, Current cost estimation method they most use is a parametric cost estimating method (e.g. cost per square foot) which needs periodic

updates of new unit cost. Also, this method has limitations on explanatory and accuracy because it does not reflect the characteristics of each project such as number of households, gross floor area, number of floors, number of piloti with household scale, etc when estimating construction cost.

For these reasons, the needs for decision supporting tools is emerging which can resolve the problem of construction cost appropriateness by estimating reasonable construction cost from the conceptual phase and to support, when budgeting , the effective enforcement of State Funding and to save the budget.

Therefore, the main purpose of this research is to develop a conceptual cost estimating system using case-based reasoning (CBR) and validate the system.

1.2 Research Scope and Method

In the early stages of a construction project, the estimated construction cost affects chiefly owner's decision-making and the cost serves as a crucial element to success of a construction project (Trost and Oberlender 2003; Lee et al. 2011). Moreover, the more the project is advanced, the less the possibility of reducing the final cost because of the high costs of modification (Duverile and Catelain 1999). Therefore, this research focuses on the conceptual design phase. The objects of this research are public housing construction projects collected from Korean public institutions. This research regards officers (engineers) in public institutions as future system users. Accordingly, this research has the meaning of public characters in terms of

those aspects.

The procedures of this research are as follows:

(1) For preliminary research, current cost estimation methods using at the early stage of a construction project are reviewed.

(2) Based on literature reviews, Case-based Reasoning Method is introduced for adapting to this research.

(3) Database is structured by 66 public apartment cost data which are collected from public institutions. Also, the developed system is introduced with the development of the cost model based on the CBR method.

(4) The reliability, effectiveness of the developed system are validated by cost predict experiments and surveys (interviews) from officers in public institutions.

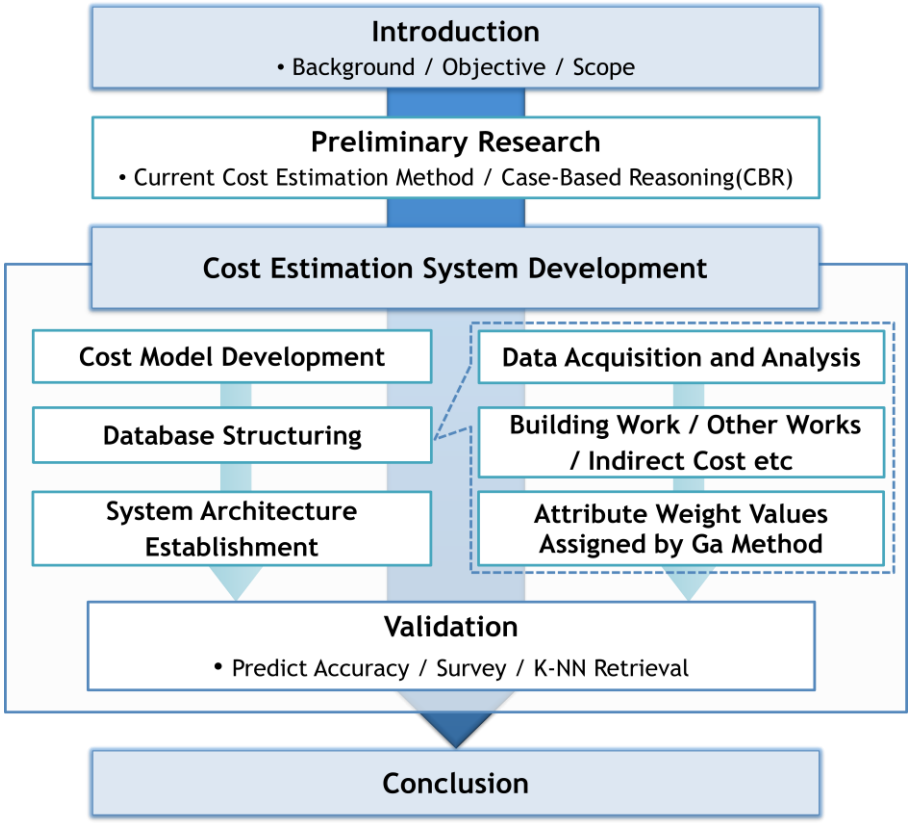


Figure 1-1 Research Method

Chapter 2. Preliminary Research

As mentioned in 1.2, this research aims to develop a conceptual cost estimating system for public housing projects. In this chapter, firstly, provides comprehensive review on current cost estimation methods in construction industry. Secondly, this chapter introduces case-based reasoning (CBR) as a cost estimation methodology. Finally, this chapter introduces Case-Based Reasoning Algorithm which is applied to this research.

2.1 Current Cost Estimating Methods

Traditionally, on initial stage, cost estimation in construction industry is based on estimator's abilities, his accumulated experience and performed through similarity analysis with historical construction project cases. As shown in table 2-1, parametric cost estimation method, which uses actual cost of historical construction projects, (e.g. cost per square foot) is the most representatively used for estimating construction cost in early stage(Kirkham, 2007). Cost estimation method using cost per square foot does not require detailed information of a construction project and is thus relatively less time-consuming method for estimating construction cost (AACE, 1999).

However, when estimating construction cost if the unit cost is applied incorrectly this method can occur considerable cost error because it does not sufficiently consider characteristics of a project. Also, it requires regular updates of cost per square foot and has a limitation that cannot be applied on a project which designed complexly.

Kim et al. (1990), Cho et al. (1998) suggested a cost model which can estimate construction costs using Regression Analysis (RA). Although this method can reduce cost predict errors of the cost model through an assumed statistical model, it has difficulties in flexibly responding to changes of time and also has a problem that there exists linear relation when has a very low correlation among variables.

Baik et al. (1997) proposed a cost model reflecting actual characteristics of a project can estimate construction cost using Monte-Carlo Simulation (MCS) which is probability simulation approach. This suggested method, though, has simple calculation algorithms compared to other mathematical cost models, it has difficulties in dealing with changes of the time and a problem related to reliability between variables is inherent.

To compensate limitations of these statistical cost models, Park et al. (2002) developed a cost model using Artificial Neural Network (ANN) and, Kim and Kang (2003) developed a cost model using Genetic Algorithm (GA). These methods have the advantage which analysis time is shorter than statistical cost models, however the models are a kind of black-box which has the lack of a description of the reasoning processes. Especially, the cost model using Artificial Neural Network (ANN) takes a lot of time determining parametric variables and an optimal neural network structure, also there are not direct approaches designing a neural network structure and establishing parametric variables (Hegazy and Moselhi, 1994).

Table 2-1 Conceptual Cost Estimating Methods

Division	Researcher (year)	Cost Estimation Method	Summary
Parametric Method	AACE(1999)	Cost Per Square Foot	·need for regular updates of cost per square foot ·difficulty of application in case of buildings which have complex design
	Kirkham (2007)		
Statistical Method	Kim et al. (1990)	Regression Analysis (RA)	·limitation on flexible responses to change of the time ·the problem that there exists linear relation when has a very low correlation among variables
	Cho et al. (1998)		
	Baik et al. (1997)	Monte-Carlo Simulation (MCS)	·a problem related to inherent reliability between variables
Artificial Intelligence Method	Park et al. (2002)	Artificial Neural Network (ANN)	·reasoning process of Neural Network is a Black Box ·there is not direct approach to design a Neural Network structure and establish parametric variables ·takes a lot of time in determining parametric variables and optimal Neural Network structure
	Kim and Kang (2003)	Genetic Algorithm (GA)	·reasoning process of Neural Network is a Black Box

2.2 Case-Based Reasoning (CBR)

2.2.1 Overview of CBR

Aamodt and Plaza (1994) define that CBR is to save the information and knowledge of past similar cases and to reuse the cases for solving a given problem. Also CBR is defined as one of the Artificial Intelligence methods which mimic the human way of thinking using the most similar past experience to solve current problems (Morcous et al. 2002).

CBR is a problem resolving approach that is basically different from other

major Artificial Intelligence (AI) approaches in many respects. CBR could be distinguished from two characteristics compared with other AI approaches. One is that CBR uses knowledge of similar past cases. The other one is that if a given problem is solved, at the same time, the problem is stored and can be employed to resolve future possible new problems.

For these reasons, CBR is being applied to diverse fields in construction industry such as Construction Litigation, Construction Fail Information Management, Construction Cost Estimation and Decision-Making for Bidding and so on (Table 2-2).

Table 2-2 Researches using CBR in Construction Industry

Construction Field	Researcher (year)	Contents
Construction Litigation	Arditi et al.(1999)	Prediction of the outcome of construction litigation tried in illinois circuit courts using CBR
Construction Information Management	Park et al. (2008)	The system establishment which systematically manages the construction fail information using CBR
Cost Estimation	Karshenas et al. (2002)	A case-based reasoning approach to construction cost estimating
	Kim and Kang (2004)	Cost estimation for apartment buildings in early stage using CBR
	Lee (2006)	Development a Case-based forecasting model for monthly expenditures of residential building projects
	An et al. (2007)	A case-based reasoning cost estimating model using experience by analytic hierarchy process
	Park et al. (2008)	Developing sustainable cost estimating model for construction projects
	Son (2008)	By the case study, analyze the on quantity variation based schematic cost estimating model in building projects
	Ji et al. (2011)	Development of a military facility cost estimation (MilFaCE) system based on CBR
Decision-Making for Bidding	Chua et al. (2001)	Present a case-based reasoning bidding system for contractors

2.2.2 CBR Process

CBR is an approach to incremental and sustained learning. CBR stores the solved case in case base for future problems. It has a circular process to

accumulate the cases. CBR usually requires following four processes (4RE); REtrieve, REuse, REvise, and REtain (See Figure 2-1).

Simple explanation of four Processes (4RE) in CBR is as follows:

(1) REtrieve

Extracting similar previously experienced cases whose problem is judged to be similar.

(2) REuse

Employing the data and knowledge by copying or adapting the solutions from the cases retrieved.

(3) REvise

If necessary, proposed solution is modified.

(4) REtain

Storing the parts of experience likely to be useful into database for future problem solving.

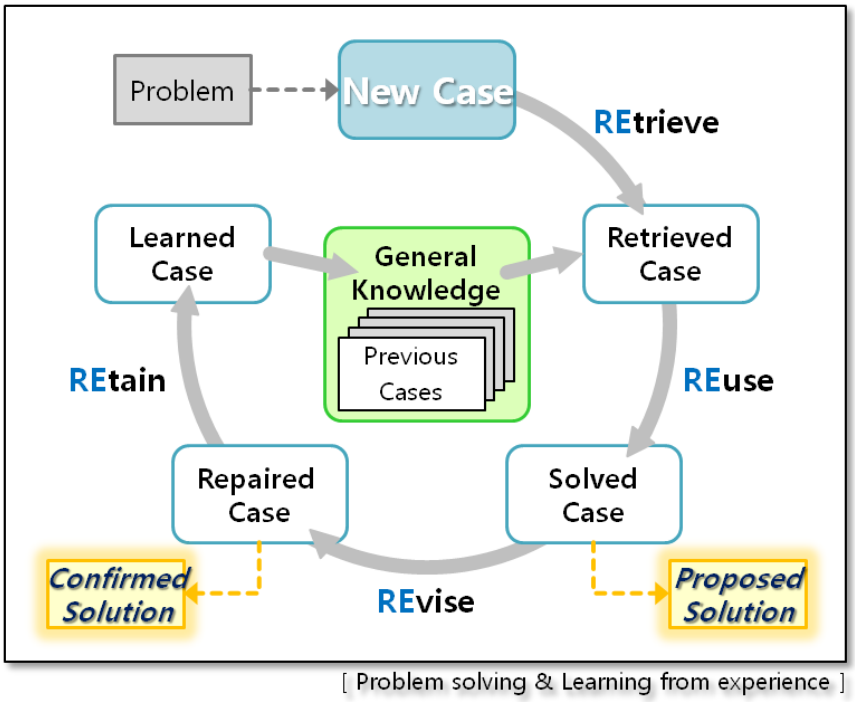


Figure 2-1 The CBR Processes (Aamodt and Plaza, 1994)

2.3 CBR Algorithms Applied to the Research

It is essential to retrieve the most similar case among past cases for solving a current given problem in CBR. In general, Inductive Retrieval method and Nearest Neighbor Retrieval method are used for similar case retrieval in CBR. Inductive Retrieval method has a disadvantage that cannot retrieve a past similar case if there does not exist a case which is the same as a current case in database. However Nearest Neighbor Retrieval method can successfully retrieve a past similar case by utilizing concrete and precise information presented as a numerical form even though the number of the past cases is insufficient or there does not exist matching cases from case-base.

