Environmental Engineering

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# Proceedings of the 11th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC 2019)

## Volume III: Buildings and Energy

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# Environmental Science and Engineering

## Environmental Engineering

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# Preface

The International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC) series was initiated by Tsinghua University of China in 1991. It has been a premier international conference on heating, ventilating, and air conditioning (HVAC) in China and has played a significant role in presenting newly found research results and exchanging ideas among colleagues from academics, research organizations, and industry in the field. The 11th ISHVAC (ISHVAC 2019) was held from July 12 to 15, 2019, in Harbin, China, hosted by Harbin Institute of Technology (HIT), and Prof. Zhaojun Wang from HIT was the president of ISHVAC 2019.

In developed countries, buildings use 40% of the primary energy, while in developing countries like China, buildings use one-third of the primary energy. Thus, energy used in buildings is very significant and a majority of the energy used in buildings is by HVAC systems that should create thermally comfortable and healthy indoor environment for their occupants. However, the indoor environment created is far from ideal because of poor design, operation, and occupant intervention. Therefore, ISHVAC 2019 focused on not only HVAC but also indoor environmental quality, health, thermal comfort, human activities, energy efficiency, renewable energy, etc. The conference provided a great opportunity to exchange new ideas and the state-of-the-art sciences and technologies, to identify solutions for problems in built environment and to build partnerships among engineers, architects, environmental scientists, facility managers, HVAC system manufacturers, and policymakers.

The themes of this conference include indoor and outdoor environment; heating, ventilation, air-conditioning and refrigeration; and building and energy. More than 600 full papers were received, 543 full papers were accepted, and 407 papers were included in the proceedings. There were eight keynote lectures, 15 workshops, 56 parallel sessions, and one poster session. More than 500 experts and scholars from 20 countries or regions attended the conference, of which more than 80 were foreign guests. The participation of many internationally renowned experts and scholars has raised the level of ISHVAC 2019. The conference had the following features:

- The conference invited prominent Indian and Russian scholars to present in plenary sessions, and their presentations were of significance to the study of global climate and energy consumption.
- Many outstanding scholars were invited to organize 15 workshops, focusing on hot issues including the thermal environment and thermal comfort, indoor environmental quality, pollutant transmission and control, human behaviors and building energy consumption simulation, smart heating, evaporative cooling, heat pump.
- During the conference, the Asian HVAC Alliance was established. We hope that the ISHVAC series would become a grand event in the field of HVAC in Asia in the future, like CLIMA conferences in Europe and ASHRAE conferences in North America.

We would like to appreciate the international advisory committee and scientific committee for their hard work and efforts in reviewing papers and providing the support needed. We also would like to thank the co-organizer Tsinghua University and co-sponsors such as ASHRAE, Journal of HV&AC, the Chinese Association of Refrigeration, and the Chinese Committee of Heating, Ventilation and Air Conditioning (CCHVAC).

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# Contents

# Research and Accuracy Analysis on Engineering Quantity Calculation of a Projected Building by BIM Software


**Xinjie Xu, Yu Wang, Jinxiang Liu, Xiaolei Yuan, Jun Bao and Xuetao Chou**

**Abstract** Engineering quantity calculation is the premise and foundation of cost control in architectural engineering. However, the traditional calculation method of engineering quantity way by manual method is inefficient and with low precision. The calculation is faster and more accurate if Building Information Modeling (BIM) technology is applied. In this paper, the development and histories of BIM applications in engineering cost management are introduced. Based on the data of an actual building, a simulation model is established by BIM software. The engineering quantities are calculated, and then, the results of the traditional manual calculation method of engineering quantity and calculation method of BIM are compared and analyzed. The data with a relative error of more than 10% is listed, and the reason for the relative error is conducted. It is concluded that the rules of BIM calculation and manual calculation are different, causing BIM method not accurate enough for some nodes. The suggested method is that BIM method is firstly applied for the total engineering quantity calculation, and then, the manual method is proposed to check the accuracy in some key nodes.

**Keywords** BIM · Engineering cost · Manual engineering quantity calculation · BIM engineering quantity calculation · Relative error

## 1 Introduction

BIM technology was originated from the end of the twentieth century and was proposed by Dr. Chuck Eastman in the USA in the computer simulation system of architecture [1]. The General Services Administration launched the national 3D-4D-BIM program in 2003 and successively released a series of BIM guidelines. Early in the 1960s, computers have been used for building cost calculations [2]. The emergence of BIM cost calculation software simplifies the original manual calculation, reduces the repetitive and tedious workload caused by design changes as well as labor

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costs and improves the working efficiency of cost personnel [3]. Since 2002, BIM technology has been widely developed and applied in Europe, USA, Japan, South Korea, Singapore, Hong Kong and Taiwan [4]. In 2009, government of Wisconsin took the lead in applying BIM technology to new large-scale public building projects in the state. Currently, BIM standards have been established in the USA, and BIM technology is being applied in US government projects.

With the development of scientific information technology, BIM spread into China in 2008. In 2010 and 2011, the committee of China commercial real estate association, engineering construction quality management branch of China construction industry association, the engineering management research branch of architectural society of China and China civil engineering society computer application branch organized and issued 'Research Report on BIM Application of Commercial Real Estate in China in 2010' and 'Application Research Report of BIM in China Construction in 2011.' According to these two reports, the perceived degree of BIM has increased by 27% [5]. In 2014, the Ministry of Housing and Urban–Rural Development promoted the popularization of BIM and the practice of BIM technology in engineering in the 12th five-year plan [6]. BIM is developing rapidly in China, especially in the field of engineering cost. Zhang et al. [7] proposed that BIM technology can be used for four-dimensional (including 4D construction progress management, 4D resource dynamic management, 4D construction quality and safety management, 4D construction site management and 4D construction process simulation) to achieve dynamic management of project cost. Ye [8] studied the application of BIM technology in project cost management according to the analysis in definition, principle, development advantages and influence of BIM in each stage of the project. Fu et al. [9] studied BIM-based engineering quantity calculation and established an engineering cost method through practical cases. Tang [10] proposed the method to solve the problems in each stage by using BIM technology based on the existing problems in the current cost management project.

## 2 Methods

As shown in Fig. 1, the process of civil construction modeling is to draw the axis based on the engineering construction drawings in the modeling software of Revit firstly, and then, the definitions of some construction such as column, beam, board, wall, door and window are established. Furthermore, the model is imported into the civil construction calculation software of Glodon for the following work.

Figure 2 shows the three-dimensional diagram of a civil engineering model. The project is a single residential building with a frame structure and a service life of 50 years. The number of building layers is six floors, of which 0 is underground and 6 is the ceiling. Each layer consists of two units; the height of the first layer is 3.5 m, while the height of the second to the sixth layer is 3.0 m. There is no difference in indoor and outdoor height, and the total height of the building is 17.9 m. The building area is 2469.38 $m^2$. The independent foundation structure was adopted under the