Technology in Society 39 (2014) 77–87

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

The combination of digital technology and architectural design to develop a process for enhancing energy-saving: The case of Maanshan China

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ARTICLE INFO

Article history:
Received 21 January 2014
Received in revised form 2 October 2014
Accepted 9 October 2014
Available online 30 October 2014

Keywords:
Digital technology
Architectural design
Building energy-saving
Performance-based architectural design method
BIM technology

ABSTRACT

The living standard of Chinese residents greatly improved during China's current economic development. However, residential building energy consumption has also grown quickly. Therefore, it is critical to carry out building energy conservation in residential premises to ensure both building comfort and controlled energy consumption. Digital technology, an effective tool, could help designers complete the energy analysis and optimization in the early planning stage for architectural design. In this paper, authors combine computer aided technology and architectural design to develop a process for optimizing energy conservation in new construction in China and compare features of traditional design methods and digital design methods. We researched the effective functions of digital technology in energy feasibility analysis, natural ventilation and sun-shading, taking the Eco-TECT software as an example. To achieve a better energy-saving effect, the performance-based architectural design method and the integration of Building Information Modeling (BIM) technology and architectural design for energy conservation were advanced through this study as preferable methods for achieving high quality living spaces and energy conservation. This paper analyzes the application of digital technology in building energy conservation, in order to provide the scientific basis for the digital technology application in architectural design and promote the development of building energy-saving in China.

1. Introduction

In the 21st century, China is in the stage of rapid urbanization and new rural construction, which is marked by the growing resident income and rising living standards. At present, economic growth has changed the conception and pattern of lifestyles in China [1]. Consequently, Chinese people in urban areas are purchasing residences with large floor space and better indoor comforts [2]. According to the

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http://dx.doi.org/10.1016/j.techsoc.2014.10.002
0160-791X/

statistics from Ministry of Housing and Urban-Rural Development (MOHURD), the total building area is 45.3 billion m^2 and the annual new built floor area is approximately 2 billion m^2, which is larger than the new built-up area in developed countries [3].

However, a critical problem that must be addressed in these buildings is high energy-consumption. Energy consumption per unit building area in China is about 2–3 times higher than the countries at the same climate conditions. It is estimated that more than 95 percent of the existing buildings belong to high energy-consuming buildings and 90 percent of newly constructed buildings are high energy consumption [4]. The building energy consumption is approximately 8.16 tons coal of standard, which accounts for 40 percent of the total energy consumption in China. Thus, it is critical for energy conservation and emission reduction in China to develop ecologic and energy-saving construction. The real estate industry has been one of the three largest energy consumption industry sectors, so it is necessary to establish a low-carbon economic model as the development direction of the real estate industry. Therefore, one main theme in the architectural design field is to explore ways to promote building energy conservation and realize urban ecological development [5–8].

The main purpose of building energy conservation is to reduce energy consumption in heating, lighting, hot-water supply, air conditioning and refrigeration heating on the premise to ensure a comfortable but energy efficient indoor thermal environment [9,10]. Energy conservation should be conducted in all new construction and development phases, including residential district planning, architectural design, engineering construction, retrofitting and occupation [11–14]. The residential planning and design always play a guiding role in energy efficiency in the life cycle of buildings, so the energy-saving concept should be involved in the early design phase [15]. Using digital technology, the architects could simulate and assess the architectural plan based on the sustainable key performance indexes. Based on these results, the energy-saving performance in different scenarios can be obtained. Thus, architects could optimize and improve the scheme until it meets the requirements of green ecological architecture [16–19].

So in this paper, we analyzed the combination of digital technology and architectural design to develop a process for enhancing energy conservation. Firstly, principles and techniques, such as active energy-saving methods and passive energy-saving methods, used in the architectural design were briefly analyzed, and results show that the passive method is preferred due to its application suitability and economic efficiency. And then, the utilization of digital technology to optimize some dominant factors was analyzed, from the aspects of building thermal comfort, natural ventilation and building sun-shading, and it was concluded that digital technology plays an irreplaceable role in this element of architectural design. Thus, to achieve high quality living spaces and energy conservation, limitations of digital technology have to be identified and resolved. Based on the above analysis, the performance-based architectural design method with the integration of BIM technology and architectural design was proposed and tested in the case of Maanshan in China.

2. Architectural design

When it comes to energy conversation for buildings, many energy-saving technology systems have to be considered in the early design stage [20,21]. Theory suggests that if this does not happen, significant barriers develop which impact energy decisions and can have long-term effects [21]. We propose using a case in China to identify opportunities for avoiding these barriers by early considering in design. In general, these energy-saving technologies can be divided into two categories: active energy-saving technology and passive energy-saving technology. The former refers to replacing the fossil energy systems by the compulsory energy systems composed of the energy supply, storage and utilization of a variety of renewable-energy resources. This method is characterized by high-investment and high-technology, but its application could be supported by a certain number of auxiliary energy [22]. However, the latter refers to buildings without mechanical and electrical equipment but using a variety of energy-saving technologies to achieve the goal of minimizing the energy demand for heating and cooling [23]. Based on this, architects could create indoor comfort and a better thermal environment primarily with the aid of passive methods, such as natural ventilation, lighting and solar radiation.

At present, due to the financial costs and technological limitations, architects tend to adopt the passive method rather than active mechanical heating and cooling systems to meet the requirement of comfort in a low-cost way. Therefore, according to the principle of climate adaptability, architects and technicians could put forward the preliminary energy-saving scheme based on the detailed analysis of the regional natural resources and environment and the numerical simulation analysis of indoor thermal environment, which would provide a scientific and accurate basis for the follow-up work, such as the structure, Heating ventilation and air conditioning (HVAC) and other professional design issues. In terms of the energy-saving planning, digital technology can be applied into residential district planning, architectural design and building retrofitting [24–26].

In the residential district planning, the architects and designers typically paid more attention to the residential and artistic matters, such as functional division, spatial environment layout and architectural design. There are few designers really focusing on the outdoor thermal environment and pedestrian comfort. However, these elements enhance the quality of life and create opportunities for energy conservation. This lack of attention creates many disadvantages to street pedestrians, outdoor living and recreation areas [27,28]. In summer, large areas are exposed to the sun without sufficient protection, so the outdoor thermal environment is poor and these regions cannot be effectively used. In fact, a good place even a good rest zone with optimal thermal comfort can be easily created with an outdoor sunshade and reasonable greenery. The residential regions in China consist of high population density, a high floor-area ratio and low green rate, which have important effects on natural ventilation. The increasing wind speed in local regions will affect the pedestrian wind comfort and