A METHOD FOR PREDICTING THE ENERGY CONSUMPTION OF A BUILDING IN EARLY STAGE OF DESIGN

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ABSTRACT: Various programs have been developed to predict the energy consumption of a building as a result of recent increased social interest in the environmental friendliness of construction as measured by energy efficiency. The goal of environmental-friendliness, which is achieved by predicting the energy consumption of a building, can be realized in the design stage by applying a variety of technologies, planning factors and planning systems. However, most energy analyzing engines are only suitable for use in the advanced stages of design because of the large amount of design information that must be entered. Thus, because the simulation programs currently used are not suitable for use in the early stages of design, this study suggests a prediction logic that provides an overview of the energy consumption of a building according to its size, scope, and purpose by analyzing statistics collected by government agencies.

Keywords: Initial stages of design, Building energy efficiency, System for predicting energy consumption, System for predicting energy cost

1. INTRODUCTION

1.1 Necessity and Purpose

Currently, interest in energy reduction has been increasing worldwide. According to the International Energy Agency (2007), building energy consumption takes up approximately 40% of total energy consumption and approximately 24% of total emissions of carbon dioxide. Thus, it is a matter of necessity to reduce the energy used for building operation and maintenance. To keep pace in these circumstances, the Korean government has been recently encouraging the realization of energy savings in the construction sector through a variety of eco-friendly policies. Unlike in general industrial and mass production, it is difficult to use sample products to test performance and environmental impact in building construction.

Therefore, it is possible that high cost remedies will be necessary to rectify the negative environmental impacts of poorly designed construction processes and completed buildings. For this reason, it is useful to be able to predict environmental performance of proposed buildings as early as possible in order to produce an environmentally friendly design.

The early determination of parameters relating to building energy consumption is important for building energy reduction and efficiency. If these variables are determined past the initial stages of design, effective building energy reduction is difficult to achieve (Yildiz, 2011). Energy performance ratings shall be determined in the initial stages to determine these parameters (Augenbroe, 1992). But, an energy performance assessment in the initial stages of design is difficult to perform due to a variety of issues. First, there is a lack of information in the initial stages. Detailed information about the planned construction is not available during the initial stage and performing building energy performance rating requires this information.

Existing energy simulation programs need a zoning of an evaluation design and a variety of input variables. Also, the input procedures are complicated and full assessment cannot be done until after the design is completed so that their use in the initial stages of design is limited.

Therefore, this study proposes a method for the early prediction of energy consumption and early economic evaluation of proposed buildings in order to support low-energy building design.

1.2 Research Methods and Procedures

The purpose of this study is to develop logic that can predict energy consumption in the initial stages of a construction project. The research methods and the procedures are as follows:

(1) Features of existing simulation programs for energy consumption prediction and the applicable limits of their use in the early stages of design are analyzed.

(2) The parameters that affect building energy consumption are defined.

(3) Logic is proposed to predict energy consumption on the basis of Korean government statistics.

(4) The main contents of this study are summarized and future research direction and assignments are suggested.

2. EXISTING ENERGY SIMULATION

2.1 Status of Building Energy Evaluation Simulation Programs

Since the 2000s, the importance of building energy reduction and efficiency improvement has been growing and related research has been actively conducted in foreign countries. In Korea, research was conducted to identify energy consumption patterns by measuring the real-time energy consumption of buildings (Sung-Sil Kim, 2003) and other research was performed to determine energy consumption trends depending on the type of building components used (Won-Gi Choi, 2007). In recent years, research was carried out to assess the energy performance of buildings in conjunction with existing building energy modeling and simulation programs based on BIM (Hyeon-Jun Mun, 2012). In addition, an energy performance assessment program tailored to domestic environmental policy such as, ECO-2, ECO2-OD was developed under the leadership of government. Overseas, a variety of advanced energy performance simulation programs such as, such as DOE-2, Energyplus, and TRNSYS, have been developed to rate energy performance. In addition, much research has been conducted to improve interoperability between building design data and energy performance assessment programs. Recent research on energy optimization entails using genetic algorithms to improve building energy efficiency (Daniel, 2010) and another study in progress about low-energy building implementation technology and program development considers the impact factors of building energy consumption (Shady, 2012).

2.2 The Problems of Existing Energy Simulations

Energy usage simulations are most effective when used in the early stages of design because many opportunities for reducing building energy requirements through application of technology and making different design choices are available at that time, leading to reduced costs (ASHERAE, 2006).