It is difficult to find out historical project cases correspond with a new case because construction projects produce a single item and have non-iterative nature. Also the most variables (i.e. gross floor area, number of floors, number of households) which are used to estimate construction cost are generally expressed in the numerical form (Lee et al. 2011). Therefore, this research employs Nearest Neighbor Retrieval method for reflecting characteristics of a construction project and applying CBR. Figure 2-2 presents the Nearest Neighbor Retrieval method which is used in this research.

In Nearest Neighbor Retrieval method, the retrieved case is chosen then the weighted sum of its features that match the current case is greater than other case in the case base. Features that are considered more important in a problem-solving situation may have their importance denoted by weighting them more heavily in the case-matching process.

Especially, the K-Nearest Neighbor method involves a procedure which is

searching for K-Nearest cases by measuring distances with the current input case among the historical cases. After searching for K-nearest cases it selects the majority of these K-cases as the retrieved one.

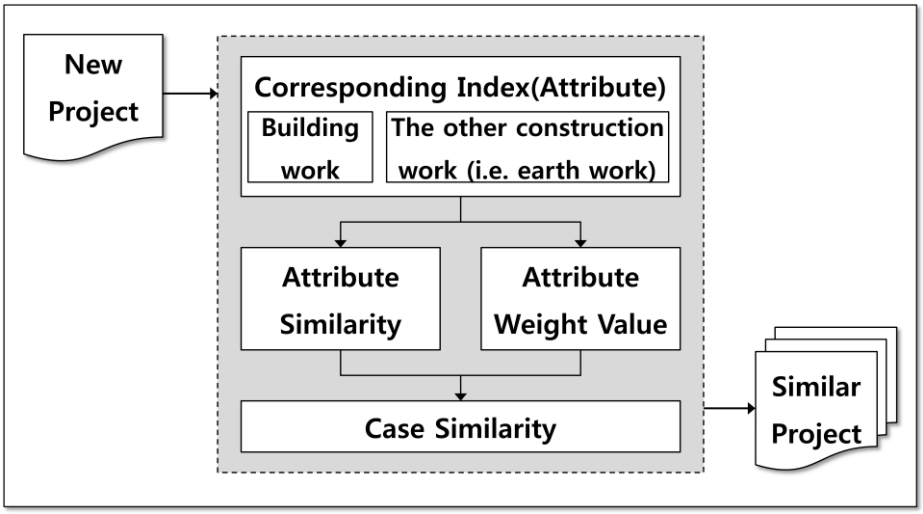


Figure 2-2 Nearest Neighbor Retrieval Process

Each case stored to a case-base is presented by several attributes which explain its features and it is necessary to define attribute similarity and attribute weight value for improving the possibility of similar case retrieval. Especially, an accurate estimation of attribute weight values is required to enhance reliability of a cost model using CBR because attribute weight values substantially influences performance of a cost model using CBR (Dogan et al. 2006). Thus, the core matters in CBR processes is to estimate proper attribute weight value and determine a measuring method to calculate attribute similarity by using estimated attribute weight value.

With this in mind, this research employs both an attribute similarity calculating method and an attribute weight value calculating method using

Genetic Algorithms (GAs), which are suggested by Park et al. (2010), they can improve explanatory and computability of an input case within ranges of an established case-base. Equation 2-1, 2-2, and 2-3 present CBR cost estimation method employed in this research.

(1) Calculating Attribute Similarity

The computation of attribute similarities is an important issue for retrieving similar cases in CBR. An appropriate similarity function needs to be developed to handle the hidden relationships between the objects associated with cased (Burkhard, 2001). This research calculates the attribute similarity by employing the principle of distance measuring suggested by Park et al. (2010). As scale-based attributes are the types of quantitative data, the similarity can be calculated by the numerical function.

$$AS(i) = 1 - \frac{\sqrt{(X_{Ni} - X_{Ci})^2}}{\sqrt{(X_{Hi} - X_{Li})^2}} \qquad \text{(Equation 2-1)}$$

Where, AS_i ; Similarity Score for Attribute i

X_{Ni} ; New Case Value for Attribute i

X_{Ci} ; Compared Past Case Value for Attribute i

X_H ; The Highest Past Case Value for Attribute i

X_L ; The Lowest Past Case Value for Attribute i

Equation 2-1 calculates how similar the attribute values of an input case are to the attribute values of each stored case by measuring the relative distances of each attribute value.

(2) Assigning Attribute Weight Value

This research uses the equation using Genetic Algorithm (GA) suggested by Park et al. (2010) for calculating each case's attribute weight. According to the definition of Nearest Neighbor, case similarity can be measured by equation 2-2. The optimal value of W_j is searched by minimizing the sum of square root of difference.

$$\begin{pmatrix} c_1 \\ \vdots \\ c_i \end{pmatrix} - \begin{pmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix} \times \begin{pmatrix} w_1 \\ \vdots \\ w_j \end{pmatrix} = \begin{pmatrix} d_1 \\ \vdots \\ d_i \end{pmatrix} \quad \text{(Equation 2-2)}$$

Where, C_i ; Cost of Case I

X_{ij} ; j^{th} Attribute Value of Case I

W_j ; j^{th} Attribute weight

(3) Calculating Case Similarity

Measuring case similarities is the last step for the Nearest Neighbor Retrieval method. According to the definition of Nearest Neighbor, case similarity can be measured by equation 2-3.

$$f_{CS}(x) = \frac{\sum_{i=1}^{n} (f_{AS_i} \times f_{AW_i})}{\sum_{i=1}^{n} (f_{AW_i})} \quad \text{(Equation 2-3)}$$

Where, n ; The number of Attribute

f_{CS} ; Function of Case Similarity

f_{AS} ; Function of Attribute Similarity

f_{AW} ; Function of Attribute Weight

2.4 Summary

In this chapter, conceptual cost estimating methods were reviewed to analyze advantages and limitations and case-based reasoning (CBR) is introduced as a cost estimation methodology. Furthermore, a CBR methodology applied to a construction industry was reviewed.

Parametric methods, statistical methods, and artificial intelligence methods for estimating conceptual construction cost were discussed in 2.1 and analyzed their limitations in estimating construction cost. Parametric methods have limitations that they need for regular updates of unit cost (cost/m2) and have difficulties of applications in case of buildings which designed complexly. Statistical methods commonly have a problem related to inherent reliability between variables. Artificial intelligence methods have a limitation that reasoning processes are a kind of black-box.

Section 2.2 examined the concept and process of CBR. It is able to utilize the specific knowledge of previously experienced problems. CBR has been diversely used in construction industry that knowledge and assessments of implemented projects are essential for resolving reoccurring problems. Also, CBR usually requires following 4 stages(4RE); REtrieve, REuse, REvise, and Retain.

CBR algorithms applied to the research were introduced in section 2.3 and mentioned processes of the Nearest Neighbor Retrieval method and its advantages when applying to estimate construction cost. This research employed the CBR methodology suggested by Park et al. (2010); calculating attribute similarity (equation 2-1), assigning attribute weight value (equation 2-2), calculating case similarity (equation 2-3).

Chapter 3. Cost Estimating System

The main issue of this chapter is to develop a cost estimation system using case-based reasoning. This chapter presents the procedure of the conceptual cost estimation model based on the CBR method, which is suggested by Part et al (2010), for public housing projects. The following section 3.1 shows CBR a cost model and section 3.2 presents data acquisition and analysis. In addition, system architecture is described in section 3.3.

3.1 Cost Model Framework

Components of public housing construction cost are direct cost, indirect cost, profits, VAT (Value-Added Tax), Supplied materials cost and so on. The cost model and its process are organized by those cost components. As diagrammed in figure 3-1, the cost model consists of three components: (1) the project information management module, (2) the direct cost estimation module (CBR), and (3) the total cost estimation module.

The project information management module starts with a project registration and is to input, manage the project information about public apartment's attributes such as gross floor area, number of floor, number of household and so on for the construction cost estimation. The direct cost estimation module utilizes the case-based reasoning method for estimating cost of building work and cost of other works which are earth work, mechanic work, electric work, communication work and landscape work. When retrieving similar cases, the system starts to compute similarity scores (0~1)

for each case in database. They have cost values that are revised to a new project's year-month using the Korean construction cost index when those cases are arrayed in ascending order. This index is categorized by 16 types of facilities that are officially announced every month by KICT (Korea Institute of Construction Technology). Numerous similar cases (K-Nearest Neighbors; K-NN) could be selected from those cases, and then the average of cost per square foot is calculated by K-NN cases. Direct cost of a new project is estimated by the average of cost per square foot. Finally, indirect cost, profits, VAT and are calculated by being multiplied with ratios and the estimated direct cost in total cost estimation module. Also the estimated total cost would be reported.

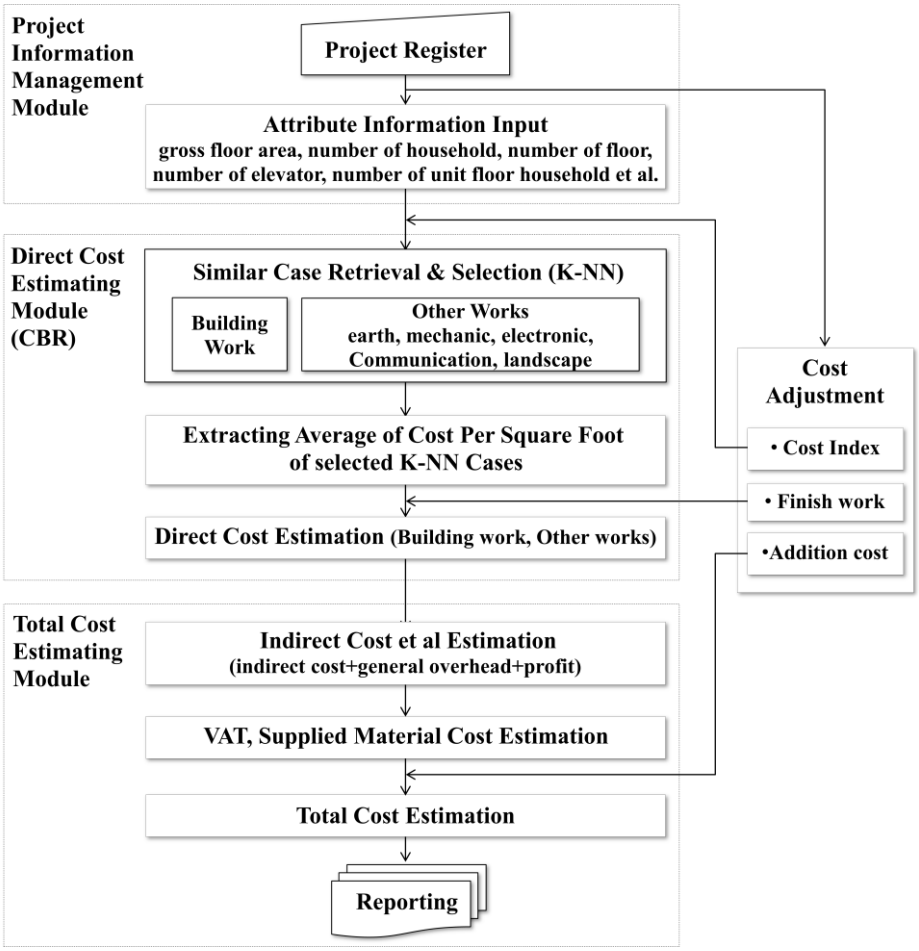


Figure 3-1 Cost Model Scheme using CBR

3.2 Data Acquisition and Analysis

Data for 66 implemented public housing construction projects from 2002-2008 were collected to organize cost database and develop a cost estimation model.

Public housing cost data were analyzed to be divided into work types and each representative area type of households which are 49m^2, 59m^2, 84m^2 and 114m^2 through a standardized cost breakdown structure presented in table 3-1. Also, in this research, the each area type of households is treated as a different

cost data because there is a difference of cost in the case of same floor area according to work types and an area type of households.

