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Multi-linear Regression Models to Predict the Annual Energy Consumption of an Office Building with Different Shapes

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Abstract

The present study describes the development of a multi-linear regression model to predict the effect of building shape on total energy consumption in two different climate regions (i.e. cold-dry and warm-marine). Seven building shapes including H-shape, T-shape, rectangle, etc. were considered in this study. The simplified model can be used to conduct a parametric study in order to investigate the effect of building parameters on total heating and cooling load. Building simulation software programs, including eQUEST and DOE-2 were used to build and simulate individual building configuration that were generated using Monte Carlo simulation techniques. Ten thousand simulations for seven building shapes were performed to create a comprehensive dataset covering the full ranges of design parameters. Statistical analysis was performed using R statistical analysis program to develop a set of linear regression equations predicting energy consumption of each design scenario. In addition, the influence of several design parameters on building energy consumption was further investigated using the sensitivity analysis procedure. The difference between regression-predicted and DOE-2 simulated annual building energy consumption were largely within 5%. It is envisioned that the developed regression models can be used to estimate the total energy consumption in the early stages of the design when different building schemes and design concepts are being considered.

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Keywords: eQUEST simulation; DOE-2 simulation; Monte Carlo simulation; Regression equations; Building energy performance.

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1. Introduction

The world energy consumption will increase by 56% in the next two decades, from 524 to 820 quadrillion Btu [1]. Hence, prediction of building energy performance seems necessary to project building energy consumptions. Many tools and techniques are available to predict the energy performance of the buildings and it is beneficial for all the stakeholders. It helps owners to project their annual energy cost, assist designers to decide on the energy conservation measures and design based on the goal of the projects for energy saving, and also enable decision makers to decide on how much energy they can save during the life cycle of a construction project. There are several tools that predict energy consumption of a building such as Ecotect, eQUEST, etc. with focus on different aspects of a building performance. For example, eQUEST provides simulation based on building components such as walls, windows, glass, as well as number of occupants, plug loads, and ventilation rate while Ecotect associates a 3D modeler with a large spectrum of energy performance analysis including thermal, energy, lighting, shading, acoustics and cost [2].

Several studies have been conducted on building energy performance [3-5] while estimation of energy consumption of a building is not a simple task as it depends on several factors [5]. According to Heidarinejad [6], there are several variables that influence building energy performance, including: (1) systems variables, (2) internal loads, (3) internal load schedules, (4) systems schedules, (5) building geometry, (6) real time weather data, (7) thermal characteristic of building envelope, (8) unban environment influence (shown in Fig 1).

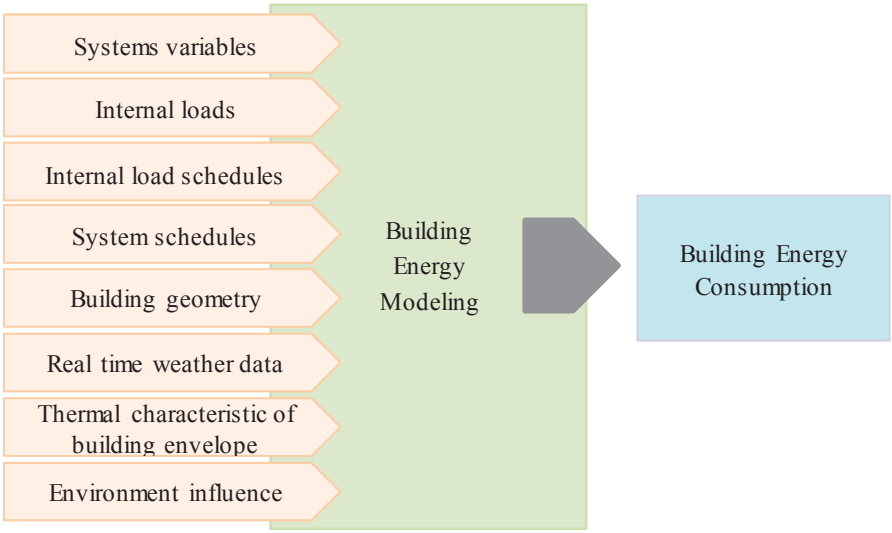

Fig. 1. Variables that influence building energy performance

This study provides a practical and realistic approach to predict energy performance of typical office buildings with a particular focus on two different climates, Billings (cold-dry) and San Jose (warm-marine). Seven office building shapes including, rectangle, H-shape, L-shape, rectangle minus corner, triangle, T-shape, and U-shape were considered. eQUEST and DOE-2 were used to build each building configuration. Monte Carlo simulation methods were employed to generate uniform probability distribution. Ten thousand simulations were performed for each building shape in each climate zone to provide a comprehensive set of data that covers a full range of design parameters. Consequently, to predict the energy performance of each building, the results of the simulation techniques were implemented into a set of regression equations.

2. Methodology

Building energy simulation techniques are used commonly to predict building energy performance. The energy simulation modelling provides projected energy usage for the buildings. It can be beneficial for any phase of a