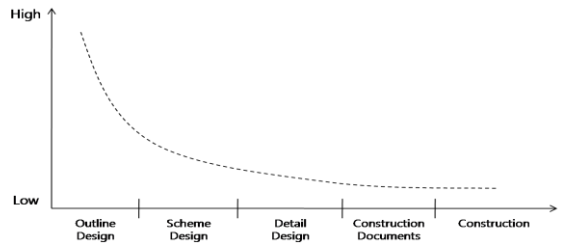

Figure 1. Energy Reduction Opportunities and the Economic Effects

Figure 1 shows the effect of applying energy usage simulation technology in various phases of a construction project. The large effect of applying energy usage simulation technology in the early stages of the project can be observed.

Various parameters related to building energy consumption should be considered in the design phase. However, there are difficulties in doing this in the early stages of a project because information about the building construction is not clear and a lot of information is needed for preexisting energy simulations.

Table 1 shows typical energy simulation tools. Each of DOE-2, Energyplus, TRNSYS, and ECO2 and ECO2-OD developed under the auspices of the Government of South Korea has similar features. However, most of the programs require many design parameters and are vulnerable to errors occurring due to large amount of data that must be entered. Thus, they are not suitable for use in the early stages of a project.

Table 1. Characteristics and Problems of the Existing Energy Simulation

Program	Step	Character	Application Range	Problems
DOE-2	Basic design stage ~ Detailed design stage	Standard of energy related programs	Placement of buildings, operating schedules, conditioning systems and economic evaluation	Need building zoning and require many design parameters
Energy-plus	Basic design stage ~ Detailed design stage	Mixed program of DOE-2 and BLAST advantages	Consumption can be evaluated by lighting, HVAC energy consumption and user defined time step	Need building zoning. Frequent errors occur due to excessive input of data
TRN-SYS	Detailed design stage	Developed for the dynamic simulation of the solar system.	A dynamic heating load calculation of building, sizeng the HVAC system, solar System Analysis	Need building zoning and require many design parameters.
ECO2	Detailed design stage	Energy efficiency rating assessment program	Total energy consumption assessment of buildings and authentication purposes of energy efficiency rating	Detailed design data and a network login are required.
ECO2-OD	Detailed design stage	Total amount of energy evaluation program for building permits for business facilities	Simplified program of ECO2 for business facilities	Input variables are relatively small, but missing mechanical and electrical equipment can lead to error.

Each of DOE-2, a prominent energy simulation overseas, Energyplus, TRNSYS, and ECO2 and ECO2-OD developed under the auspices of the Korea Energy Management Corporation has a number of advantages.

However, as shown in Table 1, Most of the programs require many design parameters and frequent errors can occur due to the input of large amounts of data. Thus, using these programs in the early stages of a project is beset with many difficulties and limitations.

3. BUILDING ENERGY USAGE EVALUATION IN THE INITIAL STAGES OF A PROJECT

3.1 The Implementation of Input Design Variables Simplification

In order to effectively predict energy consumption and costs in the early stages of a project, the implementation of input design variables should be simplified. To do this, the main input parameters that should be analyzed are those parameters that account for large variations in usage.

Table 2. Parameters to be considered as a Phased Design

Outline Design Stage	Scheme Design Stage	Detailed Design Stage
Orientation	Glazing area	Different heating systems
U-Values	Glazing type	Different heating control strategies
Heat recovery systems	Shading and/or blinds	Different cooling systems
Light/heavy construction	Blind control	Different Cooling control strategies
Air exchange rate	Orientation	Different ventilation strategies
Space consumption	Air change rate	
Glazing area	Material adjustment in overheating areas	
Floor plan depth	Lighting strategy	
Fuel type	Cooling required: yes/no?	

Building energy consumption changes for each design parameter typical in existing simulation systems are shown in Table 3 based on the results predicted by the ECO2 program. Elements that lead to large energy savings can be determined from these values and the degree of the effect of each element on the prediction of building energy consumption can be compared.

The design variables that have a significant impact on the energy consumption prediction can be simplified as shown in Table 4 in order to improve the usability of simulations in the early stages of a project. Building information is the basic information that can be obtained in the early stages of a project. Input design parameters have been extracted based on some of the parameters in the outline design stage shown in Table 2 and elements from Table 3.