Public housing cost can be mainly divided into direct cost and indirect cost. The direct cost is classified to building work, which is including apartment buildings, underground parking lot and additional facilities, and other works that are earth work, landscape work, mechanic work, electric work and communication work. In this research, indirect cost et al is presented as the sum of indirect cost, general overhead and profit. Indirect cost et al is presented as ratio (%) measured by comparing with direct cost.

Table 3-1 Cost Breakdown Structure

Division			Unit	Cost (Won)	Cost Form In Database
Direct Cost	Building Work	Each Apartment building	Building		Per Gross Floor Area
		Underground Parking Lot	Complex		Per Parking volume
		Additional Facilities			Per Gross Floor Area
	Other Works	Earth Work	Complex		Per Site Area
		Landscape Work			Per Landscape Area
		Mechanic Work			Per Gross Floor Area
		Electric Work			
		Communication Work			
Indirect Cost et al	Sum of Indirect Cost, General Overhead, Profit		Complex	Ratio (%)	

3.2.1 Building Work

Cost database of building work consists of apartment buildings, underground parking lot and additional facilities. In this research, apartment buildings are divided into representative area types of households which are $49m^2$, $59m^2$, $84m^2$ and $114m^2$, then the other types are excluded from analysis targets.

Apartment building database is made up of cost information and 7 parameters such as number of household, gross floor area, number of unit floor household, number of elevator, number of households of unit floor per elevator, number of piloti with household scale and number of floors. Database of underground parking lot consists of cost information and attributes which are number of underground floor, area, parking volume. Also, additional facility database is composed of area and cost information. In building work division, individual cost is used for apartment building database and complex unit cost is used for underground parking lot and additional facilities database rather than individual cost. Table 3-2 shows a database structure of apartment buildings organized by a standardized classification system presented in table 3-2.

Table 3-2 Database Example of Apartment Buildings

Division		Parameters							Cost Information	
Apartment building	AreaType (m2)	X1	X2	X3	X4	X5	X6	X7	Total Cost (Thousand Won)	Cost (Won/X2)
k101	59	22	2452.91	2	12	1	2	4	1,303,089	531,242
k102	84	46	5065.7	4	12	1	4	4	2,670,302	527,134
k103	59	20	1654.12	2	11	1	2	4	912,157	551,446
k103	84	42	4629.73	4	11	1	4	4	2,553,043	551,446
k104	59	38	3103.27	4	10	2	2	0	1,796,698	578,969
k105	59	20	1648.42	4	5	2	2	0	1,082,968	656,973
k106	59	30	2472.63	6	5	3	2	0	1,563,441	632,299
k107	59	18	1508.43	4	5	2	2	4	1,068,383	708,275
k201	84	24	2638.56	2	12	1	2	0	1,478,020	560,162
k202	84	48	5277.12	4	12	2	2	0	2,647,914	501,773
k203	84	48	5277.12	4	12	2	2	0	2,629,430	498,270
k204	59	46	3749.87	4	12	2	2	2	2,034,718	542,611
k205	84	40	4448.13	4	11	1	4	4	2,398,184	539,144

Note: (X1) Number of Households, (X2) Gross Floor Area, (X3) Number of Unit Floor Households, (X4) Number of Floors, (X5) Number of Elevators, (X6) number of households of unit floor per elevator, (X7) number of piloti with household scale

3.2.2 Other Works and Indirect Cost et al

Other works include earth work, landscape work, mechanic work, electric work and communication work. Apartment building database uses building unit. The other hand, database of other works is structured with attributes, weight values and cost information by complex units

When organizing cost database of other works, cost per unit area is estimated by using site area in company with earth work cost for earth work and landscape area with landscape work cost to landscape work. In addition, cost per unit area is calculated by using gross floor area along with its cost in the cases of mechanic work, electronic work and communication work.

Indirect cost et al consists of sum of indirect cost, general overhead and profit. It is presented as ratio (%) by comparing to direct cost and analyzed into complex units based on public housing projects which are collected from public institutions. The following table 3-3 shows the cost component ratios that are analyzed from data for 66 implemented public housing construction projects collected from public institutions. Analyzed ratios of indirect cost et al are used to estimate indirect cost et al of a new project in the total cost estimation module of the developed system.

Table 3-3 Cost Component Ratios of Public Housing

Division			Unit	Cost Component Ratio	Cost Form In Database
Direct Cost	Building Work	Each Apartment building	Building	67.1%	Per Gross Floor Area
		Underground Parking Lot	Complex		Per Parking volume
		Additional Facilities			Per Gross Floor Area
	Other Works	Earth Work	Complex	3.8%	Per Site Area
		Landscape Work		3.5%	Per Landscape Area
		Mechanic Work		14.3%	Per Gross Floor Area
		Electric Work		7.4%	
		Communication Work		3.9%	
	Total			100%	
Indirect Cost et al	Sum of Indirect Cost, General Overhead, Profit		Complex	20.9%	Ratio (%)

3.2.3 Attribute Weight Values Assigned by GA Method

To extract cost impact factors, expert survey was implemented and then attributes of building work and other works were selected. Attribute weight values of each work were assigned by using GA method suggested by Park et al (2010) which is equation 2-2 along with cost database organized by this research. The following table 3-4 presents attributes weight values of each work calculated.

Table 3-4 Attribute Weight Values Assigned by GA Method

No	Impact Factors (Attributes)	Attribute Weight Values								
		Building Work				Other Works				
		49m^2	59m^2	84m^2	114m^2	Earth Work	Mechanic Work	Electronic Work	Communication Work	Landscape Work
1	Site Area	-	-	-	-	-	0.668	0.763	0.819	-
2	Building Area	-	-	-	-	0.318	-	-	-	0.324
3	Gross Floor Area	0.554	0.715	0.812	0.659	0.318	-	-	0.153	-
4	Landscape Area	-	-	-	-	-	-	-	-	-
5	Number of Household of each building	0.003	0.002	0	0.029	-	-	-	-	-
6	Total Number of Complex Household	-	-	-	-	-	0.214	0.111	0.028	-
7	Number of Unit Floor Household	0.007	0.096	0	0	-	-	-	-	-
8	Number of Apartment Building	-	-	-	-	0.364	0.118	0.126		0.676
9	Number of Floor	0.155	0	0.090	0.209	-	-	-	-	-
10	Number of Elevator	0.083	0.052	0.049	0.059	-	-	-	-	-
11	Number of Households of Unit Floor per Elevator	0	0.080	0	0	-	-	-	-	-
12	Number of Piloti with Household Scale	0.198	0.055	0.049	0	-	-	-	-	-

3.3 System Development

The system was developed by a grant (Grant No. R&D06CIT-A03) from the Innovative Construction Cost Engineering Research Center funded by the Ministry of Land, Transport, and Marine Affairs (Government of Korea). The principal development tools used for developing this system are JAVA, JSP, Eclipse and ERWin.

The following figure 3-2 and 3-3 show system architecture and database ERD. The system architecture consists of Cost DB organized by analyzing cost data of public housing projects, Scenario DB being used when a user wants to adjust the estimated cost by the system and CBR Processor which is procedure for estimating total cost of a new housing project. Also, the developed system is an on-line system based on the internet (Web Server) to improve generality and usability, also public ordering officers (Terminal Units) can use the system with individual ID and PW.

Every public institution ordering housing construction projects can use this system for estimating conceptual construction cost. They are able to manage their historical projects by uploading the information of the projects to the cost database of the system.

To meet the needs of public officers for comparing alternatives of finishing work costs through the system, this system established scenario database with regard to finishing works. System users can measure conceptual cost reflecting a variety of finishing work scenarios on the system.

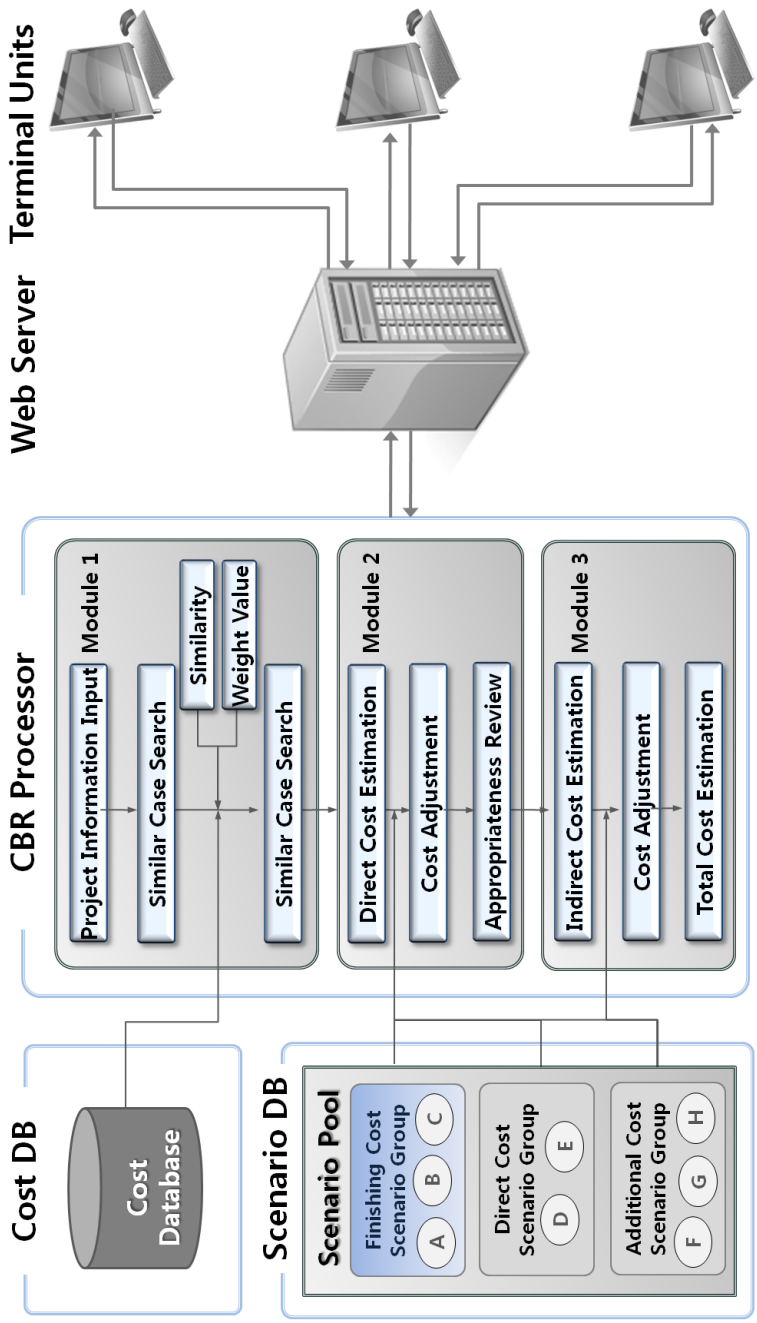


Figure 3-2 System Architecture

3.4 Summary

This chapter presents cost components analysis of public housing construction projects, a cost model development. The cost model consists of the processes for estimating the cost components and the cost model using CBR suggested by Park et al (2010) is structured by 3 modules; (1) the project information management module, (2) the direct cost estimation module (CBR), (3) the total cost estimation module. This research employed the Korean construction cost index announced every month by KICT (Korea Institute of Construction Technology) for adjusting the historical cost data.

Subsequently, it is necessary to structure cost database and the procedures of data acquisition and an analysis method were introduced in sector 3.2. The results of data analysis were presented in table 3-2. The results are used for establishing cost estimating processes of the system and estimating indirect cost et al in the total cost estimation module. Also attribute weight values assigned by GA method presents in table 3-3.

Finally, System architecture is structured with the CBR processor (3 modules), cost database, scenario database, web server and terminal units. To improve accessibility of system users, this research develops the web-based conceptual cost estimating system. Cost database could be shared by each public institution and easily updated by users. By establishing scenario database, the system users (officers; engineers in public institutions) are able to compare diverse alternatives on finishing work cost.

Chapter 4. Cost Estimating Processes through The System

As mentioned in chapter 3, this research developed a cost estimating system for the conceptual design phase. In this chapter, detailed cost estimation process is described through the suggested cost model's 3 modules which are Project Information Management Module, Direct Cost Estimating Module (CBR) and Total Cost Estimating Module presented in figure 3-1.

The cost estimating procedures of the system was established in the order of occupying cost ratios analyzed by a standardized cost classification system (table 3-2) on the public housing projects to be intelligible for users. Each stage uses the results of the former stage.

Firstly, in this research, the stage of project information management module was organized to input and manage the information of a new project for estimating conceptual costs. Secondly, in the direct cost estimating module, direct costs are estimated in the order of cost ratios (building work, other works; earth work, landscape work, mechanic work, electric work and communication work) using input information of the project in the former stage, then the total direct cost are aggregated with each work cost. Finally, in the total cost estimating module, indirect cost is calculated by multiplied a ratio of indirect cost et al and the direct cost, then a conceptual cost of the new project is estimated by the sum of the direct cost and the indirect cost et al. detailed cost estimating processes of the system are explained in the next 3 sections with interfaces of the system.

4.1 Project Information Management Module

The first module is a stage of inputting project information which is project name, project manager, ordering institutions, design year-month and so on. In this module, a new project is registered into the system by inputting project information for cost estimation.

Project information is divided into apartment complex information and apartment building information for minimizing redundancy input. Apartment complex information includes gross floor area, landscape area, building area, site area, area of underground parking lot, gross floor area of additional facilities, number of buildings and number of complex household for estimating cost underground parking lot, additional facilities and other works which are earth work, electric work, landscape work, mechanic work and communication work. Apartment building information is to building name, area type, gross floor area, number of household, number of unit floor household, number of floor, number of piloti with household scale, number of elevator, and number of households of unit floor per elevator for estimating cost of each building. Figure 4-1 shows a system window inputting apartment building information and the process of project information management module is as follows:

(1) Project Registration

(2) Project Information Input -Apartment Complex

(3) Project Information Input -Apartment Buildings

Figure 4-1 Apartment Building Information Input Window

4.2 Direct Cost Estimating Module (CBR)

The second module is a phase to estimate the direct cost of a new project using the input project information and the estimation process has two sections. One is to estimate building work cost and the other one is to estimate costs of the other works which are earth work, electric work, landscape work, mechanic work and communication work.

Direct cost estimation for apartment buildings is performed by similar case retrieval and selection from database with the input information. When estimating apartment building cost, the cost estimating process is repeated by the number of buildings. In the case of cost estimation of underground parking lot and additional facilities, it is the same as with the building direct cost estimating procedure.

Cost estimation process of the other works is implemented through similar case retrieval and selection from database and divided into earth work, electric work, landscape work, mechanic work and communication work. The following figure 4-2 and 4-3 present similar case retrieval window and apartment building cost estimation window.

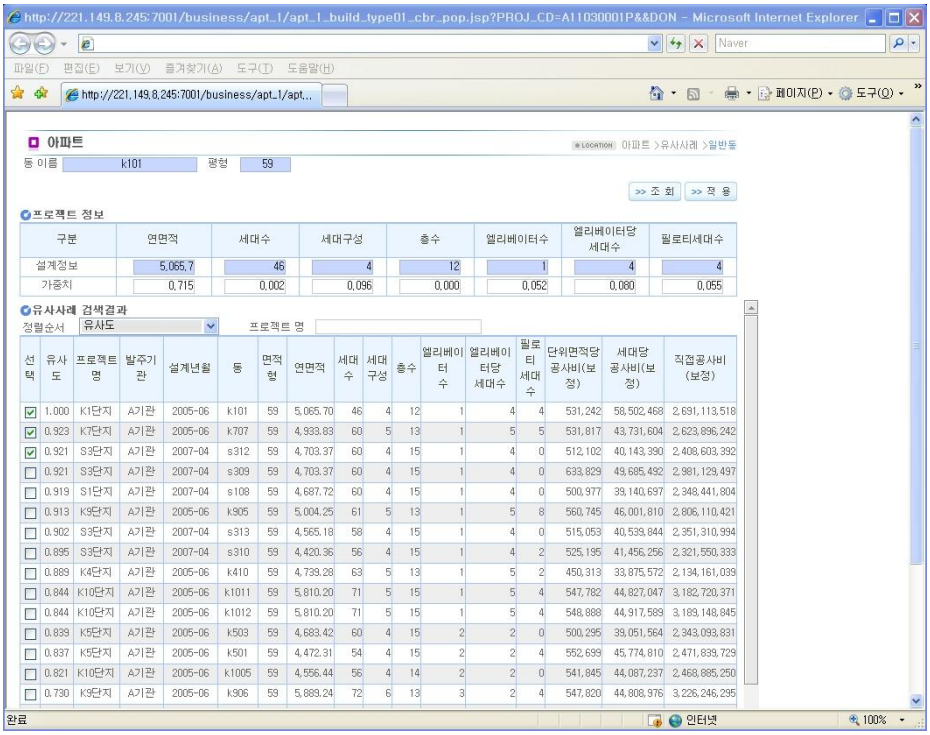
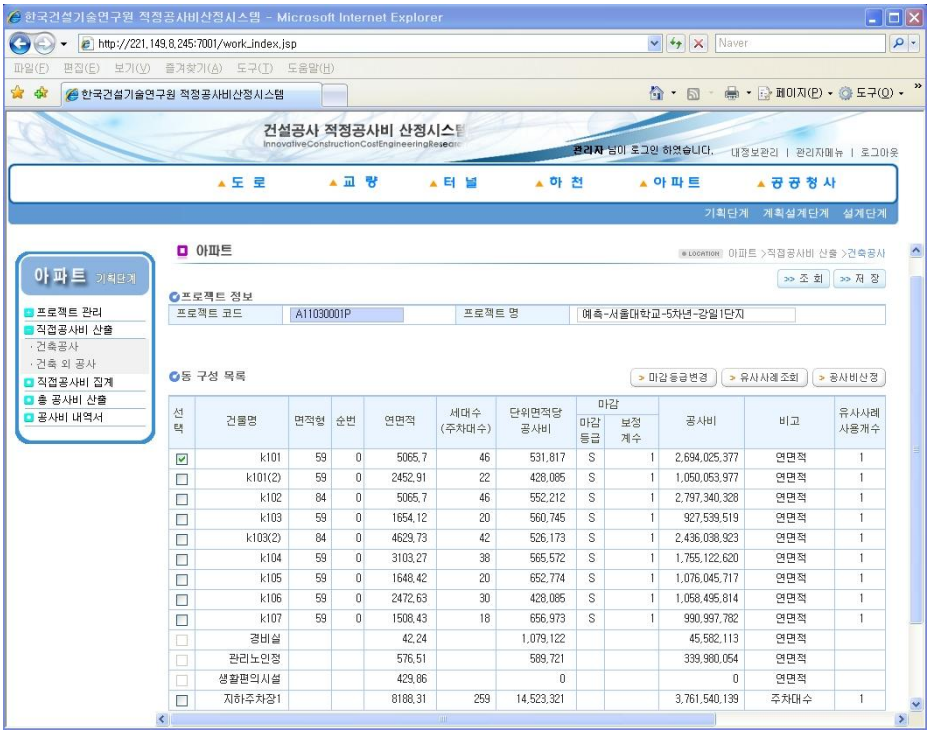


Figure 4-2 Similar Case Retrieval Window (Apartment Building)



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							마감 등급	보정 계수			
☑	k101	59	0	5065.7	46	531,817	S	1	2,694,025,377	연면적	1
☐	k101(2)	59	0	2452.91	22	428,085	S	1	1,050,053,977	연면적	1
☐	k102	84	0	5065.7	46	552,212	S	1	2,797,340,328	연면적	1
☐	k103	59	0	1654.12	20	560,745	S	1	927,539,519	연면적	1
☐	k103(2)	84	0	4629.73	42	526,173	S	1	2,436,038,923	연면적	1
☐	k104	59	0	3103.27	38	565,572	S	1	1,755,122,620	연면적	1
☐	k105	59	0	1648.42	20	652,774	S	1	1,076,045,717	연면적	1
☐	k106	59	0	2472.63	30	428,085	S	1	1,058,495,814	연면적	1
☐	k107	59	0	1508.43	18	656,973	S	1	990,997,782	연면적	1
☐	경비실			42.24		1,079,122			45,582,113	연면적	
☐	관리노인정			576.51		589,721			339,980,054	연면적	
☐	생활편의시설			429.86		0			0	연면적	
☐	지하주차장1			8188.31	259	14,523,321			3,761,540,139	주차대수	1

Figure 4-3 Apartment Building Cost Estimation Window

4.3 Total Cost Estimating Module

As discussed before, the cost estimating method of total cost estimating module is based on cost ratios and the building direct cost estimated by the former module. Indirect cost et al, which is sum of a indirect cost, general overhead and profits, is estimated by being multiplied a ratio of indirect cost et al and the direct cost. When calculating a indirect cost et al, user can choose one of the ratios of stored cases in system database or input a ratio on system. In the case of supplied materials cost estimation, it is estimated by multiplying supply value, which is sum of direct cost and indirect cost et al, and ratio set by users. In addition, additional cost such as green certification cost and allowance can be supplemented by ratios over estimated direct cost.

By aggregating the results of estimated costs for a new project, the output over total cost can be reported. Figure 4-4 shows total cost estimation window. Every value provided from the system are editable if users want and also estimation results can be stored and exported as a type of spread sheet file.

Figure 4-4 Total Cost Estimation Window

4.4 Summary

In this section, detailed cost estimation processes are introduced by the developed cost model's 3 modules; the project information management module, the direct cost estimation module and the total cost estimation module. Every module uses the results by former stages.

Firstly, the project information management module has 3 steps; (1) project registration, (2) project information input -apartment complex, (3) project information input -apartment buildings.

Secondly, the direct cost estimation module is to estimate total direct cost of a new project by sum of cost of building work and other works (earth work, landscape work, mechanic work, electric work and communication work) using the information of the former module

Finally, indirect cost et al of the new project is calculating by being multiplying a ratio of indirect cost et al and the direct cost, then the conceptual cost is estimated by aggregating the direct cost and indirect cost et al.

Chapter 5. Validation

This chapter is to validate the system; therefore firstly validation in terms of the estimating accuracy and the effectiveness of the developed system is schemed and elaborated in section 5.1. Validation results and suggestion on one of the CBR issues, concerns how many cases would be chose to predict the construction cost, are described with discussions in section 5.2.

5.1 Validation Method

To examine estimating accuracy and the effectiveness of the developed system, two types of validation is schemed.

One is total cost estimating accuracy test of the system using 9 public housing projects not included on system database among 66 collected projects from public institutions because it is required to choose test cases to validate the estimating accuracy and the random selection of the test cases among cases in system database may affect the accuracy testing. When retrieving similar cases and selecting a similar case, 1-NN based method is used to predict the cost. Estimating accuracy of the system is presented by comparing estimated cost through the system and actual cost of test cases. This estimate results are represented and compared with their absolute error ratio (AER) which can be defined as below (Equation 5-1). CA and CE denote actual cost and estimated cost. In addition, estimating accuracy of the system is examined by comparing with estimate error ranges on project definition which are suggested by AACE International (the Association for the Advancement of

Cost Engineering), ANSI (American National Standards Institute), ACostE (Association of Cost Engineers). The following table 5-1 shows the profile of cases for system test.