Table 3. Design Parameters for Building Energy Usage Changing

Passive Elements	Savings Rate[%]	Active Elements	Savings Rate[%]
Insulation performance	0.4	HVAC system	5.0
U-Value	1.1	Boiler efficiency	3.5
Shading coefficient	12.3	Ambient cooling	5.5
Window area ratio	3.7	Turbo chiller	12.8
Insulation location	0.3	Geothermal heating and cooling	21.7
External shades	1.5	Lighting density	19.1
Infiltration rate	0.1	Renewable energy	7.2

Table 4. The Design Information and Parameters of Buildings at an Early Design Stages

Building Information	.Building usage .Building total floor area .Local conditions
Parameters	.Azimuth of the building .Wall area .Window area ratio .HVAC type .Ice thermal storage and district heating rate .FCU utilization rate

3.2 Development of the Logic for the Prediction of Energy Consumption

The annual energy usage by use of the building, floor area, and energy source was analyzed to develop the logic for predicting energy usage. The analysis was done based on Korean government statistics (Ministry of Knowledge Economy the total energy surveys, 2011). Collection of public statistics and unit conversion was necessary in order to integrate this data, since the energy usage of buildings is presented such that usage-specific, area-specific and energy source-specific information is presented individually.

Schools, research institutes, communication facilities, and other buildings among the survey data were excluded due to a high variance in the reliability of the data. The energy consumption data of apartments were excluded as well because the data collected were based on apartment complex as a whole instead of each household individually.

Based on the extracted data, the proportion of energy consumption per unit of each building type was analyzed and the energy consumption per unit area was calculated by multiplying the total floor area ratio changes and the average energy consumption. The prediction logic for energy consumption developed in this process is summarized in Figure 2.

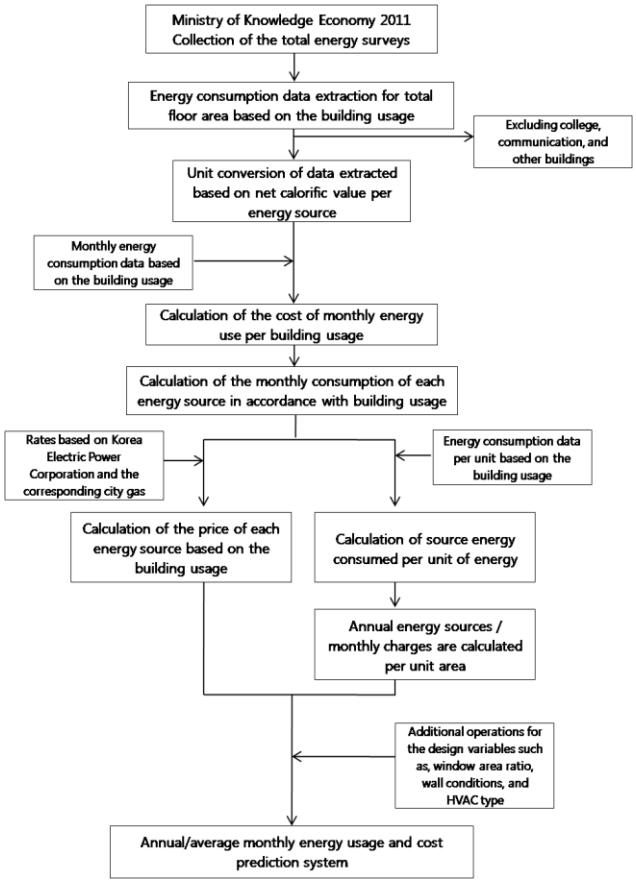

Figure 2. Energy Consumption Prediction Logic

4. CONCLUSIONS

This study was done to develop logic that can be incorporated into the design of a system for the prediction of building energy consumption in the early stages of a construction project and to contribute to the development of green building. After investigating existing energy simulation programs, most of the programs are not suitable to be used in the early stage of construction projects because they require a lot of design information. In this study, input variables required when predicting energy usage, such as, building information, total floor area, local conditions, azimuth of the building, Wall area and window area ratio, HVAC type, Ice thermal storage and district heating rate, and FCU utilization rate, were extracted by using parameters to be taken into account in the initial design phase and the variations of building energy usage per design parameters. Furthermore, the prediction logic of the energy consumption was presented using the data shown above and public statistics provided by the Korean government. The study describes basic research to predict the energy consumption of building at an early stage of the construction process. The developed prediction logic for building energy consumption can be applied flexibly in the early stages of projects. Continued research in the area is suggested for the efficient management of future energy usage and energy costs.

5. ACKNOWLEDGEMENT

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