Table 5-1 Profile of Test Cases

Region	Project	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	Total Cost (Won)
1	A	9	200506	24550.06	37426.94	4265.99	93583.46	17.38	116.70	2	5~12	327	282	34,077,412,926
	B	13	200506	36913.25	84759.32	5876.39	14986.70	15.92	170.55	1	12~15	814	722	63,006,157,710
	C	14	200506	40971.74	94038.23	6983.84	13299.78	17.05	177.57	1	12~15	798	694	78,025,908,838
2	D	25	200802	34989.00	71624.98	7198.74	15884.50	20.57	142.51	3	6~13	592	475	82,175,163,452
	E	29	200802	51364.00	79903.57	16186.03	17991.58	3151	105.97	2	3~7	646	471	93,410,268,695
	F	8	200802	13304.00	38672.89	3024.74	5358.52	22.74	189.86	2	9~15	305	235	44,782,865,908
3	G	11	200807	12609.00	19588.63	2774.99	5196.36	22.01	101.87	1	5~7	153	133	25,738,086,566
	H	13	200807	28105.00	75840.91	6094.49	10712.84	21.68	191.33	2	13~17	602	509	87,211,354,650
	I	12	200807	20726.00	50285.43	4457.53	7499.17	21.51	163.74	2	10~17	430	382	54,653,562,108

Note: (X1) Number of Apartment Building, (X2) Design Year-Month, (X3) Site Area, (X4) Gross Floor Area, (X5) Building Area, (X6) Landscape Area, (X7) Building Coverage Area, (X8) Floor Area Ratio, (X9) Number of Underground Floor, (X10) Number of Floor, (X11) Parking lot Volume, (X12) Number of Complex Household

$$\mathrm{AER}(\%) = \begin{cases} \text{if } \mathrm{C_A} - \mathrm{C_E} > 1, \ \textit{then} & [(\mathrm{C_A} - \mathrm{C_E}) - 1] \times 100 \\ \text{otherwise,} & [1 - (\mathrm{C_A} - \mathrm{C_E})] \times 100 \end{cases}$$

(Equation5-1)

The other one is an effectiveness test of the developed system. This test was implemented by comparative evaluation on appropriateness of the results, reliability of the results, conveniences of the method and estimate time-saving between the system and current cost estimation method being used for public institutions. Also surveys in terms of the system evaluation on adequacy of the results, system usability and system applicability was performed by public officers (engineers). The test was performed by survey and interview from officers in public institutions. The simple profile of the interviewees is introduced in table 5-2.

Table 5-2 Profile of The Interviewees

Working Region	Capital Area		Non-Capital Area	Total
	10 People		9 People	19 People
Working Experience	Below 5 Years	5 ~ 15 Years	Above 15 Years	
	3 People	8 People	8 People	

5.2 Implementations

Table 5-3 presents results on total cost estimations through the developed system. The results of validation on estimating accuracy of the system using 9 test cases show that the range of absolute error ratio (AER) is from 0.49% to 13.88%. Mean AER and S.D are shown as 4.61% and 4.54%. Especially, in the 5 test cases of total 9 test cases, absolute error ratio of less than 5% was presented as table 5-3. Thus, the estimate accuracy of the system has overall lower absolute error ratio and is considered to be relatively superior.

However, in the cases of project F and H, AER is 9.48% and 13.88%. The results are quite higher than absolute error ratios of other test cases. This means that estimate error could be high in the case of using a case has the highest case similarity when estimating cost through the stage of similar case retrieval. In terms of the estimation accuracy of the system, it could be considered that more high estimation accuracy could be obtained by organizing database with much more implemented project cases.

Table 5-3 Comparison of Absolute Error Ratio (AER)

Region	Project	X1	Actual Total Cost	Estimated Total Cost	Absolute Error Ratio (%)
1	A	9	34,077,412,926	33,909,093,573	**0.49**
	B	13	63,006,157,710	64,084,688,483	**1.71**
	C	14	78,025,908,838	79,882,717,053	**2.38**
2	D	25	82,175,163,452	83,152,193,388	**1.19**
	E	29	93,410,268,695	97,832,991,649	**4.73**
	F	8	44,782,865,908	49,026,604,284	**9.48**
3	G	11	25,738,086,566	27,142,041,632	**5.45**
	H	13	87,211,354,650	99,316,317,901	**13.88**
	I	12	54,653,562,108	58,338,254,698	**6.74**
Mean			**4.61**		
S.D			**4.54**		

The following table 5-4 shows comparison results of estimate error ranges suggested by AACE International, ANSI and ACostE. Moreover, the estimate error ranges are compared with target error range of the system which is set by results of survey on appropriateness between estimated cost and actual cost from public institutions.

AACE proposes five classes of cost estimate based of level of project definition. And it defines the expected accuracy range for each class. When level of project definition corresponds to 1% to 15%, the accuracy is -15% to 20% (AACE 2005), -20% to 20% (ANSI Standard Z94.0) and -15% to 15% (ACostE). The target error range of the system is -15% to 15%. The developed cost estimation system has error rate of -0.49% to 13.88%. The average and standard deviation of error rates are 4.61% and 4.54%. Also, the range of error ratio estimated from the system is -0.49% to 13.88%. This error rate is superior to accuracy suggested by AACE, ANSI, ACostE and target error rate set by officers in public institutions. Therefore, it is considered to be acceptable for conceptual cost estimation.

Table 5-4 Comparison of Error Ratio

Division		(Class 4)
Estimate Error Range*	AACE(2005)	-15% ~ +20%
	ANSI Standard Z94.0	-15% ~ +30%
	Association of Cost Engineers (UK) ACostE	-20% ~ +20%
Target Error Range of The System		-15% ~ +15%
Results of Validation	Mean	4.61%
	Range	-0.49% ~ +13.88%
	S.D	4.54%

* AACE, 2005, International Recommended Practice No. 18R-97

For effectiveness test of the developed system, surveys and interviews were implemented by public officers about 4 comparative assessment items on appropriateness of the results, reliability of the results, conveniences of the method and estimate time-saving between the system and the current cost estimation method being used for public institutions.

As a result, shown in table 5-5, the respondents evaluated that the developed cost estimation system is relatively more superior to current cost estimation method. In detail, they responded that appropriateness of the estimation result is more advanced than current estimation method. In terms of reliability of the results, the system was evaluated to more superior. Also relative superiority level of the system on convenience of the method was assessed to be very high to current cost estimation method being used in public institutions. Especially, with respect to estimate time-saving, it was dominant opinions that the system could improve efficiency of cost estimating work.

Table 5-5 Comparative Evaluation on Between the System and A Current Cost Estimation Method

Cost Estimation Method / **Assessment Items**	**Current Method**		**VS**	**The System**	
	Relative Superiority Level				
	Very High 1	**High 2**	**Similar 3**	**High 4**	**Very High 5**
	<--I-----I------I------I-----I-->				
Appropriateness of the Results				○(3.7)	
Reliability of the Results				○(3.6)	
Convenience of the Method					○(4.6)
Estimate Time-Saving					○(4.6)

Note: ( ) Average Point of the Response

Following figure 5-1, 5-2 and 5-3 present the assessment results of the developed system about adequacy of the results, system usability and system applicability by officers in public institutions.

Looking at the assessment results about adequacy of the results in Figure 5-1, the public officers responded that cost estimating processes of the system have clarity and ranking of the similar cases is adequate. However they answered that it is required to choose similar cases based on estimator's experience and environment of the new project because variations of each cost per square foot of similar cases occur when retrieving similar cases. Comprehensive assessment point in terms of adequacy of the results was 3.8 and it can be relatively adequate that conceptual cost estimation could be possible through the system. Public officers expressed that the system may be more improved if additional system validation and reliability of the organized database is implemented.

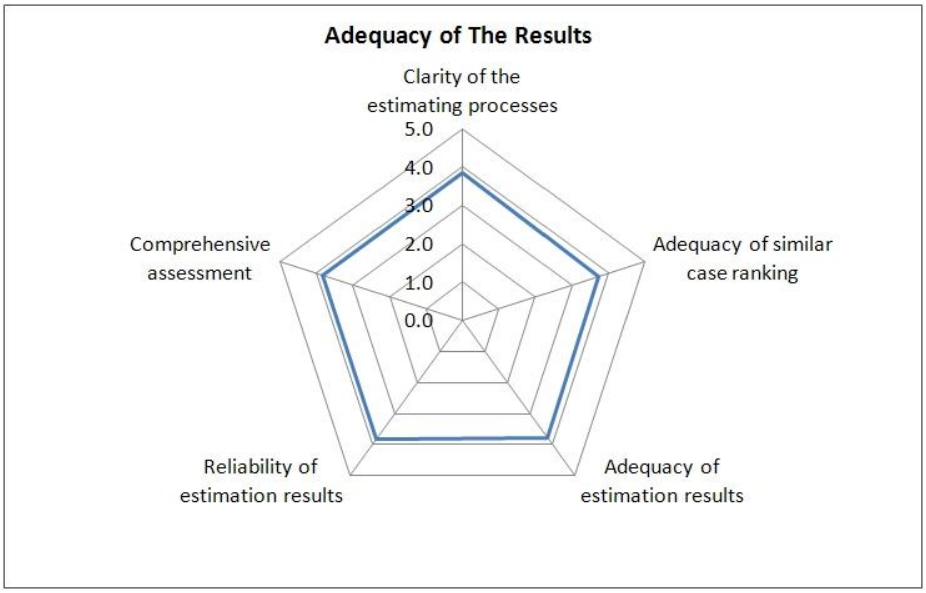


Figure 5-1 Adequacy of the Results

Figure 5-2 shows assessment results on system usability by public officers. It was compiled that lucidity of the estimating processes is 4.1, clarity of input-output is 4.2, ease of input-output is 4.2, immediacy of 4.3 and comprehensive assessment is 4.3. Respondents evaluated that they can understand cost estimating processes because procedures of the system are substantially simple and perspicuous. In general, the system was evaluated that it is superior with regard to system usability.

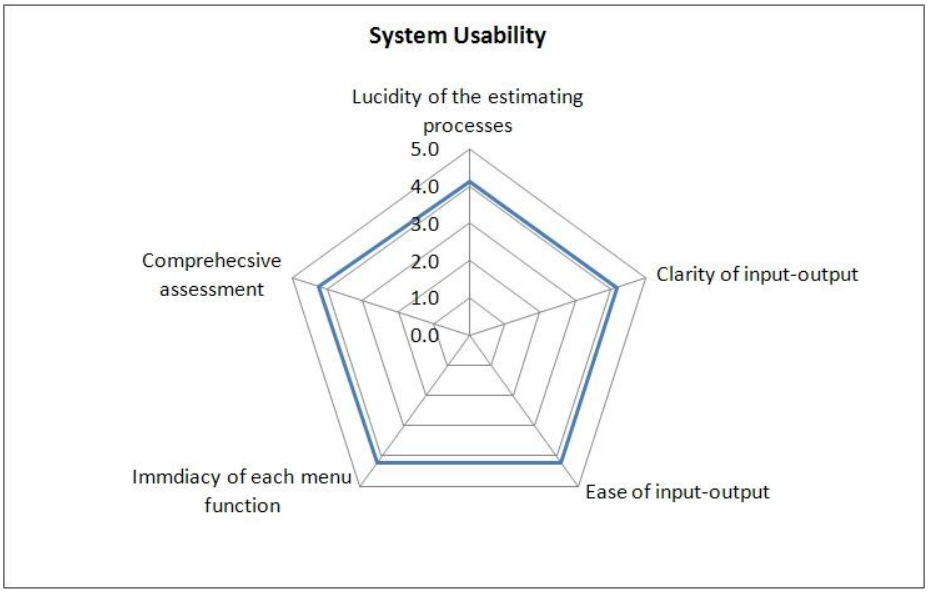


Figure 5-2 System Usability

To investigate the applicability of the developed system to cost estimating tasks of public institutions, this research surveyed on system applicability from public officers; task conformity, applicability of results, adequacy of the results form, task improvement and comprehensive assessment. Future users of public institutions generally evaluated that the system could improve their current environment of cost estimating tasks. Task conformity between cost estimating processes of the system and current cost estimating works in public

institutions was high as 4.1point and results of the system available for downloading as a form of Excel files was evaluated to be remarkable with respect to applicability of results.

However, there were opinions that the overall design improvement of system and a form of Excel files is required because the system interface is a little bit unsatisfactory.

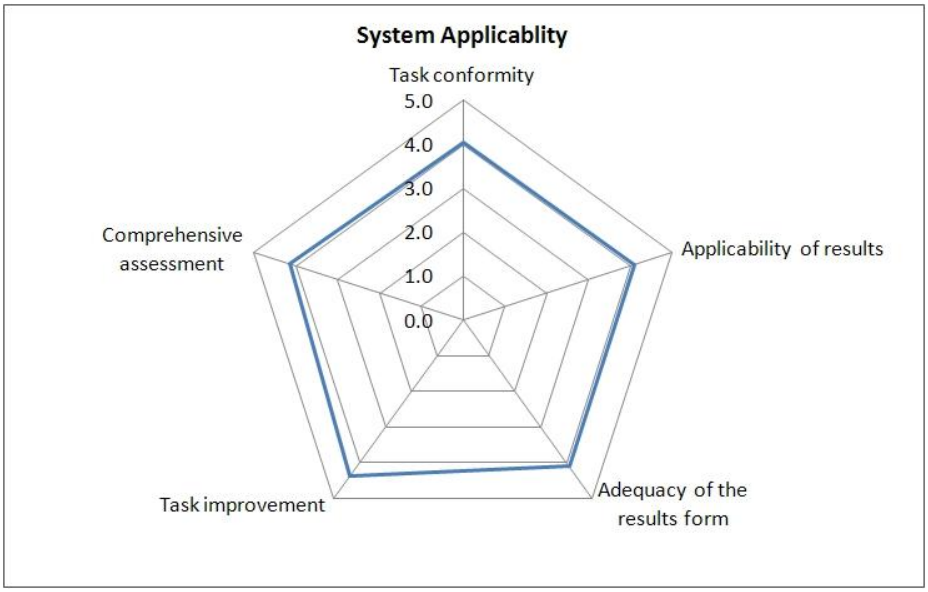


Figure 5-3 System Applicability

5.3 Summary

In this section, the estimating accuracy and the effectiveness of the developed system were validated through the 2 validation methods; (1) total cost estimating accuracy test of the system using 9 public housing projects excluded on the system database, (2) survey and interview from public officers (engineers) using assessment items on system effectiveness.

Subsequently, the accuracy of the conceptual cost estimating system is measured by error ratios. By applying the cost estimating process to the test cases, the error ratios were calculated. As a result, the system has total cost error rate of -0.49% to 13.88% and mean error rate of 4.61%. Compared with the definition of AACE, ANSI, ACostE, target error rate set by officers in public institutions, it is considered to be acceptable for conceptual total cost estimation.

Finally, with respect to the effectiveness of the system, the system was evaluated to be more superior than current cost estimating methods used in public institutions. It was dominant opinions that the system could substantially improve the conceptual cost estimating tasks of Public officers if the system is employed to the public institutions.

Chapter 6. Conclusions

6.1 Results and Discussions

In the early stages of a construction project, the estimated construction cost effects chiefly owner's decision-making and the cost serves as a crucial element to success of a construction project (Trost and Oberlender 2003; Lee et al. 2011).

Even though the importance of the cost estimating is getting highlighted, especially in the case of public housing construction projects in Korea, there are difficulties in predicting the proper construction cost due to the insufficient information of a construction project and the uncertainty of main factors related to the construction cost. Moreover, excluding a few of the public institutions, there are problems in properly estimating construction cost due to the lack of a conceptual cost estimating system and hardly have engineers for reviewing the adequacy of the estimated construction cost.

In an effort to deal with these issues, this research developed a cost model using case-based reasoning equations suggested by Park et al. (2010). A conceptual cost estimating system was developed for public housing projects using the cost model with 66 implemented public housing projects collected by public institutions.

The system was validated to estimating accuracy and the effectiveness by a cost estimating accuracy test and surveys on the system from officers in public institutions. As a result of cost estimating accuracy test, the system has

error rate of -0.49% to 13.88% and average and standard deviation of the rates are 4.61% and 4.54%. This error rate is superior to accuracy (at Class 4) suggested by AACE, ANSI, ACostE and the target error rate set by public officers. Therefore, it is considered to be acceptable for conceptual cost estimation. In addition, public officers assessed that the developed system could substantially improve conditions of current cost estimating works for housing projects.

6.2 Contributions

The contributions of this research can be grouped into three parts.

First, this research has significance that a total conceptual cost estimating system which can was developed for public housing projects and the developed system has total cost error rate of -0.49% to 13.88 and mean of 4.61%. It can be acceptable for conceptual cost estimating.

Second, this research developed a cost estimating system that has the public characters with respect to 2 aspects. One is that officers (engineers) whoever are in public institutions can use the system after ID/PW are being issued from a web-site. The other one is that users can upload their historical projects to cost database and efficiently manage those information. Furthermore, public institutions can share knowledge of their implemented public housing construction projects.

Third, this research tried to obtain empirical results on the estimating

accuracy and the effectiveness of the developed system by implementing accuracy tests and surveying officers (engineers) in public institutions. As a result, the estimating accuracy is superior to standards suggested by AACE, ANSI, ACostE and the target accuracy set by public officers.. In addition, public officers assessed that the developed system could substantially improve conditions of current cost estimating works for public housing projects.

6.3 Limitations and Future Researches

The limitations and future researches of this research can be grouped into three parts.

First, this research include a limitation that additional validation is needed on attributes used for retrieving similar cases because estimate error could be high in the case of using a case has the highest case similarity when estimating cost through the process of similar case retrieval.

Second, the developed system, in this research, has a difficulty for decision-making on new factors influence cost estimation such as ‘Green Building Certification Criteria’, ‘Housing Performance Rating Indication System’ and so on. In other words, the system has weakness to respond changes. Future researches on methods of reflecting the changes are needed.

Third, the system does not consider reflecting regional characteristics of projects and this can occur estimating errors. Thus, it is necessary to develop local index for adjusting construction cost.

Appendices

Appendix A: The System Interfaces

Appendix B: The System Database ERD

Appendix C: The System Evaluation Sheet (Survey)

Appendix A: The System Interfaces

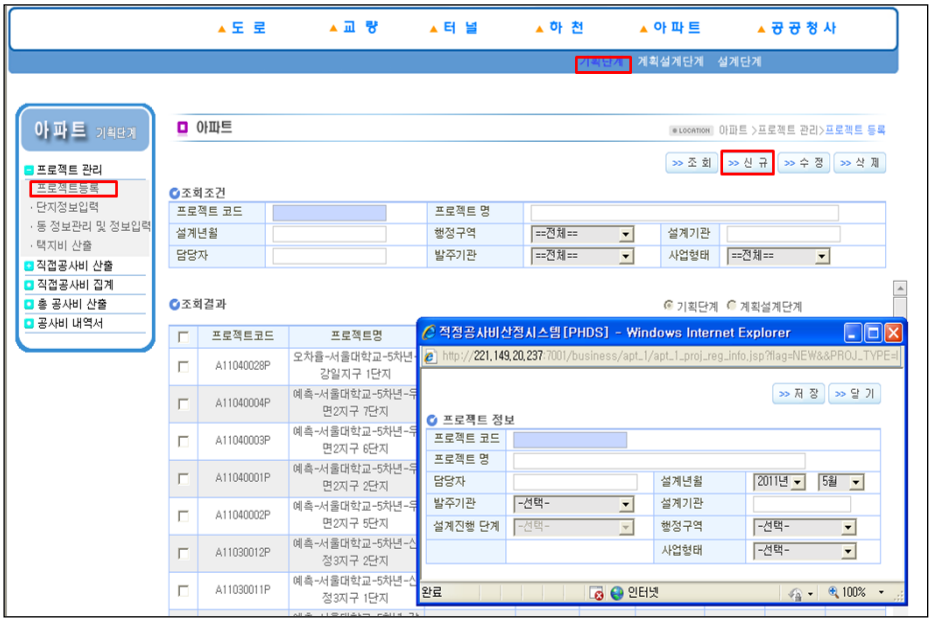


Figure A-1 Project Registration Tab

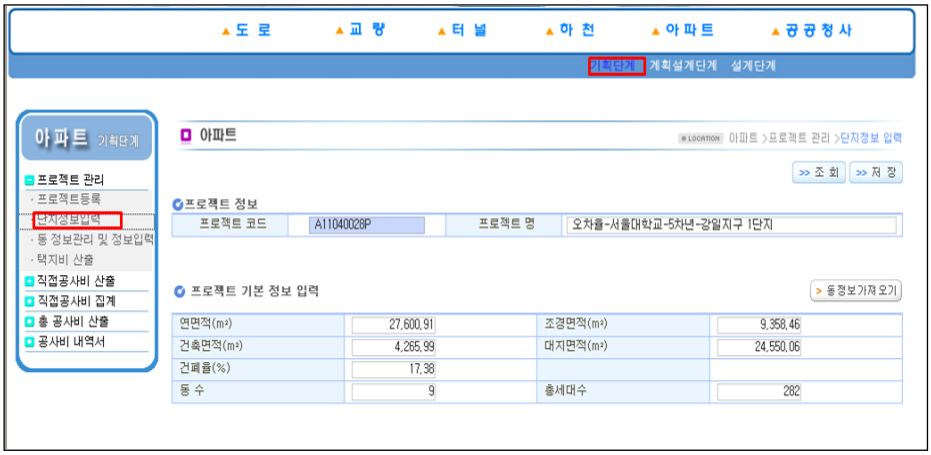


Figure A-2 Apartment Complex Information Input Tab

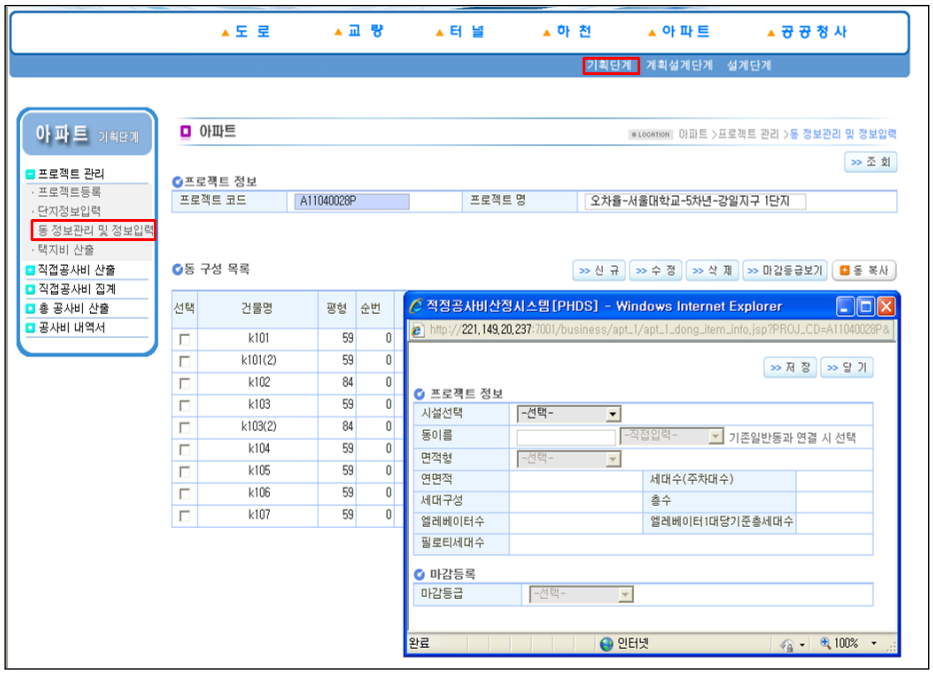


Figure A-3 Apartment Information Management and Input Tab

Figure A-4 Finishing Level Selection Tab

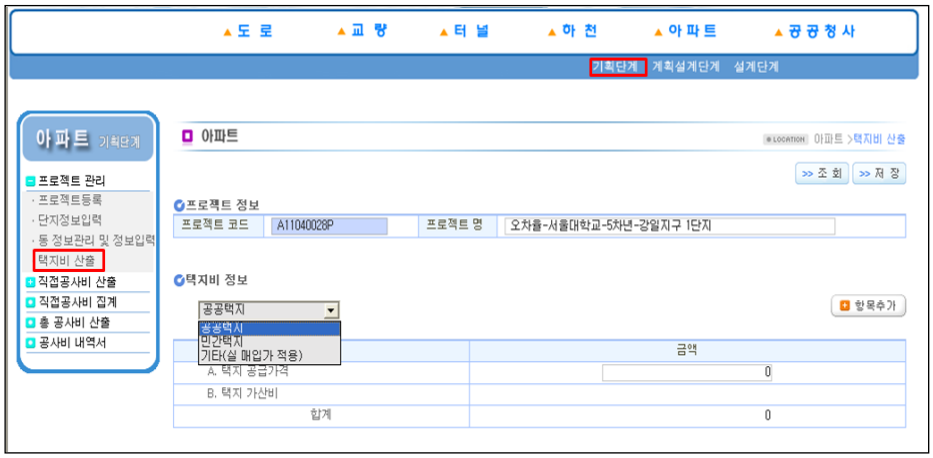
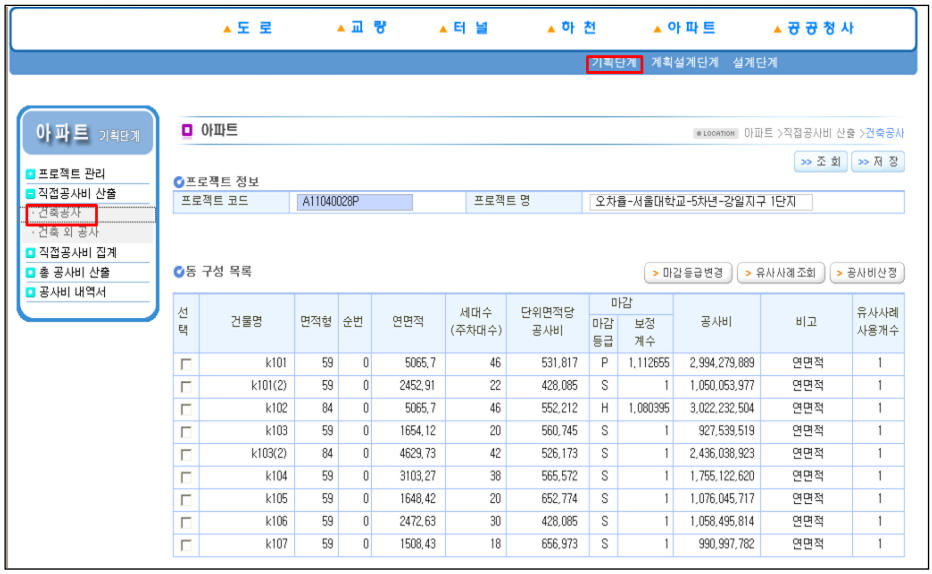


Figure A-5 Land Price Estimation Tab



선택	건물명	면적형	순번	연면적	세대수 (주차대수)	단위면적당 공사비	마감		공사비	비고	유사사례 사용개수
							마감 등급	보정 계수			
☐	k101	59	0	5065,7	46	531,817	P	1,112655	2,994,279,889	연면적	1
☐	k101(2)	59	0	2452,91	22	428,085	S	1	1,050,053,977	연면적	1
☐	k102	84	0	5065,7	46	552,212	H	1,080395	3,022,232,504	연면적	1
☐	k103	59	0	1654,12	20	560,745	S	1	927,539,519	연면적	1
☐	k103(2)	84	0	4629,73	42	526,173	S	1	2,436,038,923	연면적	1
☐	k104	59	0	3103,27	38	565,572	S	1	1,755,122,620	연면적	1
☐	k105	59	0	1648,42	20	652,774	S	1	1,076,045,717	연면적	1
☐	k106	59	0	2472,63	30	428,085	S	1	1,058,495,814	연면적	1
☐	k107	59	0	1508,43	18	656,973	S	1	990,997,782	연면적	1

Figure A-6 Direct Cost Estimation Tab of Building Work

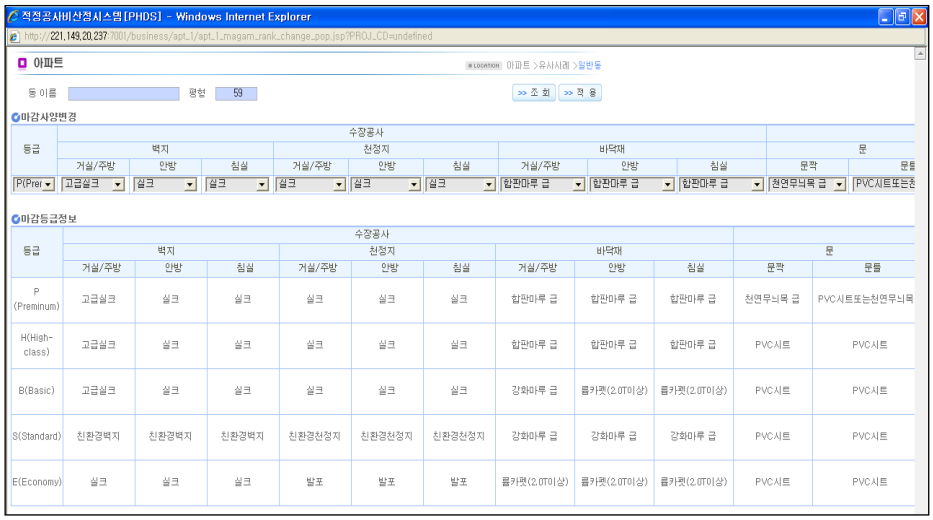


Figure A-7 Finishing Level Modification Tab

Figure A-8 Direct Cost Estimation Tab of Other Works

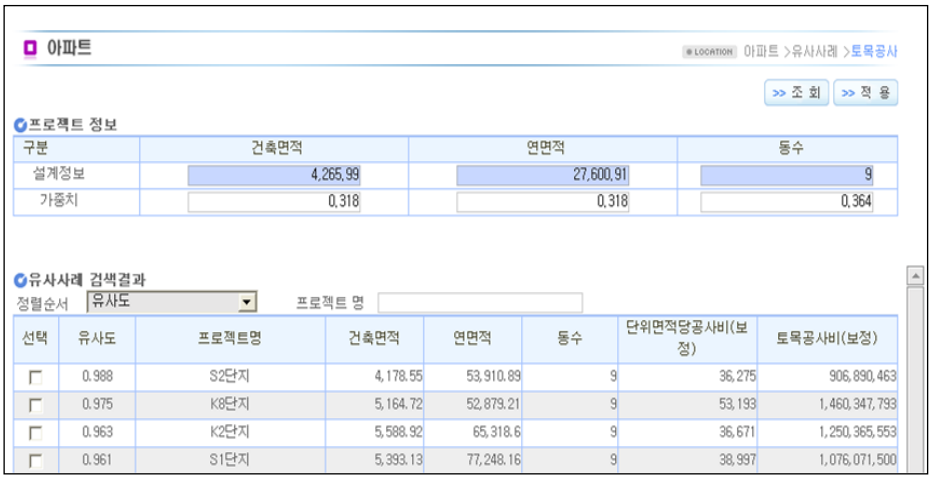


Figure A-9 Direct Cost Similar Case Retrieval Tab of Other Works

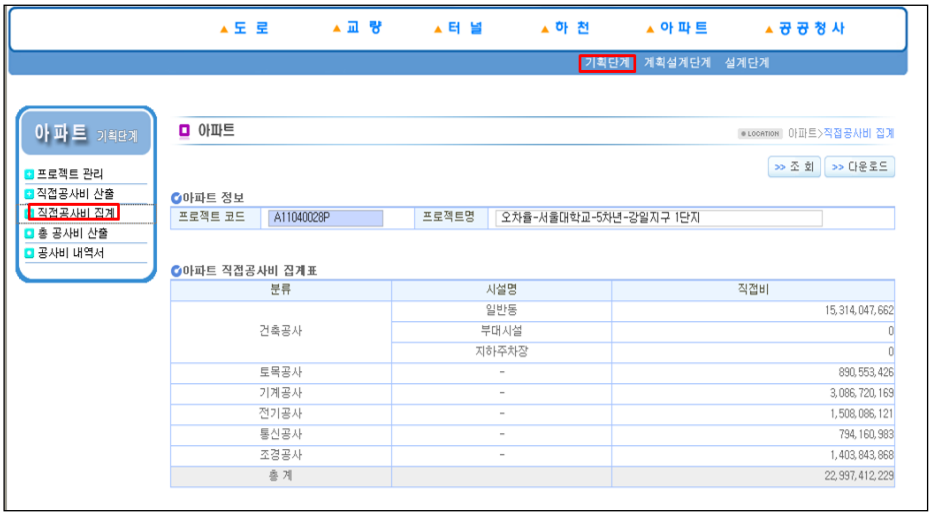


Figure A-10 Direct Cost Aggregate Tab

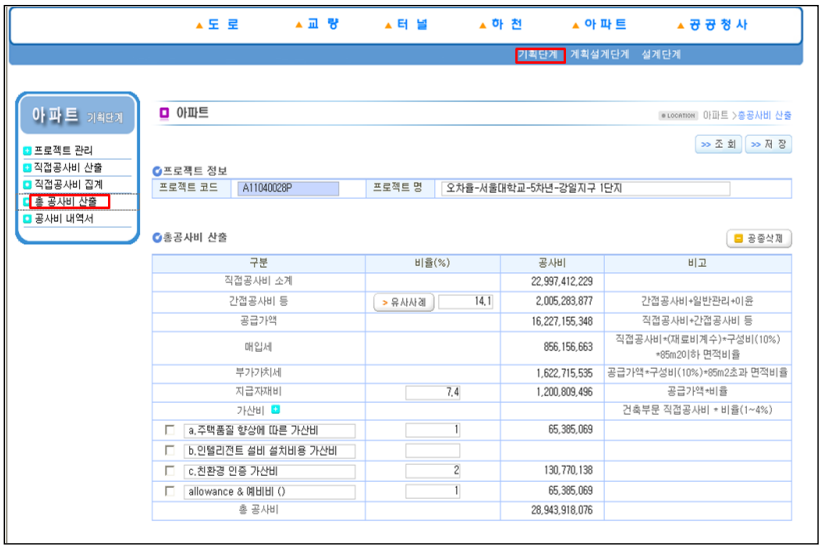


Figure A-11 Total Cost Estimation Tab

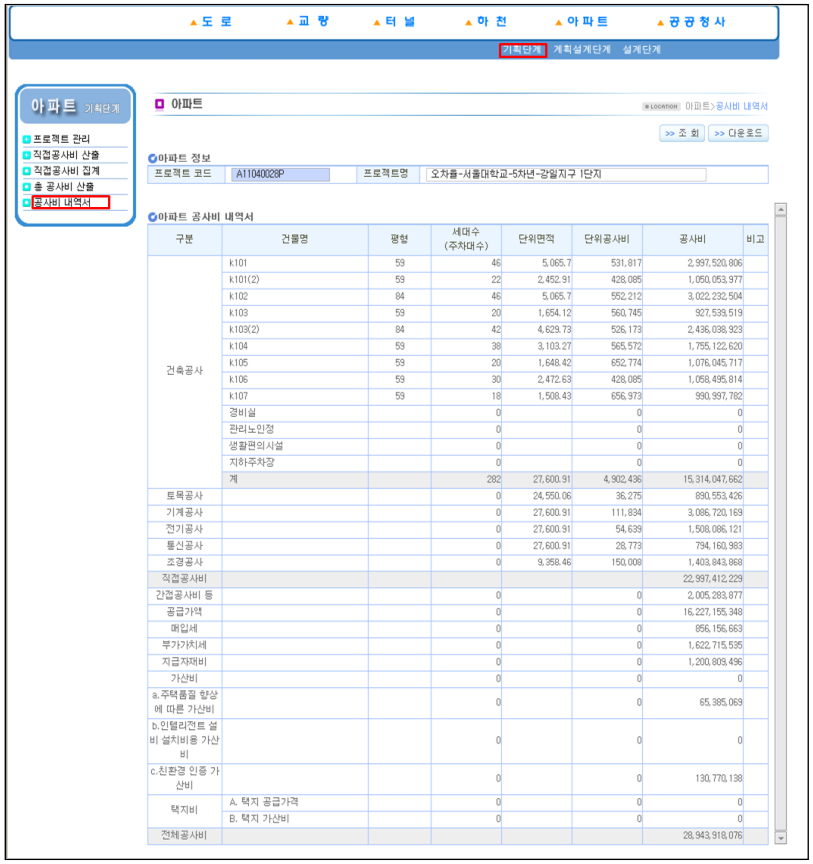


Figure A-12 Detailed Statement Tab of the Total Cost

Appendix B : The System Database ERD

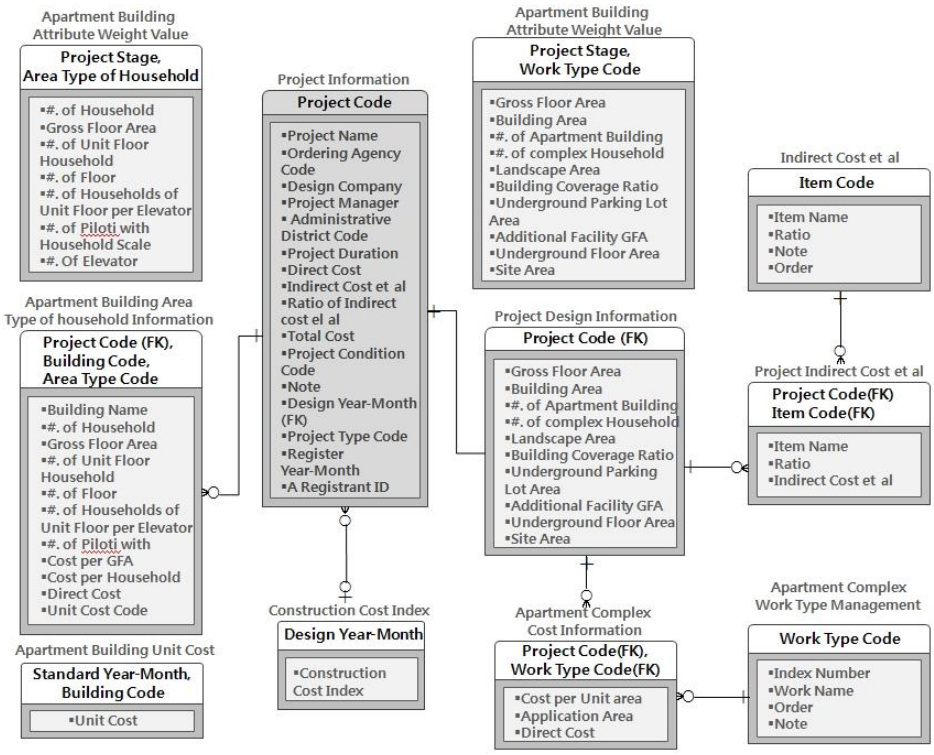


Figure B-1 The Database ERD (Entity Relationship Diagram)

Appendix C: The System Evaluation Sheet (Survey)

시스템 평가서

◆ 평가개요

평가대상 시스템	기획단계 적정공사비 산정 시스템 (이하 ICCE시스템)
시스템 활용단계	기획단계(사업구상 단계)
시스템 활용목적	사업구상 시 예산(공사비)산정, 예산안 제출시 뒷받침 자료 제공

◆ 현행방식과의 비교평가 (평가항목 별 우위가 있다고 생각하는 방식에 체크)

(1)기존 예산(개략공사비)산정 방법을 간략히 기입하여 주십시오.

(Ex. 예산승인 기관, 예산확보절차, 예산산정 시 참고자료, 예산산정방법 등)

(2)기획단계에서 추정한 예산과 실시설계 최종 설계가와의 차이는 어느 정도가 적정하다고 생각하십니까?

①5~10%　②10~15%　③15~20%　④20~25%　⑤25%이상

평가항목 \ 산정방법	현행방식		vs	ICCE시스템	
	상대적 우위수준				
	매우높음	높음	비슷함	높음	매우높음
산정결과의 적정성					
산정결과에 대한 신뢰도					
산정 방법의 편의성					
예산(공사비) 산정 소요시간					

◆ 시스템 총괄 평가

평가 항목	ICCE시스템 수준				
	매우낮음	낮음	보통	높음	매우높음
**** 결과의 적정성***					
(1)결과산정 과정이 명확한가?					
(2)시스템에서 산정한 유사사례의 순위는 적정(타당)한가?					
(3)산정된 공사비는 적정한가?					
(4)산정된 공사비를 신뢰할 수 있는가?					
(5)결과의 적정성에 대해 종합적으로 평가한다면?					
**** 사용의 편의성***					
(1)시스템 진행과정을 쉽게 이해할 수 있는가?					
(2)시스템 진행과정 상의 입·출력 사항이 명확한가?					
(3)정보 입·출력을 간단히 할 수 있는가?					
(4)각 매뉴별 기능을 쉽게 파악할 수 있는가?					
(5)사용의 편의성에 대해 종합적으로 평가한다면?					
**** 시스템 활용성***					
(1)시스템의 진행과정과 실제 업무흐름이 일치하는가?					
(2)실제 업무에서 필요로 하는 결과물을 제공하는가?					
(3)실제 업무에 바로 사용할 수 있는 형태로 결과물을 제공하는가?					
(4)시스템 사용이 업무 효율성을 개선할 수 있는가?					
(5)시스템 활용성에 대해 종합 평가한다면?					

◆ 추가 의견수렴

(Ex. 시스템의 문제점, 개선방안, 실무 활용을 위한 필요사항 등)

Figure C-1 The System Evaluation Sheet (Survey)

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국 문 초 록

건설프로젝트의 기획단계에서 산정된 공사비는 발주자의 의사결정과 프로젝트를 성공적으로 수행하는데 큰 영향을 미친다.

그러나 국내 공공아파트 건설프로젝트의 경우, 몇몇의 발주기관을 제외하고는 산정된 공사비에 대한 신뢰성과 설명력이 높은 건설공사비 산정 시스템을 구축하고 있지 않기 때문에 사업 초기단계에서 적정한 공사비를 산정하는데 어려움이 있다. 또한 대부분의 공공발주기관에서는 개략공사비를 예측하고 검토할 수 있는 인력을 보유하고 있지 못하고 있다.

이에 따라, 본 연구는 선행연구에서 제시한 사례기반추론을 활용하여 공사비를 산정하는 방법론과 공공발주기관에서 수집한 66건의 공공아파트 프로젝트 사례들을 이용하여 공공아파트 프로젝트의 기획단계에서 개략적인 공사비를 산정할 수 있는 시스템을 개발하였다. 개발한 시스템의 데이터베이스에 포함되지 않는 9건의 공공아파트 프로젝트 사례와 19명의 공공발주기관의 공사비 산정업무와 관련된 실무담당자들을 대상으로 하여 시스템의 예측 정확성과 적용된 방법의 타당성 및 효용성에 대해 검증하였다.

검증결과, 본 연구에서 개발한 시스템은 −0.49% ~13.88%의 예측 오차율과 4.61%의 평균 예측 오차율을 나타내었으며, 이는 본 연구에 공공발주기관의 실무담당자를 대상으로 설문 조사하여

설정한 시스템의 목표오차율 보다 우수한 정확도로 볼 수 있다. 또한 공공발주기관의 실무자들은 본 연구에서 개발한 시스템이 현행 공사비 산정업무의 환경을 크게 개선할 수 있을 것이라고 평가하였다.

본 연구는 공공아파트 프로젝트의 초기단계에서 공공발주기관의 공사비 산정 업무의 효율성을 높일 수 있는 공사비 산정시스템을 개발하였다는데 그 의의가 있으며, 공공발주기관의 공사비 예측 기술 및 사업비 관리 기술 발전의 토대를 제공하고 공사비 산정결과의 정확성 및 일관성을 향상시킬 수 있을 것으로 기대한다.

주요어: 공사비 예측 시스템, 사례기반추론, 공공아파트, 기획단계

학 번: 2010-23174

감사의 글

지금 이 페이지에 막 접한 순간, 2년 전 건설기술연구실의 문을 두드리던 그 때가 떠오릅니다. 이 곳에서 더 성장하게 될 나 자신을 기대하면서 느꼈던 그 설렘과 가슴 벅참이 아직까지 생생하게 다가오는 것 같습니다. 하지만, 2년이라는 석사과정의 시간은 너무나도 빠르게 그 끝을 향해가고 있습니다.

한참 부족한 제 자신이지만 제게 많은 도움과 격려를 아끼지 않았던 분들이 있었기에 조금씩 성장해 나갈 수 있었고 적잖은 시행착오를 겪었지만 석사학위논문이라는 작은 결실을 맺게 되었으며, 그 어느 것과도 바꿀 수 없는 값진 배움과 경험을 얻을 수 있었고 건설기술연구실과 함께할 수 있었습니다.

지금의 이 순간을 만들어 주신 모든 분들께 가슴으로부터의 감사의 말씀을 일일이 전해야 마땅하지만, 이 공간을 통해 짧게나마 전하고자 합니다.

먼저 건설기술연구실을 만들어 주신 김문한 명예교수님께 감사 드립니다. 제가 건설기술연구실이라는 좋은 환경에 속할 수 있도록 기회를 주시고 석사과정으로서 연구활동에 매진할 수 있도록 물심양면으로 이끌어주신 이현수 교수님과 박문서 교수님께 진심 어린 감사의 말씀을 전합니다. 항상 응원해 주시고 조언과 격려를 아끼지 않으시며, 학업의 길을 열어주신 이규성 교수님께 감사와 존경의 뜻을 전합니다. 바쁘신 와중에도 많은 시간은 내주셔서 조언을 해주시고 연구에 몰입할 수 있도록 도와주신 지세현 박사님 감사합니다. 그리고 연구실의 행정업무를 도맡아 해주신 신동숙 실장님 감사합니다.

연구실 생활을 해 나가는데 많은 도움을 주신 동료 연구원들에게 감사의 뜻을 전하고자 합니다. 연구실의 맏형님이시며 든든하신 은배형님, 연구실 실장으로서 연구실을 위해 너무나도 많은 일을 해 주신 선우형, 유진누나, 진호형, 유학준비 하시느라 바쁘신 와중에서도 항상 할 수 있다는 자신감을 심어준 준오형, 연구실 일이라면 누구보다도 앞장서는 현수, 성실하고 노력을 몸소 보여주며 연구원들의 모범이 되는 성주, 파트타임 박사과정이지만 크게 의지할 수 있었던 재인형님, 수 많은 경험과 실무경력을 바탕으로 조언과 격려를 아끼지 않으신 성근형님, 연구활동과 여가활동 모두 훌

륭한 광표, 동생이지만 마음이 잘 맞았던 병기, 차분하고 듬직한 모습을 많이 보여준 재곤형님, 연구실 안과 밖에서 너무나도 많은 시간을 함께 해 이제는 정말 가까운 친구가 됐고 앞으로도 항상 함께 할 가족 같은 수영이(영원한 사수)와 정훈이, 공사비 프로젝트를 같이 수행하면서 이제는 눈빛으로도 마음이 서로 통하는 요섭, 열정적으로 초고층 프로젝트를 수행해 나가고 있는 민혁, 늘 친절하고 배려심 많은 주연누나, 썰렁하다지만 개그코드가 나랑 맞아서 항상 웃음을 함께했던 성봉이형, 大哥你吃饭了吗？이 말로 너무 친해졌고 성격 좋은 봉기, 연구실에서 동고동락했고 서로 의지가 많이 됐던 나의 연구실 유일의 동기 헬리콥터(RC)를 사랑한 명기, 늦게까지 연구실에 남아 연구하는 모습을 많이 보여줘서 나에게 좋은 자극이 많이 된 권식, 건설기술연구실이 낳은 DJ 연정훈(쩌~툰x2 파이팅~승리의 연정훈), 학문적으로 본받을 만한 모습을 많이 보여줬고 겸손한 민규, 항상 큰 목소리로 다가오며 긍정적이고 밝은 모습의 종우, 축구 잘하고 잘생긴 동생 진강이, 농구를 잘해서 골키퍼가 되었지만 시합 때 마다 멋진 선방을 보여준 믿음직한 강혁이, 예의 바르고 마음씨가 따듯한 태윤이, 샤랄라하고 샤방샤방한 느낌을 주는 연구실로 만들어준 호준이, 민지, 석영이, 예지.

제 가슴속에 있는 감사의 마음을 다 전할 순 없었지만 건설기술연구실에서의 소중한 추억과 경험을 함께 나눴던 우리 건설기술연구실 모든 연구원들에게 감사의 말씀을 전합니다.

그리고 멀리서 진심 어린 응원과 격려 그리고 사랑과 믿음으로 제가 가는 길을 지지해주고 존재 그 자체만으로도 항상 든든한 버팀목이 되어주는 친구(親舊) 민태, 성엽이, 성우, 영일이, 정욱이, 헌칠이, 형진이에게 감사의 마음을 전합니다.

언제나 저를 믿고 응원해주시고 지켜봐 주시며 오늘의 저를 있게 해주신 아버지, 어머니께 감사하고 사랑한다는 다시 한번 말을 이 자리를 통해 전합니다. 제게 하나뿐인, 유일한 동생 원식이에게 말로는 표현할 수 없는 감사와 사랑의 마음을 전합니다.

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이 흥 근